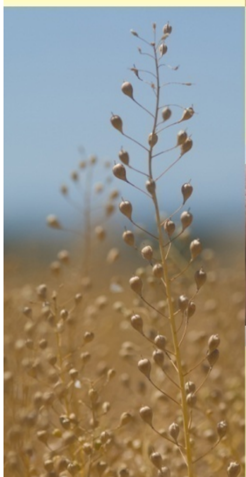
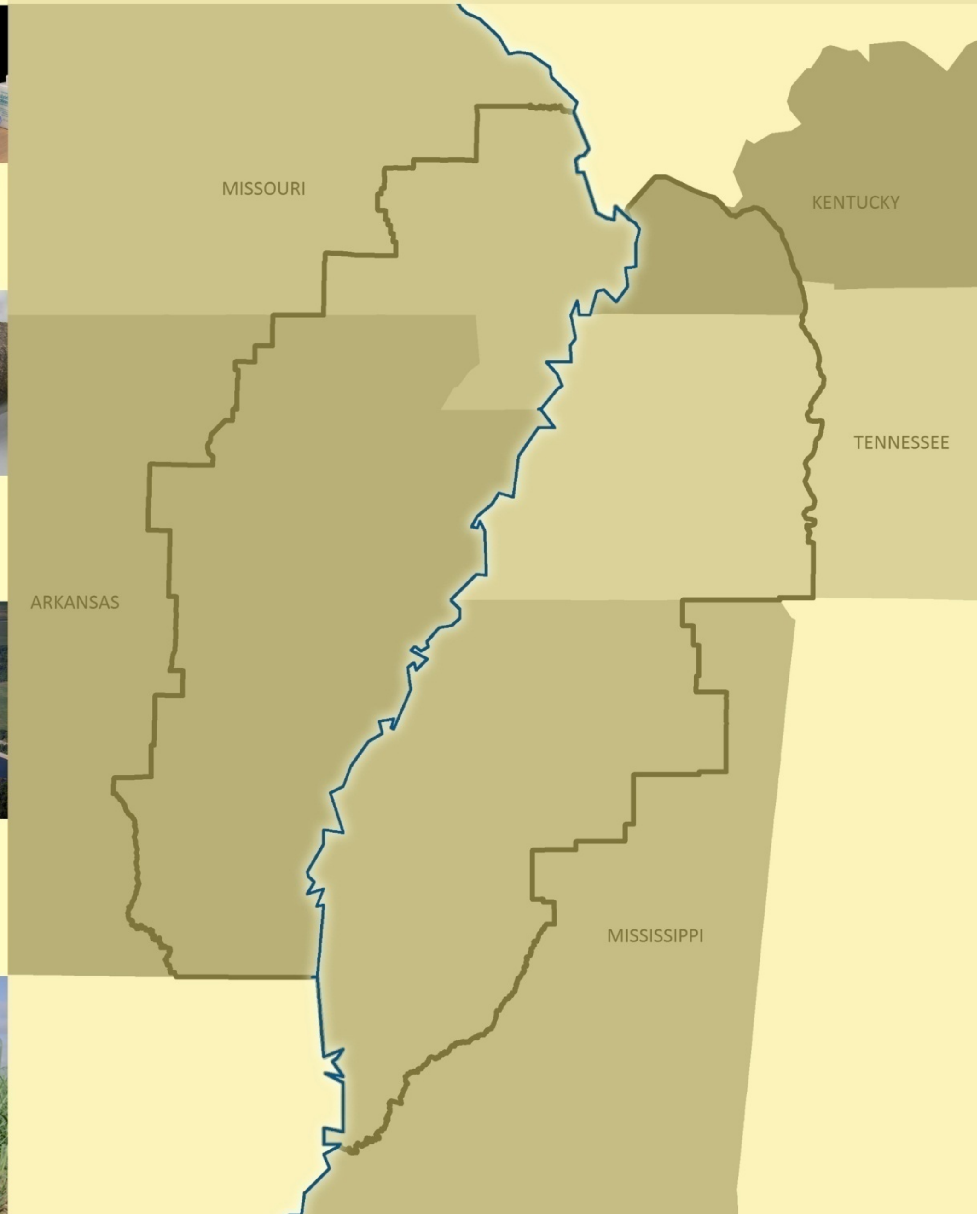


Regional Strategy for Biobased Products in the Mississippi Delta



Prepared for: The 98 Counties in the Mid-South Mississippi Delta Region Located in Arkansas, Kentucky, Missouri, Mississippi and Tennessee

Prepared by: Battelle Technology Partnership Practice

August 2009

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The Business of Innovation

The development of the Regional Strategy for Biobased Products in the Mississippi Delta was coordinated by Memphis Bioworks Foundation.

www.memphisbioworks.org and www.agbioworks.org.

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Regional Strategy for Biobased Products in the Mississippi Delta

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CONTENTS

The Mid-South Mississippi Delta region, comprising 98-counties in five states, is rich in biomass resources. New industrial applications for biomass are emerging driven by powerful economic, strategic and environmental forces. Moving forward, the region has unprecedented opportunities for new biomass-based economic development.

Executive Summary

A New Energy and Materials Paradigm

The first decade of the 21st Century has driven home the realization that an economy built on finite fossil-based carbon resources is unsustainable and ultimately fraught with risk. From an **environmental** perspective, the release of carbon dioxide from the accelerated combustion of fossil fuels, and other activities employing fossil carbon resources, is now broadly recognized as a driver of global warming and climate change. From a **strategic security** perspective, a dependence on foreign fossil-resource supplies places the United States at risk from foreign regimes and cartels over which control is far from assured. From an **economic** perspective, the necessity to import a substantial portion of the U.S. petroleum requirements has resulted in a huge redistribution of global wealth, as domestic consumers and businesses are faced with volatile and unpredictable energy resource prices. There is a clear need for development of renewable and sustainable alternative energy and materials resources to drive the U.S. and regional economies into the future.

Biomass Defined:

There are many recognized definitions for the term "biomass." In this report, biomass includes all agricultural crops and trees in harvested, unprocessed form including all southern row crops and residues; alternative crops such as canola and perennial grasses; and woody biomass.

Within this report biomass is segmented into four primary categories:

1) oilseeds;

2) sugar & starches;

3) lignocellulosics;

4) niche crops.

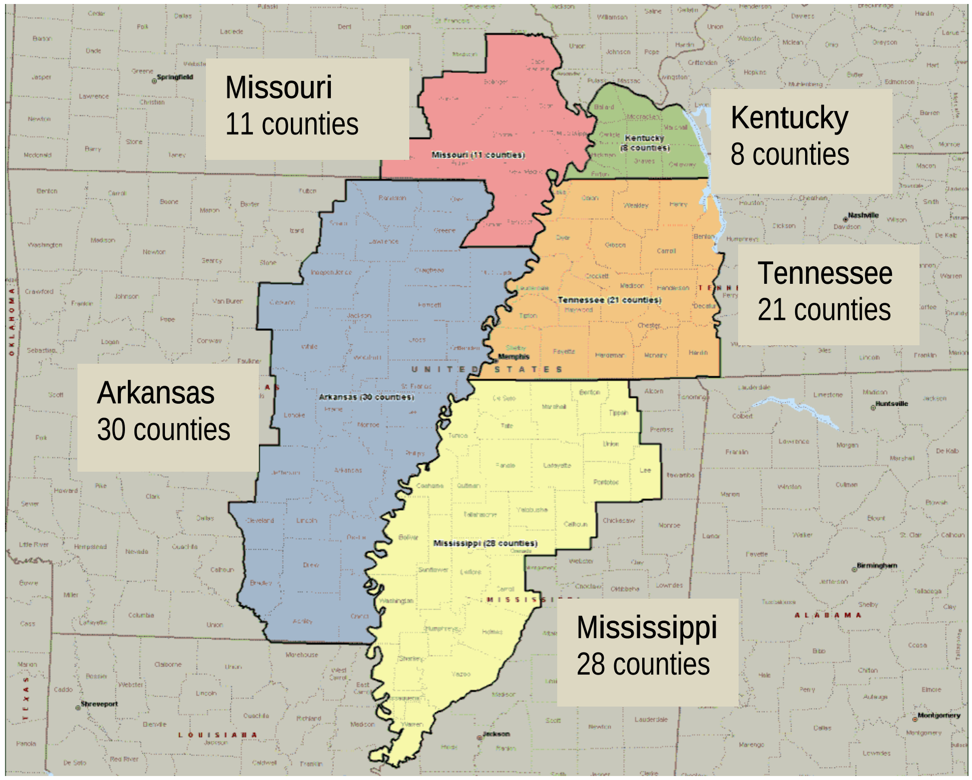
Each biomass segment presents unique characteristics as a feedstock—affording opportunities to produce a wide range of products including: biofuels and energy, green chemicals, biobased materials, and health and nutrition products.

The unique convergence of powerful strategic, environmental and economic imperatives is now aligned with **political vision** to accelerate R&D and business development in sustainable and renewable resources. The world's leading agricultural, biotechnology, chemical and petroleum industries are currently reconfiguring into new partnerships and structures to capitalize on the manufacture of biobased products. This new emerging industry is driven by resource issues, as well as the ability to develop unique, high performing products from plants. The results are new supply chains, strategic relationships and new opportunities.

Biomass is the Mid-South Mississippi Delta Region's Renewable Resource

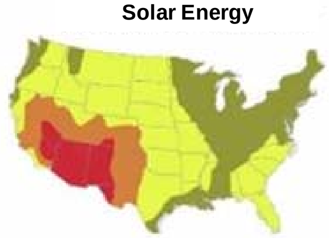
The Mid-South Mississippi Delta, the subject of this study, encompasses 98 counties, distributed across parts of five states (Arkansas, Kentucky, Mississippi, Missouri and Tennessee). The region comprises a broad historic flood plain and its forested perimeter, centered around the Mississippi River. Characterized by common topography, a variety of productive alluvial soil types, high levels of surface and groundwater availability, and a favorable climate and comparatively long growing season, the region has become a centerpiece of agricultural diversity and productivity in the southern U.S.

Figure ES-1: The 98-County Mid-South Mississippi Delta Region

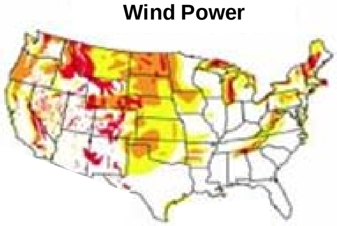


The 98-county Mid-South Mississippi Delta region represents a contiguous biomass production area covering 36 million acres (56,000 square miles).

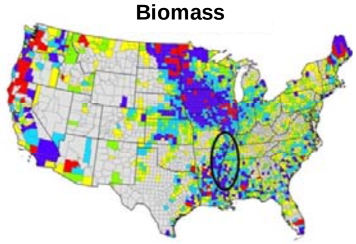
Solar Energy



Wind Power



Biomass



While various areas of the United States are well-positioned to commercially exploit other renewable assets—*principally solar and wind, but also tidal, hydro and geothermal*—**the primary renewable asset of the Mid-South Delta region is biomass**, as is clearly seen from the national resource maps to the left. **Importantly, among renewable resource options, biomass stands out as the most flexible resource for economic development, as it can be used to generate energy (heat and electricity) and serve as a sustainable and adaptable feedstock for downstream processing to produce liquid transportation fuels, chemicals, and materials.** For those regions, such as the Mid-South Mississippi Delta Region, that are rich in biomass, the future holds significant opportunity for economic development and growth built around a new biomass production and processing industry.

The Mid-South Mississippi Delta region has a combination of assets that provide significant strategic advantages in the development of a strong biomass-based economy. These advantages include the diversity of current biomass production (corn, cotton, soybeans, wheat, rice, grain sorghum, hardwoods, and softwood); existing industrial infrastructure that can be adapted to make biobased products; and superior logistics that can be redeployed locally to move biomass from field to factory and can also be used to reach distant markets with finished biobased products. These characteristics offer a near-term economic development opportunity that will mitigate risk, leverage public and private investment, and attract technology partners from outside the region. This "foundation" will lead to a future regional bioprocessing industry characterized by new supply chains, decentralized rural biorefineries, and diverse agricultural and forestry options for farmers and foresters.

Unlike the Midwest, which tends to concentrate its agriculture into massive contiguous plantings of homogeneous crops (such as corn in Iowa and wheat in Kansas and Nebraska), Mid-South Mississippi Delta farmers produce a broad variety of row crops. The region is suited to the production of a diverse range of grains, oilseeds and dedicated biomass crops. The region's farmers have a demonstrated capability to be flexible in their selection of crops based on commodity market opportunities, rotation requirements and other factors. For example, according to USDA, Tennessee farmers in 2007 increased corn planting by 42% while reducing cotton planting by 20%. The region's farmers have the equipment and skills to make these dramatic shifts, given the right opportunity.

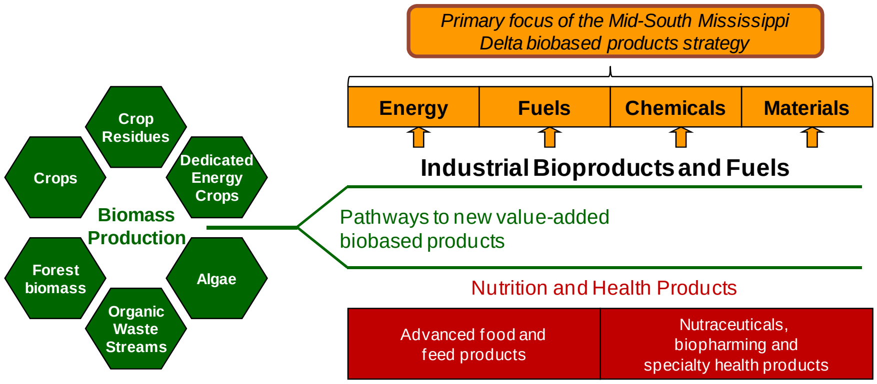
The Mid-South Mississippi Delta region's land use is heavily agricultural. A total of 21.5 million acres of land is in farms (59.5% of total regional land area), of which 17.6 million acres is either cropland or pasture land. Added to the row crop and pasture forage production area is forest land contained within the region. The 98 counties contain almost 13.9 million acres of forestland (38.4% of total regional land area). Together the row crop land, pastures, and forests cover 31.5 million acres or fully 87.2% of the total 98-county regional land area. Clearly the region is rich in biomass resources.

Pathways to Biomass Products

Plant and animal biomass resources have been used by humans for many thousands of years, primarily for food and feed. Notably, some crops (such as cotton in the Mid-South) have provided a fiber feedstock, while forest biomass has been the primary resource for the pulp/paper industries, and plant oils/animal fats have been the raw materials for the oleochemical industry. However, **the flexibility of plant biomass, in combination with modern advancements in processing and conversion technologies, is driving rapid progress in the utilization of biomass as a feedstock—which must ultimately replace fossil resources—for a variety of new and expanded industrial uses.** This industrial bioprocessing is greatly expanding product opportunities from renewable resources.

Biomass is now being used for electricity generation via direct combustion and gasification applications; bioderived oils and sugars are being used in the manufacturing of a range of liquid biofuels, and plants are increasingly being employed in the manufacture of innovative materials, including specialty chemicals and plastics. In addition to the use of biomass as an industrial feedstock, plants also are being modified to produce specialized human health products such as functional foods and nutraceuticals and as "factories" for the production of pharmaceutical and industrial products. The general pathways to value-added biomass-based products are illustrated in Figure ES-2.

Figure ES-2: Pathways to Biomass-Based Products



> Biotechnology and modern breeding techniques are increasing yields and creating new value-added plant traits. The ability to manipulate and improve plants provides a dynamic platform for innovations which will further enhance the economics of biomass feedstocks for a range of industrial applications.

Traditional food and feed production are long-established sectors of the national economy. The supply chains for commodity food and feed are highly consolidated and there is only moderate room for new value-added ventures and independent innovators. However, the utilization of biomass as a core industrial feedstock and renewable energy/fuel source represents a recent development and a distinct opportunity for new transformational economic rural development.

The use of biomass as a processing feedstock provides opportunities for new crop rotation options, revenue, and value-added processing income for farmers and foresters. The new jobs and economic activity created through novel biomass-feedstocks and the downstream fuels, specialty chemicals, and materials make the development of the "industrial bioprocessing" pathway a compelling strategy. The resulting renewable biomass economy will reduce carbon emissions and replace imported fossil-resources, making the industrial bioproducts and fuels pathway even more crucial to U.S. sustainability and progress.

The Delta Biobased Economy

An industrial bioprocessing pathway using biomass feedstocks offers an exciting new economic development opportunity for the Mid-South Mississippi Delta region but it represents a quite different model and value-chain from the current fossil-resource based economy and from the mature biomass food and feed industry, as illustrated in Table ES-1.

Table ES-1: Comparison of the Biomass Industrial Platform versus Traditional Platforms

Biomass Industrial	Biomass Food & Feed	Petroleum / Fossil Fuel
Renewable	Renewable	Non-Renewable / Finite Resource
Potentially low carbon	Potentially low carbon	High carbon emissions
Domestic production	Domestic production	Highly dependent on imports
Opportunities for new supply chains, partnerships, technology and innovation	Mature, heavily consolidated industry	Mature, heavily consolidated industry
Lignocellulosic biomass processed locally	Can be shipped globally for processing	Can be shipped globally for processing

While biobased industrial development brings fresh challenges, the upside benefits of a biomass-based economy are highly attractive, including:

Near-Term Advantages:

- Reutilization/redeployment of existing industrial infrastructure for bioprocessing.
- Introduction of new rotational crops such as canola and sunflower that will offer farmers increased options, revenue opportunities, and increased yields from existing regional acres.
- Opportunities to create new supply chains.
- Opportunities to attract regional investment via pilot demonstration projects with new partners.
- Added value for underutilized biomass resources such as crop and forest residues, and processing by-products.

Mid/Long-Term Advantages:

- The development of rural decentralized biorefineries processing oilseeds, sugar crops, and lignocellulosic biomass.
- Opportunities for the growth of high-value biomass on marginal lands.

The general economic development benefits of the biobased model are broad and substantial:

Generation of new jobs and income from development and production of new biomass feedstocks and biobased products	Distributed rural and urban economic development	Reduced dependence on foreign resources and positive impact on the balance of trade	Environmental benefits from reduced carbon emissions and petrochemical based pollutants	Carbon trading and offset opportunities for the region

Biomass Feedstocks for Industrial Development

Mid-South Mississippi Delta biomass intended as a feedstock for downstream processing contains one or more of the constituents shown in Table ES-2. Bioprocessing technologies seek to convert these components into useful downstream products such as fuels and chemicals, which can displace finite fossil-fuel derived materials.

Table ES-2: Primary Biomass Feedstocks

Feedstock	Key Chemical Component(s)	Crop Examples
Oils	Plant oils: triglycerides	Soybeans, Canola, Camelina, Algae
Starch	Glucose, polysaccharide	Corn, Barley, Grain Sorghum, Rice
Sugar	Disaccharides, glucose, fructose	Sugar Cane, Sugar Beets, Sweet Sorghum
Lignocellulose	Lignin, cellulose, hemicellulose	Wood, Crop Residues, Switchgrass, Miscanthus, Cotton

These feedstock constituents can be converted by both existing and emerging technologies, into four primary industrial product application areas:

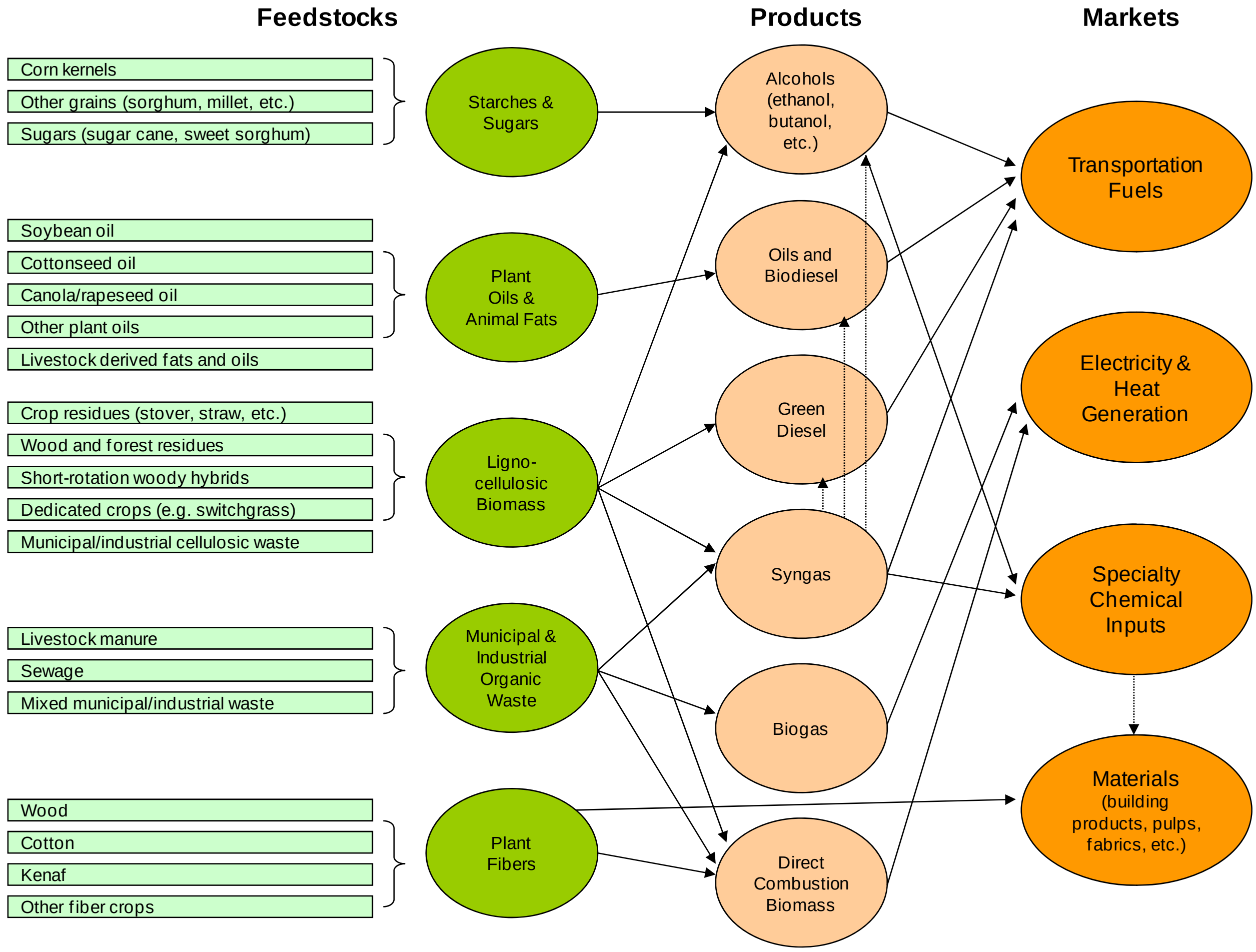
- Electricity and heat generation
- Liquid fuels
- Building block, intermediate and specialty chemicals
- Biobased fibers and materials.

In many instances the products can be derived from multiple biomass processing pathways as shown in Figure ES-3, which illustrates the complexity of the biomass to market opportunity.

Regional Biomass Availability

The Mid-South Mississippi Delta study region currently produces all of the four primary biomass feedstock components shown in Table ES-2, most in substantial quantities. There are near-, mid- and long-term industrial development opportunities using each feedstock, as described in the following sections.

Figure ES-3: Process flow of Biomass Feedstocks to Biobased Products to Market Applications



Regional Oils Supply

The Mid-South Mississippi Delta region is not a major livestock production or processing region, so the availability of animal-based oils and fats is relatively limited. The main source of renewable oil within the region is plant oils, primarily deriving from soybeans, and to a lesser degree cottonseed.

In 2007 the region's soybean production was 5.5 million tons (196 million bushels) harvested from 6 million acres (39% of total primary cropland) with an average yield of 0.9 tons per acre per year. Given the value of soybeans in global commodity markets and the inexpensive outbound logistics, most of the region's soybean output is exported using the Mississippi River.

Opportunities exist to expand the types of oilseeds grown within the region, and analysis performed for this study shows that the region has particularly favorable characteristics for the growth of new value-added oilseed crops as shown in Table ES-3.

Table ES-3: Alternative Oilseed Crops ranked by commercial opportunity

Rank	Oilseed	Fatty Acid/Oil Properties
1	Sunflower	Oleic fatty acid: industrial and food oil use
2	Winter Canola	Polyunsaturated oil: industrial and food use + biodiesel feedstock
3	High Erucic Acid Rapeseed	Erucic acid used in multiple industrial products
4	Camelina	Biodiesel and oleochemical refinery base feedstock
5	Flax	Linolenic acid; oleochemical and health food use

Current Regional Plant Oil Supply

5.5 million tons of soybeans are being produced with the majority improved through biotechnology. The region's soybeans are predominantly exported for food and feed use. However, there is one large soybean solvent-based processing facility and several small mechanical crushers in the region. Some specialty and/or organic soybeans are being delivered through identity preservation methodologies to customers primarily in Asia.

Although cotton acreage has been in decline, there is still cottonseed processing in the region with four major processors.

The production of higher-value chemical products from oils in the region, including genetically-modified specialty oils, is currently limited by the lack of regional oilseed crushing capacity. The high value of specialty oil products, and the high yield potential of the regional growing environment for new oilseeds crops, does suggest that the pursuit of enhanced crushing capacity for the region should be a priority.

Dedicating 400,000 acres to oilseed crops such as sunflowers or winter canola would support five 200 ton per day multi-purpose oilseed crushing facilities (assuming a yield of 1,500 lbs per acre). Winter oilseed crops at this volume would likely represent a new double-cropping opportunity, being incorporated into current crop rotations and using land often idle during the winter months. Alternatively, supplanting 400,000 acres of cotton (a non-food crop) with new higher-value oilseeds also would not impact current food crop production. The study team strongly supports the U.S. cotton industry and its downstream products; however, it is likely that cotton acreage will increasingly be available for other rotation crops, due to economic considerations.

Regional Starch Supply

The region is a major producer of starch crops, primarily corn (9.2 million tons), rice (5.3 million tons), wheat (1.6 million tons), and grain sorghum (0.8 million tons). Much of the corn acreage is planted with genetically modified corn. Starch crop production is summarized in Table ES-4 below.

Table ES-4: Primary Regional Starch Crops[1]

Crop	Harvest million tons	Acreage million acres (% of primary cropland)	Yield tons/acre
Corn	9.2	2.6 (17%)	3.6
Rice	5.3	1.7 (11%)	3.2
Wheat	1.6	1.4 (9%)	1.1
Sorghum	0.8	0.4 (2%)	2.2

Like soybeans, the vast majority of regional grain production is exported from the region, with only limited processing or value-added activities taking place in the 98 counties. Unfortunately, the ease and cost-effectiveness of outbound logistics on the Mississippi River has made it

[1] USDA NASS Agricultural Census 2007 as summarized in BES sub-report

attractive to export these crops to large centralized processing facilities in the Midwest, to the detriment of the regional processing base. As with soybeans, the lack of significant value-added local processing has resulted in minimal job creation for integrated agricultural businesses in the region.

Current Regional Starch/Grains Supply
16.9 million tons of corn, rice, wheat and grain sorghum are being produced with the majority of the corn improved through biotechnology. These crops are predominantly exported from the region for food and feed use. However, there is some regional processing including food products and ethanol.

The primary markets for these grains are for human food and livestock feed. Corn (starch-based) ethanol production is a first-generation bioprocessing pathway, now under question for longer-term growth and sustainability due to the food-fuel conflict. As a result, it is unlikely that the grains/starch platform will be an expanding feedstock for an industrial bioproducts economy within the Mid-South Mississippi Delta region, at least not for commodity liquid transportation fuels. There are, however, high-value lower-volume specialty products derived from starches, as well as residues from the production and processing of starch crops that may be commercially sustainable within the lignocellulosic feedstock platform discussed below.

Regional Sugar Supply and Sweet Sorghum Opportunity

In the study region,sweet potatoes are produced, primarily in Mississippi, as a food crop and sweet sorghum is grown solely as a boutique crop for syrup production. Presently, there are no significant commercial volumes of sugar feedstocks for downstream processing. Research farm tests of sweet sorghum within the region do, however, show this to be a crop with significant regional production potential. Sweet sorghum would have the advantage of allowing near-term development of liquid fuels production from sugar (using well-established sugar fermentation technologies) while the remaining sweet sorghum lignocellulosic biomass (bagasse) could be used for process energy, solid fuels for co-firing, animal feed, and eventually a feedstock for lignocellulosic fuels processes.

Current Regional Sugar Supply
Dedicated sugar production crops are not currently grown on a commercial scale within the region, with the exception of sweet potatoes grown for food. However, sweet sorghum has significant near-term potential. There are also longer-term efforts underway to expand other sugar crops in the region through improved breeding and development activities.

Native to Africa, sweet sorghum is a tall, leafy member of the grass family that resembles corn. Agronomic practices for several open-pollinated varieties of sweet sorghum are well established in the study region, where the crop requires low inputs, is drought tolerant, and offers a good rotation option with other commodity row crops. Adoption of sweet sorghum as a biobased products and bioenergy feedstock in the U.S. has been limited by a lack of breeding advancements, availability of mechanized harvest and milling equipment, as well as market demand for the raw materials. Sweet sorghum is often noted for its photosynthetic efficiency as a C4 plant which captures CO_2 and converts it into valuable sugar. Sweet sorghum has a very efficient, strong root system that allows it to produce under low water requirements.

Currently, there are no commercially available harvesters designed specifically for sweet sorghum, but at least one major equipment company has a harvester in development. Several harvester prototypes for dedicated sweet sorghum were developed in Italy between 1980 and 1990 but experience indicated the best solution was the adaptation of sugarcane harvesters. Two harvesting methods are being used today for sweet sorghum: harvesting the crop in field with transport to a separate location for crushing; and harvesting and crushing the crop with one machine on a single pass through the field. Sweet sorghum will typically average over 10 dry tons/acre biomass in the southern U.S., based upon a wet crop yield of 30–40 tons/acre and 70% moisture content.[2]

The juice from sweet sorghum may be extracted through milling or diffusion extraction. The majority of the sweet sorghum being grown today is used to make sorghum syrup which is produced by small farm-based operations and sold in local markets. Efficient juice extraction can yield between 400 and 600 gallons of ethanol per acre (gpa) from the sugar, while the crushed stalks (bagasse) represent a cellulosic feedstock, with the potential to produce an equal quantity of ethanol per acre. Louisiana Green Fuels, LLC (Laccasine, LA) is installing the nation's first large industrial scale facility, which will share an existing sugar cane diffusion extraction unit for seasonal processing of 10,000 tons per day sweet sorghum to 25MM gpy ethanol, utilizing only the juice sugars.

The project team has identified sweet sorghum as the preferred near-term sugar/dedicated energy crop for the study region. As an *annual crop*, sweet sorghum will achieve its full production yield in the season of its planting and may be readily incorporated into rotations with other Delta crops. Sweet sorghum sugars are judged to be the most direct and accessible feedstock for near-term manufacture of fermentation-derived biobased products and biofuels. Other sugar feedstock candidates could potentially include sugar beets, sugar cane and expanded production of sweet potatoes, depending on whether varieties and production practices can be adapted to this area. As the leading potential dedicated energy crop for the region, sweet sorghum offers the flexibility of an annual crop, with the potential to produce significant amounts of sugar and lignocellulosic biomass for processing.

Regional Lignocellulose Supply

Lignocellulose, derived from woody biomass, dedicated energy crops, and crop/agricultural residues represents the primary sustainable, high availability feedstock for industrial bioproducts development in the region. Analysis performed for this project indicates that the 98-county Mid-South Mississippi Delta region could produce the following estimated lignocellulosic biomass on an annual basis (Table ES-5).

[2] Fred L. Allen and Richard Johnson. "Corn Hybrid & Sweet Sorghum Silage Tests in Tennessee 2008." The University of Tennessee Institute of Agriculture, available at http://www.utextension.utk.edu/publications/spfiles/SP618-2008.pdf

Table ES-5: Sustainable Lignocellulosic Biomass Availability

Biomass Source	Total Production, million tons/year	Estimated sustainable usable quantities, million tons/year
Agricultural field residues	31.5	7.2
Agricultural processing residues	1.3	1.3
Forest residue biomass	9.8	6.4
Forest stem wood biomass	12.7	12.7
Dedicated energy crops	31.5	31.5
Totals	**86.8**	**59.0**

Agricultural Field Residues. Harvested crop production in 2007 was 25.0 million tons on a dry matter basis, with total production of field residues from these primary crops (not including hay) totaling 31.6 million tons, of which 7.2 million tons (23%) is estimated to be sustainably removable based on the 1:1 corn stover-to-grain ratios provided by U.S. Department of Agriculture and the U.S. Department of Energy in the "Billion Ton Report"[3] published in April 2005. Corn stover and rice straw comprise the primary crop residues in the study region by volume. The Billion Ton report's estimates for crop residues may not convert readily to the Mid-South Mississippi Delta region given the difficulties in harvesting and handling rice straw (due to its high silica content) and the potentially lower stover to grain ratio in the region (versus the high-yield Upper Midwest production zones). These regional variables are acknowledged in the Billion Ton report, which points out that the grain-to-residue ratio (or the inverse, harvest index) is affected by grain yield, regional differences, technology improvement, crop density and other factors.

In the near-term, corn cobs may represent the most accessible crop residue for the region. Harvesting of corn cobs in a one-pass system is feasible and is being developed as a component of the Midwest corn ethanol industry. There is already an existing market in some regions for corn cobs at approximately $80.00 per ton, to be used in the production of chemicals such as furfural. Companies such as POET Biomass, a division of POET, and DuPont Danisco Cellulosic Ethanol, LLC are developing conversion technologies specifically targeting corn cobs as feedstocks for biochemical conversion using enzymes. Given the agronomic characteristics of the region and the uncertainties in collection of crop residues, all residue sources are included in the overall inventory of lignocelluloseic biomass potential, but are not considered by the study team to be the most attractive near-term feedstock option.

Agricultural Processing Residues. Predominantly comprised of cotton gin trash and rice hulls, an estimated 1.3 million tons of processing residues are available annually.

[3] "Biomass as a Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply"; Oak Ridge National Laboratory for USDA and USDOE; April 2005. (Page 25)

Regional Lignocellulosic Biomass Supply Expansion Opportunities via Dedicated Energy Crop Production

- 2.4 million tons on idle land
- 3.1 million tons on CRP land
- 4.6 million tons on pasture land
- 21.4 million tons on crop lands

Forest Biomass. In addition to farm generated biomass the region also contains significant forest land resources. Forest-based lignocellulosic biomass in the region is 624 million tons (95 million tons of branches and tops, 105 million tons of rough and rotten material, 22 million tons of small diameter stem wood, 87 million tons of medium diameter stem wood, and 316 million tons of large diameter stem wood). To achieve the optimal economic value, stem wood from medium- and large-diameter trees is expected to continue to be supplied to the saw timber and pulp markets. **The project team has made the assumption that development of a new regional bioprocessing industry can be realized in a manner that does not disrupt existing biobased segments which add value to biomass. Therefore, for the supply scenario projected in this report, only 10% of the medium- and large-diameter stem wood is considered available for new industrial biomass applications.** Based on an assumed harvest cycle of 28 years, the estimated amount of average potentially removable forest residue biomass would be 6.4 million tons per year, and the estimated amount of average potentially removable medium- and large-diameter stem wood would be 12.7 million tons per year.

Dedicated Energy Crops. In addition to currently available biomass, there is significant regional potential for an expanded lignocellulosic feedstock supply using agricultural crop lands. There is, however, a balance to be struck between utilization of biomass for new downstream bioprocessing while at the same time maintaining existing profitable agricultural products and markets. **The project team sought to propose dedicated biomass expansion options that recognize this balance and could be accomplished with limited detrimental effects on existing production—notably maintaining regional production capacity for food commodities.**

The team concludes the following additional *dedicated energy crop*[4] (DEC) production opportunities may be sustainably and realistically pursued:

- Production of DECs, such as perennial switchgrass or miscanthus on 25% of the region’s idle lands at 12.0 tons per acre per year—for a total annual production of 2.4 million tons.
- Production of DECs, such as perennial switchgrass or miscanthus, on 25% of the region’s Conservation Reserve Program (CRP) lands at 12.0 tons per acre per year—for a total annual production of 3.1 million tons.
- Production of DECs, such as perennial switchgrass or miscanthus, on 15% of the region’s pasture land at 12.0 tons per acre per year—for a total annual production of 4.6 million tons. It is estimated that this substitution of dedicated energy crops for pasture land could result in an 80,000 head/year reduction in regional marketable beef cattle.

[4] Dedicated biomass crops are frequently referred to as Dedicated Energy Crops (DECs). They constitute crops (such as switchgrass, miscanthus, sweet sorghum, and woody crops) grown specifically for biomass applications, as opposed to use in food and feed applications.

- Production of DECs on 10% of the region's cropland. While more aggressive expansion of DECs on cropland is possible, this planning scenario was selected with the intent to minimize any impact on land currently used to produce food crops. This scenario would utilize 1.43 million acres of cropland, or about 60% of the 2007 cotton acreage, the region's primary non-food crop and the crop most generally under economic pressure for substitution. Expressed as lignocellulosic biomass at an estimated 15.0 tons per acre, this represents annual production of 21.4 million tons. **For prime row cropland, the project team concludes that *sweet sorghum*, with both sugar and lignocellulosic components for processing, represents the preferred energy crop for near-term development, in preference to perennial crops such as switchgrass or miscanthus.**

Biobased Products Production Potential

The industrial products that could potentially be made from biomass feedstocks are extremely diverse making product and volume projections difficult. However, it is possible to estimate the product *potential* for the study region's lignocellulosic biomass resource by calculating an estimated ethanol yield, representing the potential production of this biobased liquid transportation fuel.

Delta lignocellulosic biomass conversion to ethanol

The production of ethanol from lignocellulosic biomass is in the initial commercial demonstration stage. The current consensus is that a realistic near to mid-term yield target would be 80 gallons of ethanol[5] per dry ton of lignocellulose, either herbaceous or woody biomass. University of Nebraska and USDA-ARS researchers also consider 80 gallons to be a realistically achievable goal, with 200 gallons of ethanol per ton of switchgrass being an approximate theoretical maximum (dependent upon feedstock). **For the scenario calculations in this study, an assumption of 80 gallons of ethanol per dry ton of lignocellulosic biomass assumption is used.**

*59 million dry tons of lignocellulosic biomass **x** 80 gallons of ethanol per dry ton =*

4.7 billion gallons of ethanol.

At current spot price for ethanol of $1.65 (July 2009) this is a $7.75 billion value.

The production of ethanol from lignocellulose and sugar fermentation could produce 4.7 billion gallons annually from sustainably harvested feedstocks in the 98-county region—without impacting current production levels of food crops.

Assuming comparable lignocellulosic conversion rates, sweet sorghum produces the same estimated total ethanol production as switchgrass or miscanthus, resulting in 4.7 billion gallons of ethanol, from all regional biomass feedstock sources described previously. In addition to the more favorable characteristics of sweet sorghum as an annual DEC for the region, fermentation of sweet sorghum sugars to ethanol is commercially demonstrated technology. Moreover, the assumed sweet sorghum lignocellulose yield of 10 tons per acre has been demonstrated in field trials by the University of Tennessee and other groups, whereas the assumed 15 tons per acre for herbaceous DECs such as switchgrass and miscanthus is at present an optimistic future goal. Finally, until lignocellulose-to-ethanol conversion technologies are demonstrated to be commercially viable, sweet sorghum sugar-derived ethanol can be produced with known technology.

The potential production of 4.7 billion gallons of liquid transportation fuel (expressed as ethanol in this calculation) from biomass feedstocks in the region exceeds the 3.4 billion gallons in total regional consumption of finished petroleum products, and could make the Delta study region a future net exporter of liquid transportation fuels under this scenario.

The calculations above provide an indication of the basic potential in commodity liquid transportation fuel production from available and sustainable non-food regional biomass. While significant biomass volumes will undoubtedly be used for the production of cellulosic ethanol or other liquid fuels, the potential exists for production of additional higher value specialty products.

Petroleum-derived products consumed in the United States have a vastly different value depending on the end use. The petroleum-based liquid fuels industry and related energy services account for approximately 67% of petroleum consumed, with an overall industry value of $350

[5] University of Nebraska-Lincoln (2008, January 14). Biofuel: Major Net Energy Gain From Switchgrass-based Ethanol. *ScienceDaily*. Retrieved June 6, 2009, from http://www.sciencedaily.com /releases/2008/01/080109110629.htm

billion dollars. However, the goods and services resulting from the higher-value plastics, coatings, resins, and related consumer products utilize only 7% of petroleum consumed, while resulting in an approximate $255 billion impact.[6]

Fractionation, or separation, of petroleum into its component constituents has been the key to developing higher-value end products. Similarly, biomass feedstocks possess compositional diversity, and several leading technology developers have pursued fractionation, or separation, of these components in order to facilitate more efficient and targeted downstream conversion of each component to value-added products. An obvious example is wet corn milling, in which the corn kernel is separated into its different components, from which value-added products are produced. Similarly, lignocellulosic biomass is comprised of three distinct components—lignin, hemicellulose, and cellulose. Historically, lignocellulose fractionation originated in the pulp and paper industry, where processes were designed to remove hemicellulose and "de-lignify" wood pulp in order to obtain a purified cellulose fraction for paper manufacturing. More recent approaches have used a combination of physical and thermal pre-processing followed by aqueous and/or solvent extractions, to afford substantially purified fractions of hemicellulose, lignin, and cellulose for further processing specific to each component.

Anticipated Development Path for Regional Bioprocessing

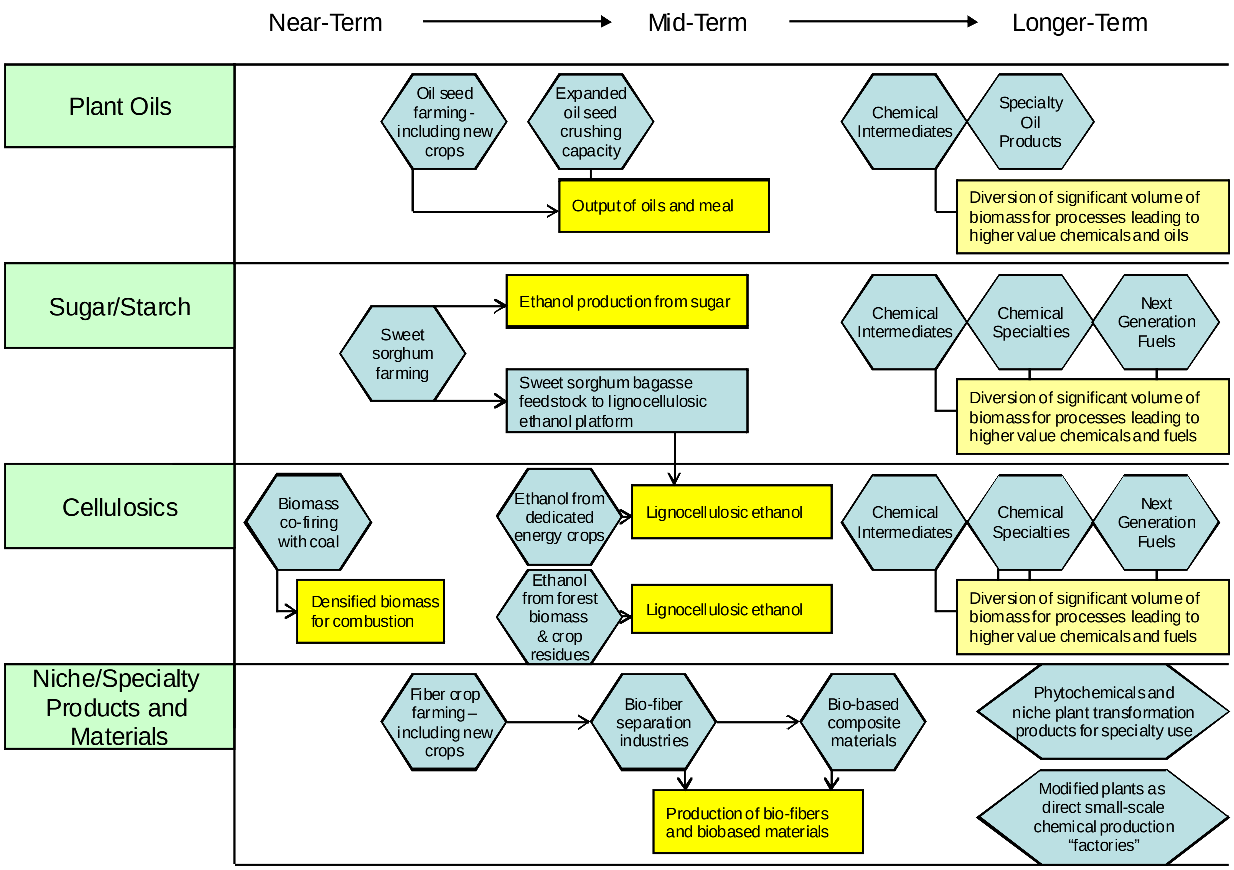
It is difficult to identify the key products and development timelines for biofuels and biobased products at this early stage of bioprocessing industry development. However the project team has projected potential product development pathways for each of the primary feedstock platforms—plant oil; sugar/starch; lignocelluloses—as well as for niche or specialty materials, as illustrated in Figure ES-4. This analysis considers the following factors:

- Characteristics of regional agricultural production
- Current and emerging technologies in biomass processing
- Emergence of new markets for biobased products
- Maintaining existing food and feed production value-chains.

The primary product development opportunities for each of these platforms are placed on Figure ES-4 according to the project team's best estimate of timing—"near-term" (current to three-years), "mid-term" (three to six years) and "longer-term" (more than six years from the present). Additional detail on each product opportunity is presented in Section VIII "Recommended Strategies" of the full report.

[6] John W. Frost, "Redefining Chemical Manufacture, Replacing Petroleum with Plant-Derived Feedstocks", Vol. 1, No. 1, Spring 2005, Industrial Biotechnology Journal

Figure ES-4: Anticipated Development Paths by Key Feedstock Platform



The Niche and Specialty Products and Materials Opportunity

Beyond the primary high volume biomass platforms (oilseeds, sugar/starch, lignocellulosic), the region also has an opportunity to encourage the development of a broad range of diverse niche and specialty products. These include agricultural fibers, smaller acreage crops with unique properties, and specialty crops with output traits. Development opportunities are summarized here and more fully described in study sub-reports.

An excellent opportunity exists to expand the growing, processing and utilization of agricultural and forestry fibers in the region, as intermediates in the production of textiles, composites, and specialty papers. The presence of the automotive industry and associated suppliers in the 98-county study region and the surrounding states may offer significant opportunity for the expansion of the production and use of agricultural fibers for fiber-reinforced composites and other automotive related applications. Additional opportunities exist in new markets with filtration media, structural components, and the application of nanotechnology to the improvement of fiber strength. There are clear rotational benefits for increasing acreages of annual bast fiber crops such as kenaf in the study region, including reduced inputs, weed suppression through fast stand establishment, and reduced water consumption.

Kengro Corporation, a farmer owned company located in Charleston, Mississippi grows and processes an agrifiber crop called kenaf, a relative of cotton and okra that can be made into products ranging from automotive composites to insulation. The company sells its branded oil absorbency products through a dealer network in the U.S. and Canada. Kengro Corporation is innovating new products including filtration media, nanocomposites, and structural composites.

Opportunities exist in the region for small acreage crops which offer novel health or industrial properties for specialty applications. Some small-scale oilseed crops such as lesquerella and castor have highly desirable fatty acid profiles that have markets in cosmetics and specialty lubricants. Research at several regional institutions seeks to identify naturally occurring chemicals in plants that may have commercial potential in health and in natural crop protection products.

A strong potential also exists for the development of enhanced or new output traits in crops. These are traits which allow the crop to produce certain characteristics desired by food, health or industrial customers. Unlike input traits in which the value proposition is directed to reduced production costs for the farmer, output traits are directed to those making products from the crops and ultimately to the consumer. Enhanced output traits will allow crops to have higher protein, stronger fibers, enhanced components, or other desirable properties for the development of biobased products. Some of these crops require specialized handling.

Using modern biotechnology tools, and often referred to as Plant-Made-Pharmaceuticals (PMPs), crops such as tobacco can be developed to directly produce medicine, industrial enzymes or other desirable products. Ongoing efforts to deregulate these crops could potentially offer a shorter and less costly path to market that may open the way for numerous companies to commercialize PMP technology. There is an increasing interest in PMPs within the study region driven by programs at Arkansas Biosciences Institute and other key universities and research organizations.

Although this report focuses on industrial uses for crops and forestry resources, there is an expanding local food industry in the region that is connecting local farmers directly with consumers. This niche industry, although low in volume and acreage, is serving to introduce new crops to the region, while providing an entry point for new entrepreneurial projects and local economic development.

Economic and Job Impacts on the Regional Economy

Based on the analysis of feedstocks, technologies, and markets, the project team has selected the most promising opportunities for development within the *next decade*, as described below. The potential employment impacts that could result from each product area are also estimated.

Occupations in industrial bioprocessing will require fundamentally different skill sets from agricultural production. Technically sophisticated lignocellulose biorefineries will most closely resemble chemical factories in terms of infrastructure, unit operations and complexity. The preparation and growth of a reliable and skilled workforce in renewable energy and biobased product processing is essential to fully exploit the regional industrial bioprocessing opportunity. Realization of replicable decentralized bioprocessing facilities across the region requires workforce development, infrastructure development, and entrepreneurism, all pursued with a long-term perspective of the opportunity.

Within the next decade it is estimated that expanding biofuels and biobased products business sectors could generate over 25,000 jobs within the Mid-South Mississippi Delta region.

- **Oilseed Crushing.** It is estimated that the introduction of new oilseed crops on 400,000 acres of Mid-South Mississippi Delta crop land would generate sufficient oilseed volumes (based on canola and sunflower seeds as the oilseed crops) to support five 200 tons per day crushing plants (using CO_2 mechanical crushing systems) with between 20 and 30 direct jobs per plant (100–150 jobs total across five facilities).
- **Biomass Combustion Feedstock Densification.** There is a near-term opportunity for developing production facilities that would produce densified biomass to provide between 2 and 5 million tons of dry biomass pellet/briquette feedstocks for co-firing in coal-fired power plants or for other direct combustion applications. This would require the development of between 13 (for 2 million) and 33 (for 5 million) pellet plants with an output of 150,000 tons of pellets per plant. At an estimated 20 jobs per pellet plant this would generate between 260 and 660 direct jobs in the region.

Bioprocessing jobs are "green jobs." This term refers to quality jobs with opportunities for career advancement in companies that provide goods or services that improve the environment or contribute to sustainability. The production of biobased products will create a unique mix of green jobs in both rural and urban areas.

- **Lignocellulosic Liquid Fuels Production.** Under the assumption that the production of ethanol and other liquid fuels from lignocellulosic materials will become commercially viable, the region's sustainable annual supply of 59 million dry tons of lignocellulosic biomass would, at a conversion rate of 80 gallons of ethanol per dry ton, have the capacity to manufacture 4.7 billion gallons of ethanol. Using the model of decentralized rural 40-million gallon output biorefineries located across the region for economic access to biomass, production of 4.7 billion gallons would require 117 biorefineries. A 40 million gyp biorefinery would require an estimated staff of 40 (4,680 jobs total across 117 facilities).
- **Niche Opportunities.** A range of alternative, niche opportunities should be continually encouraged in the region that will enable entrepreneurship, offer new opportunities to farmers, and supply unique raw materials and products to biobased industries. The diversity and uniqueness of these small business opportunities does not lend itself to quantifying potential job growth.

Based on review of multiple biorefinery economic impact studies, and a national impact analysis performed for the Biotechnology Industry Organization,[7] the project team concluded that a 5.0 employment multiplier should be used in deriving an estimate of jobs created within the developing regional industrial bioprocessing industry. The resulting

[7] Bio-era (Bio Economic Research Associates). "U.S. Economic Impact of Advanced Biofuels Production: Perspectives to 2030". February, 2009. Study performed for BIO.

job projections using a 5.0 multiplier (four indirect jobs for every one direct job) are shown on Table ES-6. Some jobs allocated to bioprocessing operations may be retained jobs, as some of the biomass feedstocks production component would comprise existing employment in farm and forestry labor.

Table ES-6: Job Generation from Biomass-Based Economic Development (5.0 Employment Multiplier)

Per Facility:

Facility Type	Direct Jobs Per Facility	Indirect Jobs Per Facility (5.0 multiplier)	Total Jobs Per Facility
200-ton per day oilseed crushing plant	25 jobs per plant	100 jobs per plant	125
150,000-ton biomass densification plants (pellets/briquettes)	20 jobs per plant	80 jobs per plant	100
40-million gallon per year lignocellulosic ethanol plant	40 jobs per plant	160 jobs per plant	200

For the Region:

Facilities	Direct Jobs	Indirect Jobs (5.0 multiplier)	Total Jobs
5 x 200-ton per day oilseed crushing plants	125	500	625
20 x 150,000-ton biomass densification plants	400	1,600	2,000
117 x 40-million gallon lignocellulosic ethanol plants	4,680	18,720	23,400
TOTALS	**5,205**	**20,820**	**26,025**

Longer-term, the introduction of processes to produce high-value specialty chemicals, chemical intermediates and second generation liquid biofuels will likely enhance the level of job creation through the development of multiple specialized chemical facilities. It is reasonable to envision a 2x growth scenario in total biomass based economic development in the region over the long-term, generated both through specialized chemical and fuel products and through increasing production volumes achieved through crop yield and process yield improvements. **Thus, within *two decades* it is reasonable to anticipate a total impact within the 98-county region approaching 50,000 total (direct plus indirect) jobs through a maturing industrial bioprocessing products economy.**

Key Observations and Conclusions

Lignocellulosic Biomass – Abundant resources within the Mid-South Mississippi Delta will make lignocellulosic biomass processing the key technology—and industry—for the region's biobased economy. In addition to sustainably available woody biomass and crop residues, production of dedicated energy crops on 10% of current cropland would more than double the region's annual lignocellulosic biomass availability, to 59.0 million tons per year. This is sufficient to produce an estimated

4.7 billion gallons of liquid transportation fuel annually, well in excess of the 3.4 billion gallon total regional consumption of finished petroleum products.

Rural Development – Due to its low bulk density and corresponding high cost to transport, lignocellulosic biomass will "anchor" future processing to the Delta region, in close proximity to its production. This offers significant potential for development of a decentralized replicable bioprocessing industry in the region, with significant job growth. In contrast, renewable wind or solar equipment and components can be (and already are) produced outside the primary regions of energy generation and those areas only require modest support staff to maintain equipment operability once in place. For the Delta region, jobs must come to the biomass.

Technology – Little conversion technology for lignocellulosic biomass is being innovated in the study region; however, international technology providers are pursuing business strategies to implement, or make technologies available, to biomass-rich regions of the country such as the Mid-South Delta. The region must position itself as an "implementation partner" to attract and enable inward technology investment.

Technology – Despite significant progress in recent years to advance the technologies necessary to produce second generation biofuels, the leading technologies for lignocellulosic conversion are just reaching the commercial demonstration stage. These early demonstration projects carry significant commercial risk, as they generally seek to validate and optimize novel technologies and processes. The International Energy Agency concludes that large-scale demonstration projects will provide the needed comparative data to determine the "best technology pathway" between the thermochemical and biochemical lignocellulose conversion routes.

Technology – The region's academic and private-sector research farms have the capability to evaluate new crop performance and determine optimum production practices. However, few of these organizations own the necessary germplasm and/or are willing and able to invest in years of breeding to advance crop genetics. It is likely that most advanced germplasm and support will be provided by companies outside the region.

New Energy Crops – *Sweet sorghum* has been identified by the project team as the preferred near-term dedicated energy crop for the Delta region, compared to switchgrass and miscanthus. Sweet sorghum is preferred due to the relative ease of incorporation of an annual crop into existing rotations; demonstrated yield and agronomic requirements; known technology to convert sugars to ethanol (or other higher-value fermentation products); and value-added disposition options for the bagasse.

New Oilseed Crops – *Sunflowers and winter canola* have been identified by the study team as the most promising near- to mid-term new oilseed crops for the region, due to agronomic compatibility and potential regional oil markets. Establishment of regional crushing facilities will be necessary to achieve the full commercial development of these crops and lead to the introduction of other oilseed crops in the future.

Biorefineries – Liquid transportation fuel biorefineries processing lignocellulosic feedstocks will most closely resemble chemical factories in terms of infrastructure, unit operations, and complexity. Highly-skilled technical and operational personnel will be required to staff these technically sophisticated biorefineries. Wage rates will reflect these skill requirements.

Workforce Development – ADTEC (Arkansas Delta Training and Education Consortium) has assembled the best practices in teaching and learning in renewable energy technology through a careful survey of programs nationwide. The ADTEC curriculum developers have created a rigorous and thoughtful curriculum in recognition of the region's strategic advantage in diverse biomass feedstocks and the bioprocessing industrial opportunity. ADTEC stands out as a program of excellence in renewable energy technology training in the region and throughout the United States.

Logistics – The Delta Region's comprehensive transportation and logistics infrastructure is a significant strength for development of a regional bioprocessing industry. Roads, river ports, rail, and intermodal facilities are generally adequate to support the envisioned decentralized economic development. Proximity to refined product pipelines sets the region apart, giving it a strategic advantage for blending and export of compatible second-generation liquid biofuels.

Logistics – Historically, river transport has reduced the availability of grain for regional processing by providing a cost-effective conduit for export to large centralized processing facilities. Lignocellulosic processing will reverse that trend, as river transport will not likely be an economical mode for inbound or outbound movement of these low bulk density feedstocks, which will need to be processed in close proximity to production. However, barge export of densified lignocellulosic biomass products—such as pellets or briquettes—as well as high bulk density chemical and fuel products, may represent a regional advantage.

Industrial Infrastructure – Co-siting of first generation regional biorefineries with existing industrial infrastructure will be desirable to reduce capital, leverage existing competencies, and mitigate risk inherent in early-stage projects. Among other regional assets, cotton gin sites that are centrally located, with buildings, scales, and utilities, may be ideal locations for new biomass operations such as pre-processing, pelletizing/briquetting, or rural sweet sorghum ethanol production. Also, transport of crops and crop residues to biorefineries could represent a new off-season opportunity to utilize farm-based rolling stock assets for revenue generation.

Near-term Opportunities – The project team has identified four near- to mid-term bioprocessing opportunities as the most promising for the region: co-firing biomass in regional coal-fired power plants and process industry coal boilers; introduction of specialty oilseed crops and local crushing facilities; development and demonstration of sweet sorghum-based ethanol production; and introduction of lignocellulosic-based ethanol and/or liquid fuel demonstration facilities.

Job Creation – Within the next decade, assuming commercial viability of lignocellulose conversion to liquid fuels, it is reasonable to foresee a biofuels and biobased products sector in the 98 counties generating upwards of 25,000 jobs (5,100 direct jobs in biorefineries and processing plants, and over 20,000 indirect jobs in the supply chain including biomass production, transportation and multiple other supporting sectors). These jobs would be distributed across decentralized small to mid-scale rural biorefineries and bioprocessing operations.

Environmental Considerations – In assessing new energy crops and biofuel processing opportunities, leaders must consider the relative impacts of the multiple options on greenhouse gas emissions, air pollution, water use and water quality. The key to this effort will be conducting thorough site-specific life cycle assessment studies on the top options under consideration.

Policy – Federal policy is now heavily incentivizing the development of the bioprocessing industry; however, the region has not significantly benefited from this support to date. State level policies, programs and incentives in regards to biomass based economic development are far from consistent across the five states, which can create an uneven playing field and result in competition, rather than cooperation.

Cooperation and Collaboration – The Mid-South Mississippi Delta bioprocessing factories of the future will be located across the region, in close proximity to lignocellulosic feedstocks. Aggressive realization of this industry provides an unprecedented opportunity for cooperation among regional entities which support and enable economic development. On a national level, leading efforts to demonstrate early commercial bioprocessing projects have generally been characterized by collaboration among academic, public, and private sector entities. The emerging bioeconomy represents a unique opportunity for cooperation—rather than competition—to accelerate economic development for the entire region. An excellent model for collaborative organization has been developed within the region and is available online as a supplemental reference report to the study.[8]

[8] Sumesh M. Arora. "A Collaborative Model for Renewable Energy Technology Adoption," Doctoral research, 2009.

Strategic Recommendations

1. Pursue Selective Near-term Opportunities: Well-conceived projects to demonstrate near-term success and develop new supply chain models by linking farmers, processors, logistics providers, and factories to make biobased products should be strongly encouraged and supported by regional agencies. Larger and replicable opportunities will result from these new supply chains and early demonstration projects. The project team has identified four near- to mid-term bioprocessing opportunities as the most promising for the region: co-firing biomass in regional coal-fired power plants and process industry coal boilers; introduction of specialty oilseed crops and local crushing facilities; development and demonstration of sweet sorghum-based ethanol production; and introduction of lignocellulosic-based ethanol and/or liquid fuel demonstration facilities.

2. Expand Bioprocessing Workforce Development: The DOL-supported Arkansas ADWIRED/ADTEC and Missouri WIRED programs represent a national best practice for renewable energy workforce development and should be expanded to other institutions in the study region to ensure that skilled local workers will be available to staff the technically demanding bioprocessing industry of the future.

3. Establish a Regional Agricultural R&D Network: The region contains a number of strong public and private research farms with leading academic and commercial agricultural R&D programs, often with overlapping objectives. A "region-focused" network of these organizations should be established to, among other things: leverage capabilities; improve program efficiency; develop consistent protocols and processes; and enhance information exchange. A vital role of this network will be coordination of regional testing and addressing institutional barriers to new crop introduction.

4. Establish a Regional Bioprocessing Technology Consortium: Much of the bioprocessing industry will be developed in rural locations in proximity to biomass feedstocks, but with limited access to the advanced technical competencies necessary to support local biorefineries. A consortium of region-based public and private entities should be established to provide ready access to process technology support services and enable the region's emerging bioprocessing industry.

5. Establish a Regional Business Development Office: The regional bioprocessing industry of the future will be decentralized, replicable, and will share common supply chain and business characteristics. To facilitate the most aggressive realization of this industry, a centralized Business Development Office is recommended, to support the efforts of the implementation partners across the five-state, 98-county region. This central coordinating office would serve as an information clearinghouse, entry point for imported technologies, focal point for funding collaboration, and resource for coordination and integration of support services.

6. Expand Farmer Networks: In order to mitigate risk, manage expectations, and facilitate communication and knowledge sharing on the production of new crops and opportunities, regional agencies are encouraged to support the formation of farmer networks and expand programs with existing farmer organizations and Land-grant University cooperative extension services. Ideally, the networks would include publicly-funded training, demonstrations and crop production, and a focus on creating and strengthening linkages between farmers and downstream bioprocessing companies. The 25Farmer Network pilot program in West Tennessee, supported by funds from the Tennessee Department of Agriculture, Memphis Bioworks Foundation and BioDimensions, Inc. may serve as a useful model for the region. Efforts should be made to increase participation of disenfranchised and minority farmers in these programs.

7. Harmonize State Policies and Incentives: The five states represented in the strategy share common biomass resources within the Delta region and will therefore share a similar opportunity to develop the bioprocessing industry within their boundaries. Leaders and key agencies within the states should adopt supportive and consistent policies to encourage value-added biobased products, which are technology and feedstock neutral. Implementation partners in the five states should collaborate to make specific recommendations for policy makers in the region.

8. Develop a Regional Policy Statement: Federal policies are going to continue to shape the economic viability of the renewables sector. Because the Mid-South Mississippi Delta region includes counties in five states, there is opportunity for the region to leverage an influential base of U.S. senators and congresspersons in shaping legislation and federal policies to favor biobased resource development. A shared position statement on federal policies and incentives should be prepared for the region's congressional delegation.

I. Introduction

A. Introduction

The first decade of the 21st Century has driven home the realization that an economy built on finite fossil-based carbon resources is unsustainable and ultimately fraught with risk. From an **environmental** perspective, the release of carbon dioxide from the accelerated combustion of fossil fuels, and other activities employing fossil carbon resources, is now broadly recognized as a driver of global warming and climate change. From a **strategic security** perspective, a dependence on foreign fossil-resource supplies places the United States at risk from foreign regimes and cartels over which control is far from assured. From an **economic** perspective, the necessity to import a substantial portion of the U.S. petroleum requirements has resulted in a huge redistribution of global wealth, as domestic consumers and businesses are faced with volatile and unpredictable energy resource prices. There is a clear need for development of renewable and sustainable alternative energy and materials resources to drive the U.S. and regional economies into the future.

The unique convergence of powerful strategic, environmental and economic imperatives is now aligned with **political vision** to accelerate R&D and business development in sustainable and renewable resources. **Among renewable resource options, biomass stands as the most flexible resource for economic development and the production of a broad range of value-added manufactured commodities and products.** Unlike the other renewable assets—*solar, wind, tidal, hydro and geothermal*—biomass has the unique capacity to generate energy AND serve as a sustainable, abundant, flexible and adaptable feedstock for manufacturing applications. For those regions that are rich in biomass, there are going to be countless opportunities for economic development and growth built around a new biomass processing industry paradigm.

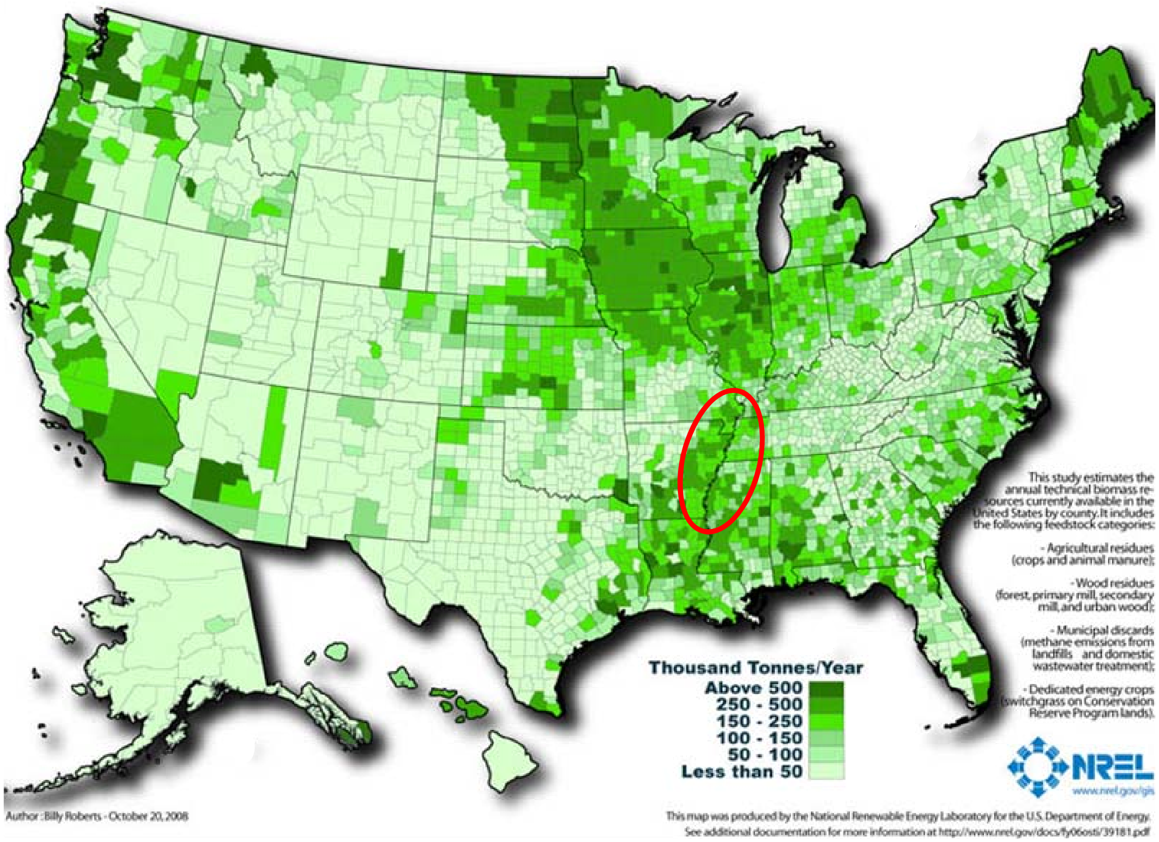
B. Biomass-Based Development and the Mid-South Mississippi Delta Region

This study encompasses a region consisting of 98 counties, distributed across parts of five states (Arkansas, Kentucky, Mississippi, Missouri and Tennessee). It comprises a broad historic flood plain and its forested perimeter, centered on the now flood-controlled Mississippi River. Characterized by comparatively flat topography, a variety of productive alluvial soil types, high levels of surface and groundwater availability, and a favorable climate and comparatively long growing season, the region has become the centerpiece of agricultural productivity and diversity in the southern U.S.

The Mid-South Mississippi Delta region has a combination of assets that provide significant strategic advantages globally in the development of a strong biomass-based economy. These regional advantages include the diversity of current biomass produced (corn, cotton, soybeans, wheat, rice, milo, hardwoods, and softwood); existing industrial infrastructure including pulp/paper and chemical assets that can be retooled to make biobased products; and superior logistics that can be used to both reach distant markets with finished biobased products and can be redeployed locally to move biomass from field to factory. These regional advantages offer a short-term platform that will mitigate risk, leverage public and private investment, and attract technology partners from outside the region. This “foundation” will lead to a future industry characterized by new supply chains, decentralized rural biorefineries, and diverse agricultural and forestry options for farmers and foresters.

Unlike the Midwest, which tends to concentrate its agriculture into massive contiguous plantings of homogeneous crops (such as corn in Iowa and wheat in Kansas and Nebraska), Mississippi Delta farmers produce a broad variety of row crops including rice, soybeans, cotton and corn. The region’s agronomic characteristics make it suitable for the production of a range of grain, oilseed or dedicated biomass crops and the region's farmers have a demonstrated capability to be flexible in their selection of crops based on commodity market demand, rotation requirements and other influencing factors.

Figure 1: U.S. Available Lignocellulosic Biomass Resources (Study region highlighted)



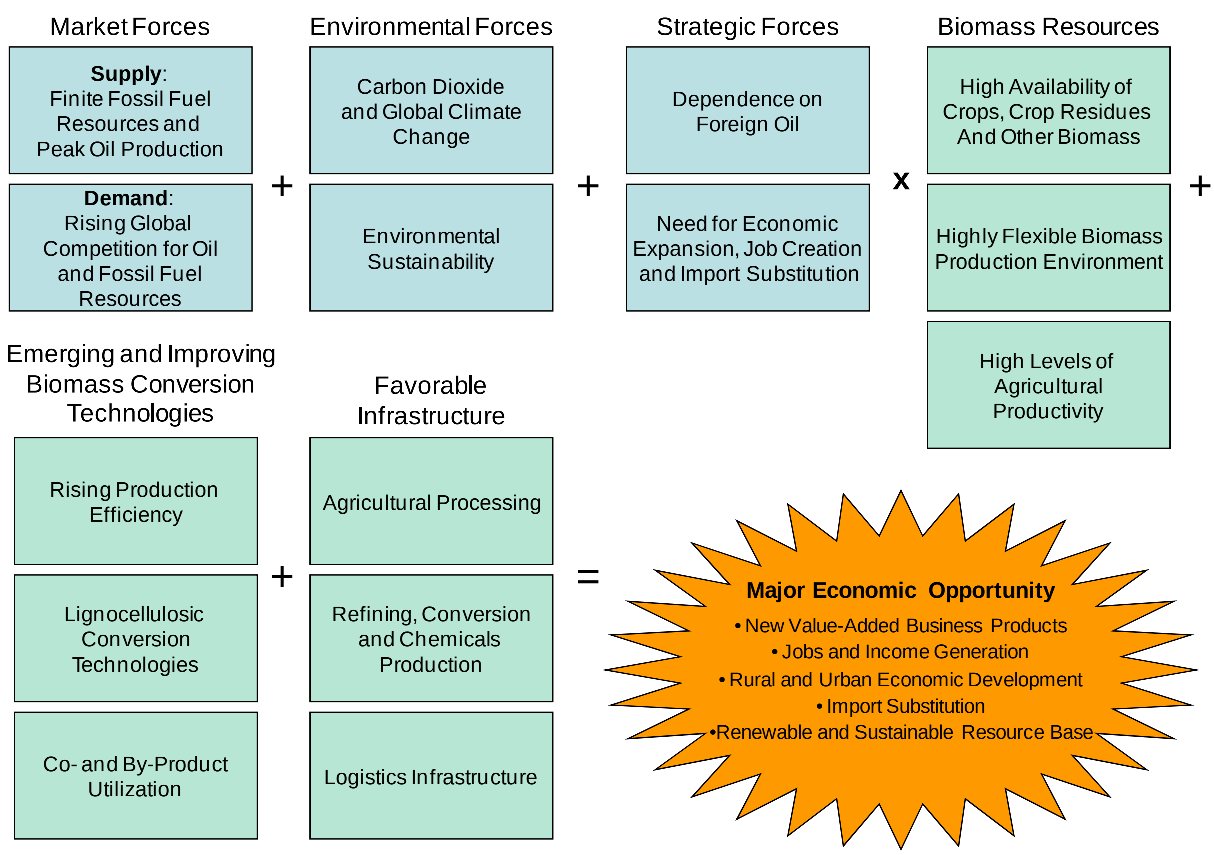
The Mid-South Mississippi Delta region's biomass productivity is evident across a range of biomass resource types, including: crops, crop residues, forest biomass and forest residues. Favorable growing characteristics of the region also give it the potential for production of dedicated biomass crops. To these agricultural and forestry biomass resources can be added biomass residue from municipal waste and industrial waste streams—available in particular concentration within the Memphis MSA in the center of the region.

C. Recognizing the Opportunity

The Memphis Bioworks Foundation is a non-profit organization dedicated to the development of the Memphis MSA and the broader Mid-South region as a center for bioscience-based economic growth. Located in the heart of the Mid-South Mississippi Delta, Memphis is the geographic and resource hub for the study region.

Memphis Bioworks Foundation recognized the powerful set of forces converging to make renewable resources and industrial bioprocessing a strategic priority and emerging economic opportunity for the country. Furthermore, Memphis Bioworks Foundation has concluded that the Mid-South Mississippi Delta region would be particularly well positioned to develop an industrial bioprocessing industry due to its high levels of biomass availability, agricultural flexibility, logistics position, existing industrial infrastructure and other favorable assets. **Combined with the region's clear agricultural and biomass production capabilities and existing assets for value-added processing of biomass, the Mississippi Delta appears to be extremely well positioned for biomass-based economic growth, as summarized in Figure 2.**

Figure 2: The Mississippi Delta Biomass Economy Equation



Following recommendations from a regional steering team commissioned in 2007, Memphis Bioworks Foundation developed a comprehensive scope of work and assembled a project team comprised of leading consulting organizations to develop a strategy for the Mid-South Mississippi Delta region that would enable and support the bioprocessing industry of the future. The project team includes leading experts in agricultural biomass development, chemical processing, technology evaluation, regional economic analysis and strategic economic development. Memphis Bioworks Foundation secured participation across five states, multiple regional economic development bodies, area industry and other key stakeholders to fund the development of the *Regional Strategy for Biobased Products in the Mid-South Mississippi Delta.*

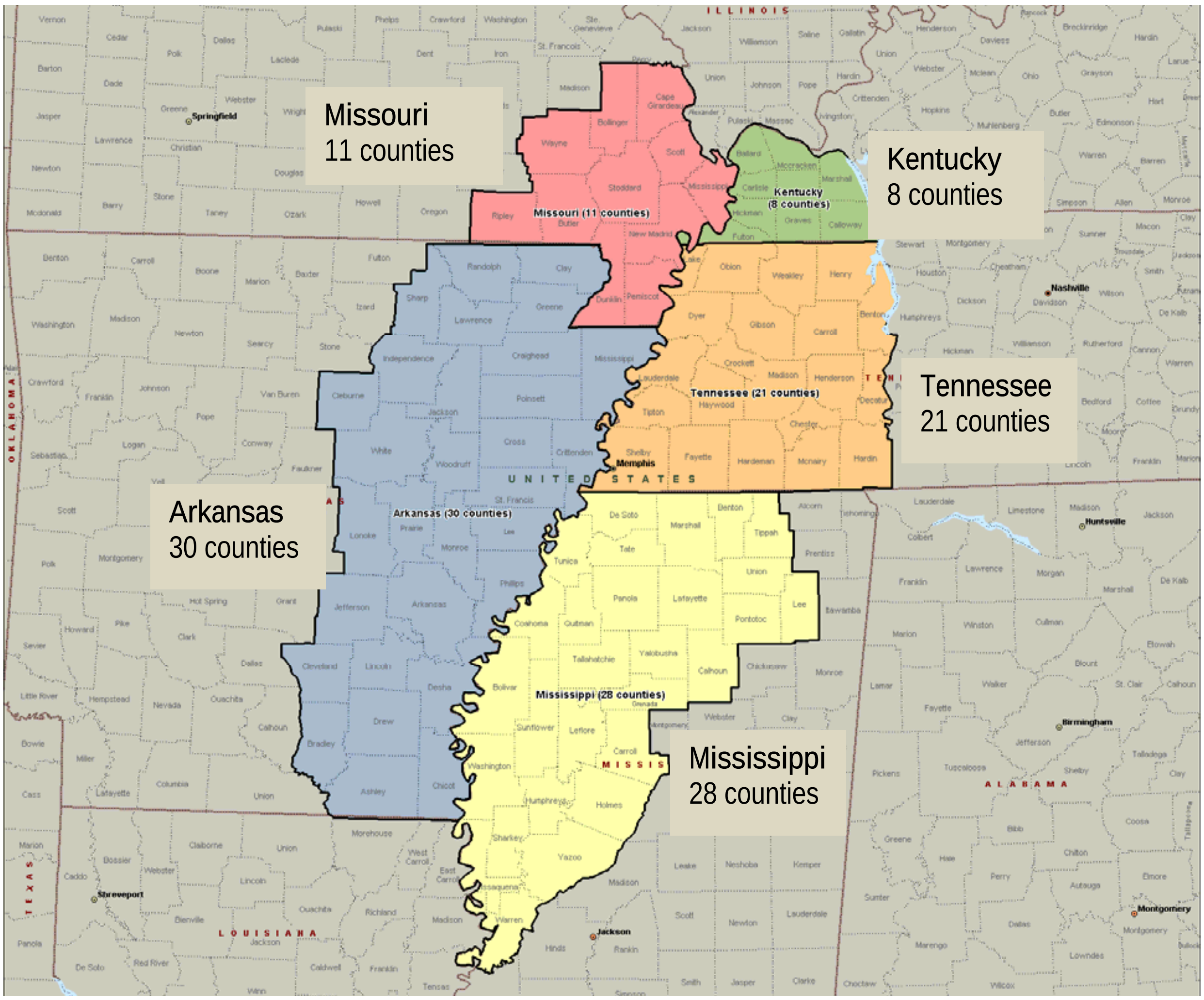
The strategy represents a first-of-kind, comprehensive regional approach to assess: biomass diversity and availability; processing technologies and products; supply and demand; economic potential and job impact; policy impact; and enablers for the bioprocessing industry of the future. The strategy provides analysis and observations regarding the development of new biomass feedstocks and biobased processing in the region, and recommendations to realize the full economic development potential of the Mid-South Mississippi Delta biomass resources.

D. Defining the Mid-South Mississippi Delta Region

The composition of the study region was determined based on a rational examination of the geography of biomass production and associated factors such as ecotype and topography.

The region, detailed in Figure 3, comprises 98 counties located within five states with the Mississippi River a central feature flowing south roughly through the center of the region. Memphis is the largest city in the region and is centrally located within the 98 counties.

Figure 3: The 98 Counties in the Mid-South Mississippi Delta Region



The study area includes 30 counties in east Arkansas, 8 in west Kentucky, 28 in northwest Mississippi, 11 in southeast Missouri, and 21 in west Tennessee.

The 98-county study region comprises a total land area of 36,077,000 acres (56,370 square miles). The 36 million acres in the study region constitute 22.2% of the total land area of the five states. The region contains a total U.S. Census estimated population (June 2007) of 3,658,666 persons, which constitutes 16.6% of the total population of the five states.

The Mid-South Mississippi Delta region's land use is heavily agricultural. A total of 21,461,400 acres of land is in farms (59.5% of total regional land area), of which 17,604,700 acres is either cropland or pasture land. The 98 counties contain 13,864,000 acres of forestland (38.4% of total regional land area). **When summed the cropland, pastureland, and forested land area (primary biomass production land) covers 31,468,700 acres or fully 87.2% of the total 98 county regional land area.** The Mid-South Mississippi Delta region represents an intensive biomass production area in the United States and biomass represents the primary commercial renewable opportunity for the region.

The basic statistics for the study area in each of the five constituent states are shown in Table 1.

Table 1: Population and Land Area Size of 98-County Study Area

State	Population in Study Area Counties	Population as Percent of State Total	Population as a Percent of 98-County Study Area Total	Land Area in Study Area Counties (acres)	Percent of Total State Land Area	Land Area as a Percent of 98-County Land Area Total
Arkansas	842,301	29.7%	23.0%	13,436,400	39.5%	**37.2%**
Kentucky	163,425	3.9%	4.5%	1,517,300	5.9%	**4.2%**
Mississippi	851,331	29.2%	23.3%	10,051,600	32.4%	**27.9%**
Missouri	304,236	5.2%	8.3%	4,251,300	9.5%	**11.8%**
Tennessee	1,497,373	24.3%	40.9%	6,820,400	25.3%	**18.9%**
Total	**3,658,666**	**16.6%**	**100.0%**	**36,077,000**	**22.2%**	**100.0%**

The Mid-South Mississippi Delta region's ecotypes and agricultural characteristics are suited to the production of a broad range of crops and dedicated biomass feedstocks. Agricultural producers in the region are flexible, and cropping statistics reveal a base of farmers willing to change their crop profile to meet the demands and opportunities in the marketplace.

Coupled with a strong transportation infrastructure (rail, road and water) and a base of existing industry in agricultural processing, fuels and chemicals sectors, the region is well positioned to take an early leadership position in the new biobased product economy.

E. Goals of the Project

The core mission of the project is to develop an analysis and recommendations for maximizing the economic value of the Mid-South Mississippi Delta's biomass assets. The project team concluded that the highest and best use of the region's grain and oilseed production would likely continue to be directed toward food and feed markets. However, the team also concluded that the "food versus fuel" debate, certainly in terms of crops other than corn, has been greatly overstated—particularly for a diverse agronomic environment such as the Mid-South Mississippi Delta, which can support commodities for both uses. While rice grains, corn kernels and soybeans have substantial value as food and feed, little value is presently realized from the large amounts of residual biomass associated with the growth and processing of these crops. Likewise, significant forest land within the region produces sustainable lignocellulosic feedstocks which have potential for processing into value-added bioproducts, including high-value fuels. **The study sought to identify the optimal pathways to realize maximum economic return from the full biomass resource of the Mississippi Delta, including underutilized residues and other biomass resources.**

Maximizing such returns requires a strategy to address an entire value-chain from biomass production, through harvesting, agricultural processing, and downstream value-added processing into intermediate and end products. A new regional supply chain—based upon biomass resources—provides a foundation for a sustainable economic future, firmly rooted in local resources. Furthermore, the distributed nature of biomass production across the entire region means that rural economies will greatly benefit from biobased economic development, while urban centers will also have an important role to play given their value-added industry bases and as hubs in the logistics and distribution infrastructure. Early stage processing of biomass and small scale biorefineries will need to be located in close proximity to biomass production and, therefore, much of this value-added processing will be distributed across the region benefiting rural areas and the Delta's smaller towns and communities.

The study also sought to inform industries within the Mississippi Delta concerning the potential for biobased inputs. Companies manufacturing and using liquid fuels, lubricants, specialty chemicals, plastics, resins, paints, materials and a host of other products may well have a biobased future. However, the biobased economy is a new world for many companies. With little agricultural experience these companies need assistance to understand how best to cooperate with the agricultural and forestry production systems to create an alternative biobased supply chain that is reliable in both quantity and quality. Additionally, many companies are uncertain how to evaluate the wide range of variables that go hand-in-hand with biologic production systems.

To address these issues, companies that are considering the transition to a biobased supply chain will need to learn a great deal about adapting systems or building new systems to access and use biobased feedstocks. One of the critical issues facing industry in the region will be organizing a reliable supply chain to assure the economic production of sufficient volumes of inputs via biomass pathways. This requirement to determine optimal biobased supply chains and the potential clustering of biomass processing and value-added industries around this biomass is a key driver of the regional strategy project.

In addition to the corporate audience, policy makers and economic development leaders need access to a strategy to guide their decision making and actions in facilitating biobased economic development. Actions on issues such as mandates for biobased content in liquid fuels, renewable energy standards, adoption of biofuels by state and municipal vehicle fleets, and tax incentives favoring biobased production and processing investments need to be driven by rational information and a logical strategy. Likewise, regional and local economic developers need guidance on what to look for in terms of assets and resources that they can deploy to encourage biobased economic development. Economic developers have questions regarding existing industrial facility characteristics and their potential for redevelopment to bioprocessing applications, and how businesses in their jurisdictions may participate in the use or development of biobased feedstocks. They need to clearly understand their local infrastructural assets, how to leverage these into greater opportunities, and what gaps need to be addressed.

The complexity of building a new biobased economy in the Mid-South Mississippi Delta is difficult to overstate. Some of the factors to be considered include:

- What crops/biomass are currently produced, what is the best use of these crops and what are the characteristics and volumes of biomass residues that are generated?
- What alternative crops are appropriate to the regional production environment and what would be their suitability and economic advantages as biobased production feedstocks?
- What agricultural processing capabilities exist within the region and what additional capabilities will be required to drive a biobased industry value-chain?
- What are the economics of transporting various biomass materials and what impact will this have on the location and scale of processing plants and biorefineries?
- What methods of transportation will be best suited to the movement of biomass, intermediate products and finished products and how well does the current transportation infrastructure within the region meet these projected needs?
- Which existing industries and companies located within the region may have a demand for biobased inputs?

- What conversion and biorefining technologies offer the best opportunity for commercial production of fuels and chemicals from biomass? What existing infrastructure exists within the region that can be adapted to the use of these technologies?
- What is the regional demand for liquid fuels, and to what extent can biofuels from regional sources be used to supplant imported petrochemical based fuels?
- What are the workforce requirements for an integrated biomass-based industrial value-chain? What specialized skills are required? How many new jobs will be generated and where will they be located?
- Which institutions are best positioned to educate and train the bioprocessing workforce of the future?

Clearly there is much to be thought through in determining answers to these questions and formulating a workable strategy for development. Just within the biomass production stage it must be realized that few industries face the annual challenges, risks and uncertainties faced by farmers. Writing in a report for The Ohio State University,[9] the Battelle Technology Partnership Practice noted that:

> *The farmer faces an almost overwhelming series of decisions each year that may make or break his or her bottom-line. What crops will I plant this year? What variety will grow best and yield the highest returns? Which commodities will be in oversupply or scarce supply this year and what effect will this have on prices? What diseases will my crops and animals face and what is my best approach to offset the threat of these? What days will be optimal for planting and which for harvest? What fertilizers and soil improvement strategies should I adopt based on my soil characteristics, crop rotation history and recent environmental factors? What planting, harvesting and processing technologies should I invest in to enhance my bottom-line? What new crops, products and varieties should I be considering based on changing consumer and market demands? No other category of business faces such a variable and risky series of decisions that must be made and repeated year after year.*

Simply introducing a new crop to the regional growing environment is a surprisingly complex task. Regional land grant universities and seed companies have to be engaged in breeding, developing and evaluating crop varieties to determine those with consistent high-level performance and the best growing characteristics within the region's agronomic environment. New crop R&D requires a significant investment in resources and time to conduct test plantings at research farms. Researchers need to determine the impacts of the region's growing environment on potential crop diseases, pest threats and plant resistance to environmental stresses. The suitability of various soil types under varying conditions and management practices has to be evaluated, input recommendations developed, integrated pest and disease management strategies produced, planting and harvesting schedules determined, and optimized agronomic and harvesting practices developed. Once these steps are taken farmers then have to be recruited to grow the crop in sufficient volume to make it a viable and reliable process input. Technologies have to be deployed for harvesting, storage, transportation and processing of the crop. New crop introduction is indeed a complex business with very long-term product development cycles (7–10 years on average).

Downstream, as technologies emerge and mature to produce value-added products from biomass there are also many variables to consider. Producers need a reliable supply and consistent quality of biomass feedstocks (especially if producing specialty chemicals or materials). Value-added product manufacturers also need a continuous stream of feedstock arriving at their plant for processing, presenting a supply, storage and logistics challenge for many seasonally harvested biomass feedstocks. In some instances

[9] Battelle Memorial Institute – Technology Partnership Practice. "The Ohio Agricultural Research and Development Center: A Generator of Positive Economic Impacts for Ohio". January 2004.

equipment and technologies for producing value-added products from petrochemical feedstocks may be adapted to biomass inputs; however, in many cases new capital investment and engineering will be required and additional processes may need to be introduced into the manufacturing system for pre-processing, processing and waste management stages. Storing biodegradable materials also brings challenges less likely to be encountered when dealing with fossil- based inputs.

Basic technology development and demonstration is still a key issue for most biobased product categories. Best practices, processes and technologies have not yet been established, particularly for production of liquid fuels from lignocellulosic feedstocks. Comprised of the woody or structural components of plants, lignocellulosic biomass represents a significant potential as a feedstock for value-added production that does not compete with food. Lignocellulosic materials are available in significant volumes in the region from crop residues (corn or sorghum stover, rice straw, etc.), from forest biomass, and from industrial waste streams (such as sawdust). Additionally, lignocellulosic materials may be produced via dedicated biomass crops grown specifically for biofuel or related applications (such as switchgrass, hybrid poplar, willow or sweet sorghum).

Abundant lignocellulosic biomass availability within the Mid-South Mississippi Delta will likely make a cellulosic processing platform the key technology for the region's biobased processing industry.

F. Structure of the Project Report

The report is separated into specific chapters on: feedstocks (biomass availability); biomass conversion technologies and biobased products; regional biobased products supply and demand; regional enablers for an emerging bioprocessing industry, the economic impact of a regional bioprocessing industry, policy implications and key conclusions and recommendations by the project team.

The analyses and observations contained in this report are supported by multiple sub-reports produced by the project team members during the course of the project. These sub reports can be accessed online at the Memphis Bioworks Foundation website: www.agbioworks.org.

G. The Project Team

A project of the size and complexity of the *Regional Strategy for Biobased Products in the Mississippi Delta* required the assembly of a customized project team. The project team retained by Memphis Bioworks Foundation comprised a team led by Battelle (the world's largest nonprofit science and technology R&D institute) and BioDimensions, Inc., a consulting and business development organization that is actively working to commercialize alternative crops and develop biobased product businesses. Multiple region-based consultancies were also brought into the team to provide specialized subject matter expertise in specific areas. The full consulting team was guided by the project steering committee organized under the Memphis Bioworks Foundation. The consulting team was comprised of the following entities:

Project Leadership Consultants

Organization	Description	Project Responsibilities
Battelle Technology Partnership Practice (TPP)	Headquartered in Columbus, Ohio, Battelle is the world's largest non-profit R&D institution. Battelle's Technology Partnership Practice is the organization's science and technology-based economic development consulting division.	Co-management of the project with BioDimensions. Biobased product market assessment. Benchmarking of activities in other biobased product development regions. Economic analysis and identification of processing assets. Overall evaluation of biobased product potentials and highest and best use of resources. Compilation of overall project report and executive summary in collaboration with BioDimensions.
BioDimensions, Inc.	Based in Memphis, Tennessee, BioDimensions is a specialized biobased products consulting and business development firm, working with clients in the conceptualization of biobased projects and specific biobased product commercialization plans.	Development of project vision and co-management of the project with Battelle. Assessment of biomass conversion technologies. Special studies in industrial infrastructure, sweet sorghum and new crop potentials. Workforce and employment evaluation. Compilation of overall project report and executive summary in collaboration with Battelle.

Specialized Project Consultants

Organization	Project Responsibilities
BioEnergy Systems LLC	Assessment of biomass availability, feedstock characteristics and production potentials.
Entira	Assessment of agronomic considerations for new crops.
Frazier, Barnes & Associates	Assessment of oilseed crops and opportunities
Strata-G, LLC	Assessment of logistics capabilities and assets for biobased products in the Mid-South Mississippi Delta region.
Winrock International	Evaluation of environmental impacts and sustainability evaluation.
Mike Ott – an Iowa-based independent consultant	Contribution to the assessment of process and conversion technologies and project financing.

H. Summary

There are multiple imperatives—strategic, environmental and economic—driving the need for renewable and sustainable resources for energy production and as feedstocks for the U.S. economy. Replacing a significant proportion of fossil-based resources, especially imported oil and petroleum products, is a central national strategy—a strategy that must be implemented at state and regional levels.

While there are various renewable resource options, the geographic distribution of these potential options is region specific. There is considerable spatial variability in the feasibility of energy generation via wind, solar, geothermal and hydro-electric technologies, and large parts of the nation cannot produce significant commercial energy via these pathways. Biomass represents the most distributed renewable energy source, but still has substantial geographic variability. Biomass also represents the only renewable energy resource for producing liquid fuels, chemicals, and materials to replace petroleum-based products, as the other renewable technologies can only be used to produce electricity. Biomass is clearly a critically important driver for the future biobased economy.

Biomass resources are generally not unique or specific within state lines. The commonality of agricultural characteristics and biomass resources across the Mid-South Mississippi Delta clearly indicates that regional cooperation to enable the bioeconomy makes the most sense. The 98-county Mid-South

Mississippi Delta is a region with high biomass availability and diverse biomass production capabilities. As such, the region has the potential to become a leader in the development of a broad biobased economy. The potential for development of other alternative energy sources is comparatively low in this region, and it is clear that biomass must form the core of a renewables-powered regional economy.

Biomass resources, coupled with significant existing logistics infrastructure, agricultural processing, refining and chemicals manufacturing, provides the Mid-South Mississippi Delta region with a strong asset base to build upon. However, the development of a biobased economy requires analysis of many variables, including agricultural production, feedstock potentials, workforce development, processing capabilities, product opportunities, regional supply and demand interactions, and a host of additional factors. For the region to make wise decisions and develop effective pathways to bioeconomy development, it needs to have a coherent understanding of the opportunities and challenges.

Memphis Bioworks Foundation has assembled a specialized consulting team to assess and quantify the biobased economy opportunity for the Mid-South Mississippi Delta region and to produce a detailed analysis and strategic recommendations for realizing that opportunity. Key stakeholders from five states and multiple public and private sector organizations have cooperated to fund and develop the project. The project represents a unique multi-state regional collaborative effort in accelerating and facilitating biobased economic development.

II. Regional Biomass

A. Regional Lignocellulosic Biomass Characterization

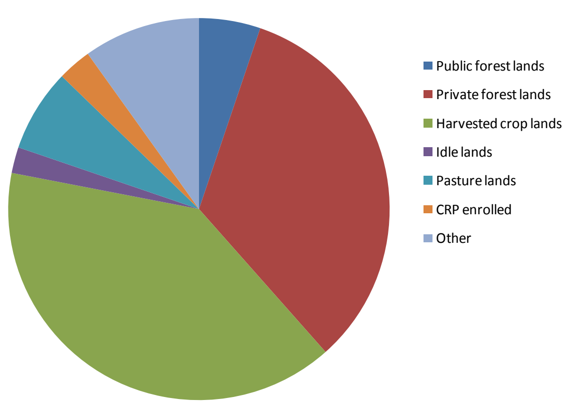
This summary is excerpted from the study sub-report "Assessment of Agricultural and Forest Biomass Resources in the Mid Portion of the Mississippi River Alluvial Valley," prepared by BioEnergy Systems LLC. The full sub-report is available online at www.agbioworks.org.

The data and analyses presented herein were prepared by BioEnergy Systems LLC under a contract with Winrock International, with support from a grant from the State of Arkansas Economic Development Commission. The Arkansas Economic Development Commission is a Funding and Implementation Partner of the *Regional Strategy for Biobased Products in the Mississippi Delta.* Excerpts from this sub-report presented here estimate production of key biomass feedstocks within the study region. This report refers to numerous tables and maps that were prepared specifically for this assessment, all of which are incorporated as attachments to the full report, which is available online. Notes regarding data sources and assumptions for calculations are provided within the various tables.

Land Use

Overview: The 98-county study region consists of the middle portion of the Mississippi River alluvial valley as well as counties to the east and west with bordering uplands and forested lands. The region encompasses a total land area of 36,080,000 acres, of which roughly 38% is forested and 59% is in farm land. Figure 4 shows a breakout of land use in the region.

Figure 4: Land Use Study in the Region

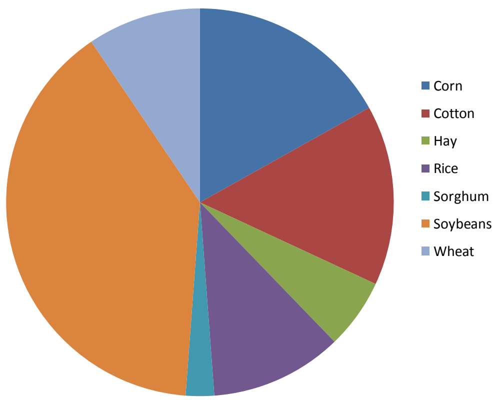


- **Forest lands:** About 86% of the study region's forestlands are privately owned, with the balance of 14% owned by Federal, state, or other public entities.
- **CRP lands:** There is widespread interest in potentially using lands currently in the Conservation Reserve Program (CRP) for production of dedicated energy crops. In 2007, just over one million acres of land in the study region was enrolled in CRP, which constituted about 2.9% of the total land area or about 7.2% of harvested cropland; approximately 385,000 acres (37%) of CRP lands are scheduled to expire during the period 2008–2012.
- **Agricultural lands:** Approximately 67% of the farm land in the study region is harvested cropland, approximately 4% of the region's farm land is idle or used for cover crops or soil improvements (i.e., not harvested or pastured or grazed), and approximately 12% of the region's farm land is used for pasture. For this analysis, primary crops produced in the region include corn, cotton, hay, rice, sorghum, soybeans, and wheat. Maps using data from USDA's Cropland Data Layer show that, as expected, most of the primary crop production occurs on the alluvial plain.

Feedstocks

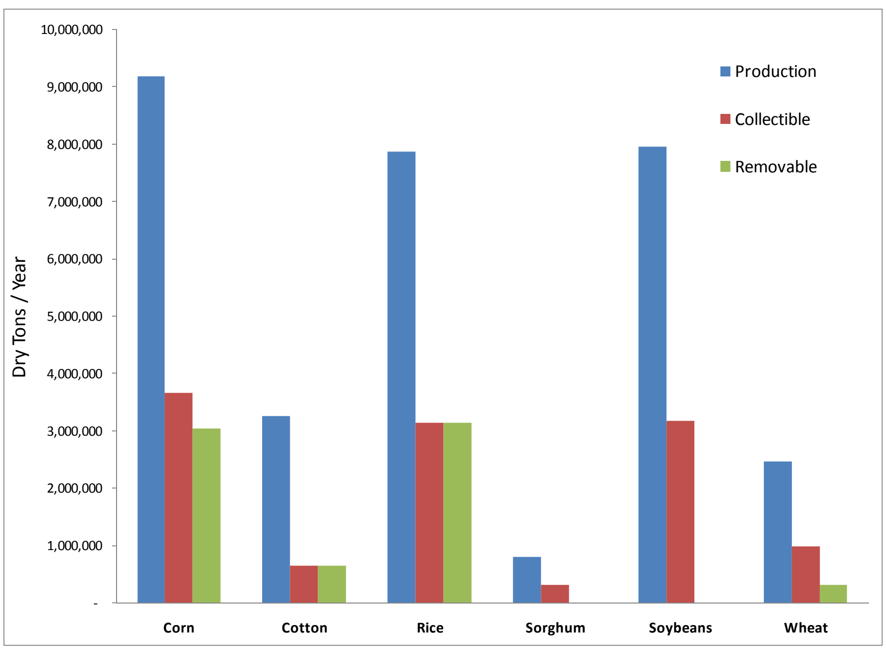
Feedstocks of primary interest within the study region include agricultural crops (e.g., corn and soybeans for first-generation biofuels production), agricultural crop residues (i.e., lignocellulosic materials from primary crops produced), agricultural processing residues (only those produced from cotton and rice were considered in this study), and woody biomass (i.e., forest-derived lignocellulosic feedstocks). This analysis also provides estimates of potential production of biomass feedstocks from dedicated energy crops, based on various assumptions as further discussed below.

Figure 5: Crop Acreage Study in the Region



Agricultural Crops and Residues: 2007 Agricultural Census[10] data were used as the basis for analyzing primary crop production and associated field residue production, along with various agronomic and other assumptions for each crop. For agricultural field residues, estimates are provided for total residue production, logistically collectible residue amounts, and sustainable removable residue amounts. Collectible and removable factors were derived from data provided in Table B.2 of the "Billion Ton Study."[11] Figure 5 depicts production acreage by primary crop in the study region. A comparison of residue production and availability is shown in Figure 6.

Figure 6: Crop Residues in the Study Region



Corn: In 2007, the region's corn grain production was approximately 9.2 million tons[12] (393 MM bushels [bu]) on 2.6 million acres (17% of total primary cropland), with an average yield of 3.6 tons/acre per year. The estimated quantity of corn stover production is 9.2 million (MM) tons/year; the estimated amount that could be collected and sustainably removed is 3.0 MM tons/year.[13]

Cotton: In 2007, the region's cotton production was approximately 1.0 MM tons (4.5 MM bales) on

[10] USDA's National Agricultural Statistics Service http://www.agcensus.usda.gov/
[11] "Biomass as Feedstock for a Bioenergy and Bioproducts Industry: Technical Feasibility of a Billion-Ton Annual Supply". USDOE and USDA. April 2005. http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf
[12] Unless otherwise noted, all tonnage figures in this report are "dry matter basis" (i.e. calculated at zero percent moisture content).
[13] Based on analysis of data in the Billion Ton study: additional data are needed, however, to ascertain sustainably removable factors specific to local production conditions.

2.3 million acres (15% of total primary cropland), with an average yield of 0.4 tons per acre per year. The estimated quantity of cotton stalk production is 0.6 MM tons/year; the estimated quantity that could be collected and sustainably removed is zero.[14] The estimated quantity of cotton gin trash production is 0.2 MM tons/year.

- **Hay:** In 2007, the region's hay production was approximately 1.7 MM tons on 0.9 million acres (6% of total primary cropland), with an average yield of 1.9 tons per acre per year. No estimates of field residue were made, based on the assumption that no harvestable residue exists after the hay is removed.
- **Rice:** In 2007, the region's rice grain production was approximately 5.3 MM tons (119 MM cwt) on 1.7 million acres (11% of total primary cropland), with an average yield of 3.2 tons per acre per year. The estimated quantity of rice straw production is 7.9 MM tons/year; the estimated quantity that could be collected and sustainably removed is 3.1 MM tons/year. The estimated quantity of rice hull production is 1.1 MM tons/year.[15]
- **Sorghum:** In 2007, the region's grain sorghum production was approximately 0.8 MM tons (33 MM bu) on 0.4 million acres (2% of total primary cropland), with an average yield of 2.2 tons per acre per year. The estimated quantity of sorghum stalk production is 0.8 MM tons/year; the estimated quantity that could be sustainably removed is zero.[16]
- **Soybeans:** In 2007, the region's soybean production was approximately 5.5 MM tons (196 MM bu) on 6.0 million acres (39% of total primary cropland), with an average yield of 0.9 tons per acre per year. The estimated quantity of soybean stalk production is 0.8 MM tons/year; the estimated quantity that could be sustainably removed is zero.[17]
- **Wheat:** In 2007, the region's wheat grain production was approximately 1.6 MM tons (61 MM bu) on 1.4 million acres (9% of total primary cropland), with an average yield of 1.1 tons per acre per year. The estimated quantity of wheat straw production is 2.5 MM tons/year; the estimated quantity that could be collected and sustainably removed is 0.3 MM tons/year.[18]

Woody Biomass: Woody biomass includes both forest-based biomass and processing residues. For this study it was assumed that processing residues generated by the region's forest products industry (both primary and secondary) are already fully utilized (mostly on-site cogeneration at forest products processing facilities), and therefore no such biomass was considered available for bioenergy/bioproducts production and was therefore not characterized in this assessment.[19] For forest-based biomass, this

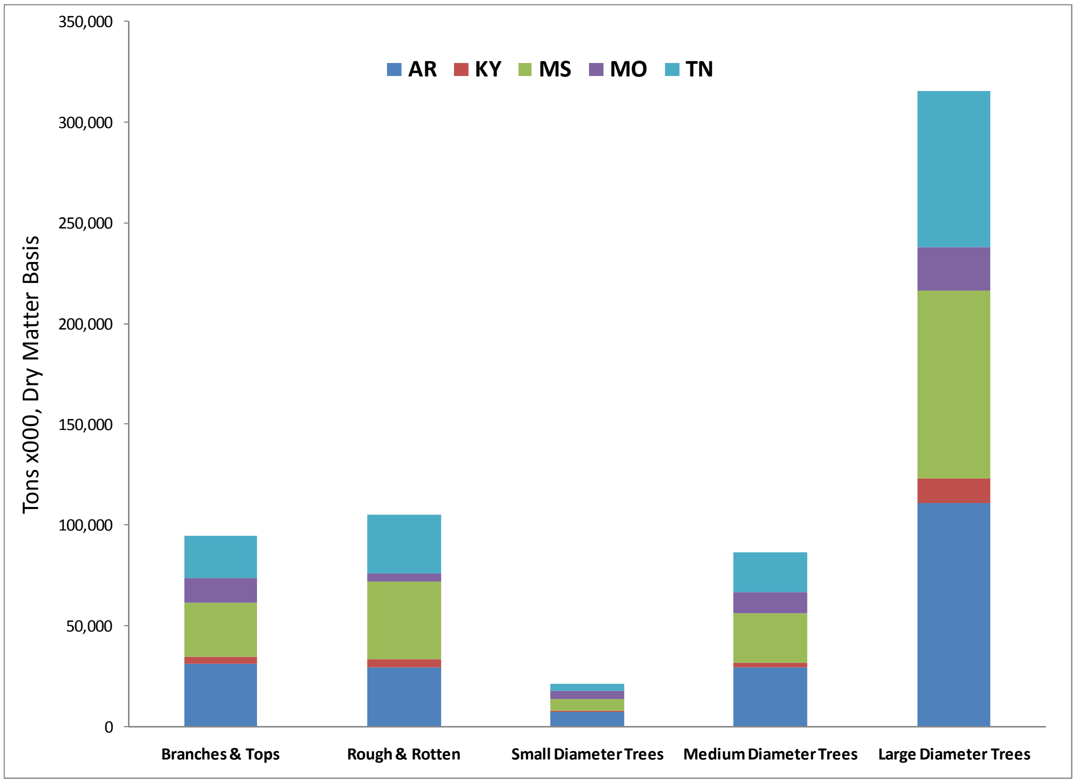
[14] Ibid.
[15] Ibid.
[16] Ibid.
[17] Ibid.
[18] Based on analysis of data in the Billion Ton study: additional data are needed, however, to ascertain sustainably removable factors specific to local production conditions.
[19] Although no central repositories of data regarding woody processing residue production are known to exist for the geographic scope of this assessment, various factors are available for estimating the amount of sawdust and other woody processing residues generated (e.g., one rule-of-thumb is 50% of each saw log). However, potential availability of woody processing residues is an economic question. Since most of these residues are currently being used by forest products manufacturing facilities for on-site cogeneration, acquisition of such feedstocks would likely reflect prices for the feedstocks that would allow the facilities to obtain replacement fuels for their on-site energy requirements. Figure 11 on page 6 of "Arkansas' Timber Industry – An Assessment of Timber Product Output and Use, 2005" (U.S. Forest Service, Southern Research Station, publication SRS-132) shows that primary mill residue "Not used" is less than 1% (http://www.srs.fs.usda.gov/pubs/rb/rb_srs132.pdf). Nonetheless, development of a target feedstock portfolio for a specific bioenergy facility should attempt to evaluate the potential production and availability of such residues.

assessment used data from the U.S. Forest Service's Forest Inventory Analysis (FIA) dataset for all forestlands in the study region. Forest biomass categories evaluated include:

- **Branches and tops:** For the purposes of this analysis, "Branches and Tops" is defined as all live biomass on forestlands from growing stock greater than 5 inches diameter at breast height (dbh), subtracting biomass attributed to merchantable stem biomass (foliage is not measured by FIA). The total estimated quantity of branches and tops in the study region is 95 MM tons, of which 82% is from hardwoods and 18% from softwoods.
- **Rough and rotten:** For the purposes of this analysis, "Rough and Rotten" is defined as all live biomass (regardless of size in dbh) on forestlands from *rough and rotten culls* (as measured by the U.S. Forest Service); bark biomass and stem wood biomass are calculated and presented separately in this analysis. The total estimated quantity of rough and rotten forest biomass in the study region is 105 MM tons, of which 92% is from hardwoods and 8% from softwoods; the total bark fraction is 7%.
- **Small diameter trees:** For the purposes of this analysis, "Small Diameter Trees" is defined as all live biomass on forestlands from growing stock less than 5 inches dbh (bark is not analyzed separately, i.e., bark is included *within* the estimated quantities of small diameter trees). The total estimated quantity of small diameter tree biomass in the study region is 22 MM tons, of which 75% is from hardwoods and 25% from softwoods.
- **Medium diameter trees:** For the purposes of this analysis, "Medium Diameter Trees" is defined as all live biomass on forestlands from growing stock of 5–11 inches dbh for hardwoods and 5–9 inches dbh for softwoods; bark biomass and stem wood biomass are calculated and presented separately in this analysis. The total estimated quantity of medium diameter tree biomass in the study region is 87 MM tons, of which 77% is from hardwoods and 23% from softwoods; the total bark fraction is 12%.
- **Large diameter trees:** For the purposes of this analysis, "Large Diameter Trees" is defined as all live biomass on forestlands from growing stock greater than 11 inches dbh for hardwoods and 9 inches dbh for softwoods, subtracting biomass attributed to foliage; bark biomass and stem wood biomass are calculated and presented separately in this analysis. The total estimated quantity of large diameter tree biomass in the study region is 316 MM tons, of which 78% is from hardwoods and 22% from softwoods; the total bark fraction is 13%.

The total quantity of forest biomass in the study area is 624 MM tons. Figure 7 provides a summary of forest biomass in the study region by type and state.

Figure 7: Summary of Standing Forest Biomass in the Study Region



The 624 MM tons of forest biomass in the region divided by the total of 13,864,000 acres of forestland in the study area equates to an average of 45 tons of forest biomass per acre. Assuming a weighted average harvest rotation of 28 years, this equates to an average potential removal rate of 23 MM tons per year, or 1.6 tons per acre per year.[20]

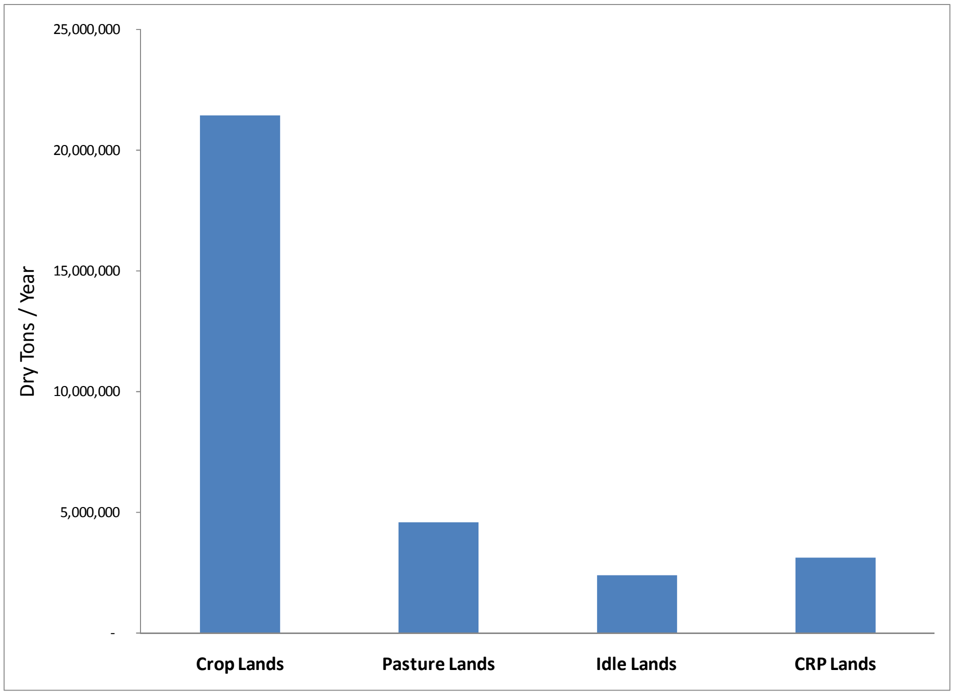
Up to 65% of forest residue biomass (i.e., non-merchantable forest biomass, which includes branches and tops, rough and rotten biomass, small diameter trees, and bark from medium- and large-diameter trees, but does not include medium- and large-diameter tree bark) could be sustainably removed, based on logistical and ecological considerations.[21] Accordingly, estimated total removable forest residue biomass in the region is 6.4 MM tons/year,[22] which equates to 0.46 tons per acre per year.[23] The total estimated amount of stem wood biomass from medium- and large-diameter trees in the region is 12.7 MM tons/year,[24] or 0.92 tons per acre per year.[25] If 10% of this amount is harvested and used for bioenergy/bioproducts, the total biomass feedstock quantity would be 1.3 MM tons/year.[26]

Dedicated Energy Crops: For this analysis, projections of potential production of lignocellulosic energy crops are based on two assumptions: estimated yield for each land category (in tons per acre per year, dry

[20] Based on assumed average harvest cycles of 30 years for hardwoods and 18 years for softwoods, and reflecting the calculations shown in Table 3.6.8 that 81% and 19% of the forest biomass in the region are hardwoods and softwoods, respectively.
[21] Derived from the Billion Ton Study and independently validated through research coordinated with the University of Arkansas' School of Forest Resources.
[22] i.e., 273 MM tons of estimated forest residue biomass ÷ 28 years × 0.65 removable factor.
[23] i.e., 6,400,000 tons/year ÷ 13,864,000 acres of forestland in the region.
[24] i.e., 352 MM tons of estimated forest *residue* biomass ÷ 28 years.
[25] i.e., 12,700,000 tons/year ÷ 13,864,000 acres of forestland in the region.
[26] It is assumed that, for economic reasons, harvest and utilization of stem wood from medium- and large-diameter trees will continue to occur primarily for saw timber and pulp markets, i.e., only a limited fraction of such high-value material (10% is assumed for this analysis) will be harvested and utilized for bioenergy/bioproducts manufacturing.

matter basis) and land participation factors for each land category on which energy crops are grown. Accordingly, this assessment did not compare yields or other attributes for particular species or variety (whether woody or herbaceous, annual or perennial), but utilized yield assumptions that are based on publicly cited projections from leading biotechnology firms (for certain herbaceous energy crops, i.e., switchgrass and miscanthus). Figure 8 shows the total estimated production of lignocellulosic biomass on the various land categories for the base case assumptions discussed.

Figure 8: Estimated Potential Biomass Production in the Study Region from Dedicated Energy Crops on Various Land Categories (based on the base case land use factors and agronomic yield)



- **Estimated production on crop lands:** For the base case assumptions of 15 tons per acre per year and 10% utilization of the agricultural crop land area in the study region (i.e., production on 11% of 14.3 MM acres), estimated production would be 21.4 MM tons/year dry matter basis. Sensitivity analyses on both key variables indicates that estimated production could range from 1.8 MM tons/year at 5% crop land utilization and 2.5 tons/acre/year to 85.7 MM tons/year at 30% land utilization and 20 tons/acre/year.
- **Estimated production on pasture lands:** For the base case assumptions of 12 tons per acre per year[27] and 15% utilization of the pasture land area in the study region (i.e., production on 15% of 2.5 MM acres), estimated production would be 4.6 MM tons/year dry matter basis. Sensitivity analyses on both key variables indicates that estimated production could range from 0.3 MM tons/year at 5% crop land utilization and 2.5 tons/acre/year to 15.2 MM tons/year at 30% land utilization and 20 tons/acre/year.

[27] For this assessment, the base case yield assumption for pasture lands was slightly reduced relative to croplands (i.e., from 15 to 12.5 tons/acre/year) based on an assumption that most pasture lands are less productive than crop lands.

- **Estimated production on idle lands:** For the base case assumptions of 12 tons per acre per year[28] and 25% utilization[29] of the idle land area in the study region (i.e., production on 25% of 0.8 MM acres), estimated production would be 2.4 MM tons/year dry matter basis. Sensitivity analyses on both key variables indicates that estimated production could range from 0.1 MM tons/year at 5% idle land utilization and 2.5 tons/acre/year to 4.7 MM tons/year at 30% land utilization and 20 tons/acre/year.
- **Estimated production on CRP lands:** For the base case assumptions of 12 tons per acre per year[30] and 25% utilization[31] of the CRP land area in the study region (i.e., production on 25% of 1.0 MM acres), estimated production would be 3.1 MM tons/year dry matter basis. Sensitivity analyses on both key variables indicates that estimated production could range from 0.1 MM tons/year at 5% CRP land utilization and 2.5 tons/acre/year to 6.2 MM tons/year at 30% land utilization and 20 tons/acre/year.

Summary of estimated lignocellulosic feedstocks in the region: The total potential biomass production in the study region can be summarized as follows:

- Production of crop *field* residues varies from 1.3 to 4.7 tons/acre/year, although sustainably removable residue quantities vary from 0 to 1.9 tons/acre/year. Total estimated agricultural field residue production that is considered sustainably removable is 7.2 MM tons/year. If 25% of this material is harvested and utilized, then annual biomass feedstock supplies from crop field residues would be 1.8 MM tons/year.
- Production of crop *processing* residues includes cotton gin trash (at the equivalent of 0.1 tons/acre/year) and rice hulls (at the equivalent of 0.6 tons/acre/year). Total agricultural processing residue production in the region is 1.3 MM tons/year (84% rice hulls). If 75% of this material is obtained and utilized, then annual biomass feedstock supplies from crop processing residues would be 1.0 MM tons/year.
- Average potentially removable forest biomass in the region is 6.4 MM and 12.7 MM tons per year for forest residue biomass and for medium- and large-diameter stem wood, respectively. This equates to an average of 1.4 tons of woody biomass per forested acre per year.[32]
- Estimates of potential production of dedicated energy crops on several land types—reflecting key assumptions for yields and land participation factors by land type—include:
    - 21.4 MM tons/year on 10% of the region's crop lands at 15.0 tons/acre/year;
    - 4.6 MM tons/year on 15% of the region's pasture lands at 12.0 tons/acre/year;
    - 2.4 MM tons/year on 25% of the region's idle lands at 12.0 tons/acre/year;
    - 3.1 MM tons/year on 25% of the region's CRP lands at 12.0 tons/acre/year;
    - 31.5 MM tons/year total, based on the above assumptions for participation levels (by land category) and agronomic yields (per land category).

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[28] For this assessment, the base case yield assumption for idle lands was slightly reduced relative to croplands (i.e., from 15 to 12.5 tons/acre/year) based on an assumption that most lands that are considered to be idle are in such condition because the land—for whatever reason (e.g., low soil fertility)—does not support high yield crop production.
[29] For this assessment, the base case land utilization factor for idle lands was increased relative to croplands (i.e., from 10% to 15%) based on an assumption that most idle lands that could achieve relatively attractive agronomic yields for herbaceous energy crops would be high priority candidates for such crops.
[30] In this analysis, the base case yield assumption for CRP lands was slightly reduced relative to croplands (i.e., from 15 to 12.5 tons/acre/year) based on an assumption that many lands that are enrolled into CRP are done so because some portion of the land does not support high yield crop production.
[31] In this analysis, the base case land utilization factor for CRP lands was increased relative to croplands (i.e., from 10% to 15%) based on an assumption that most CRP lands that could achieve relatively attractive agronomic yields for herbaceous energy crops would be high priority candidates for such crops.
[32] i.e., 4.5 MM tons/year 13.9 MM acres of forestland in the study region.

Table 2: Summary of Regional Lignocellulosic Feedstock Availability

	Total Production MM tons/year	Sustainable Usable Quantities MM tons/year *	Fraction of Total net Amount Available
Agricultural Field Residues	31.5	7.2	12%
Agricultural Processing Residues	1.3	1.3	2%
Forest Residue Biomass	9.8	6.4	11%
Forest Stem Wood Biomass	12.7	12.7	22%
Dedicated Energy Crops **	31.5	31.5	53%
Totals	**86.8**	**59.0**	

*Based on the factors and assumptions described in this assessment

**Based on the projections set forth in this assessment

Changes in Agricultural Production 1987–2007

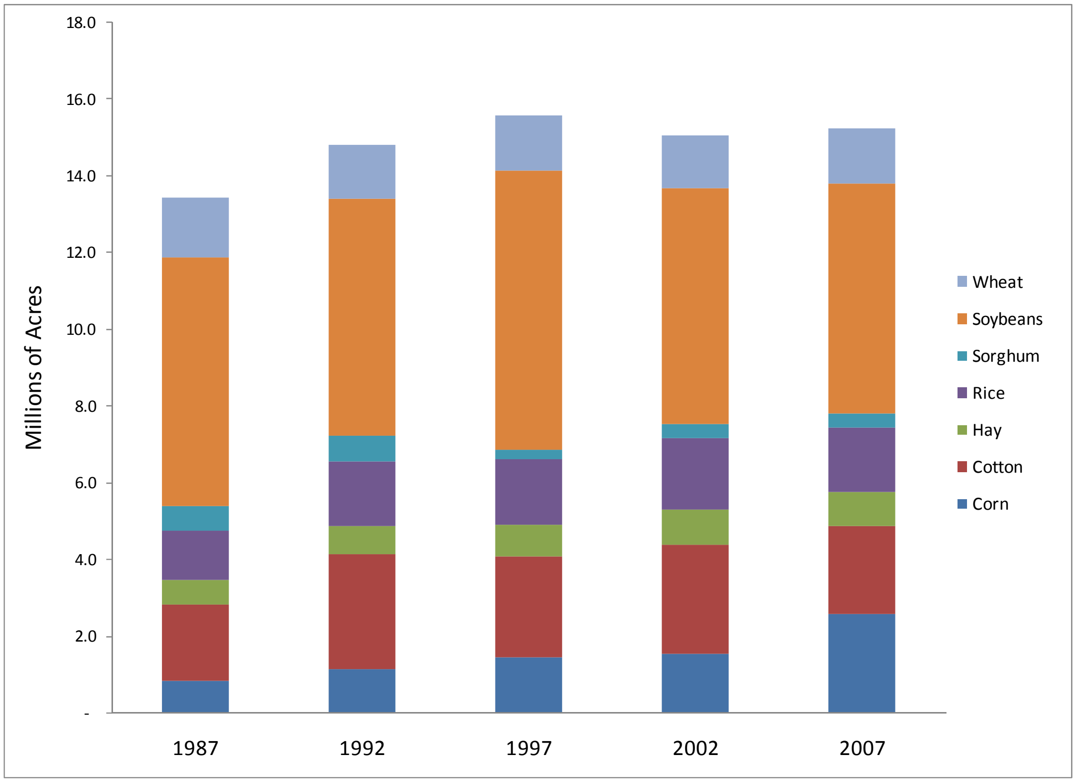
Historic data (production acres, production quantities, and average yields) were analyzed by county for the past five agricultural census periods (i.e., 20 years, spanning 1987–2007)[33] for corn, cotton, hay, rice, sorghum, soybeans, and wheat were analyzed and summarized in both tabular and graphical formats. Figure 9 presents the acreage and production data by crop by Census period. Figure 10 depicts the historic acreage data graphically.

Figure 9: Historic Data for Agricultural Crops in the Study Region

	acreage, x000					production, dry tons x000				
	2007	2002	1997	1992	1987	2007	2002	1997	1992	1987
corn	2,575	1,531	1,430	1,146	812	9,168	4,412	4,002	3,416	2,042
cotton	2,288	2,843	2,636	2,986	2,010	976	1,079	968	1,050	709
hay	893	917	834	732	647	1,654	2,033	1,702	1,356	1,095
rice	1,681	1,882	1,714	1,700	1,278	5,318	5,279	4,276	4,147	2,959
sorghum	360	343	242	660	642	808	646	420	1,229	1,130
soybeans	5,995	6,157	7,295	6,183	6,480	5,485	5,631	6,301	5,671	4,169
wheat	1,442	1,391	1,445	1,421	1,566	1,617	1,630	1,737	1,643	1,639
Total	15,235	15,064	15,595	14,827	13,433	25,027	20,710	19,406	18,511	13,743

[33] i.e., including Ag Census data from 2007, 2002, 1997, 1997, and 1987; spanning a period of 20 years.

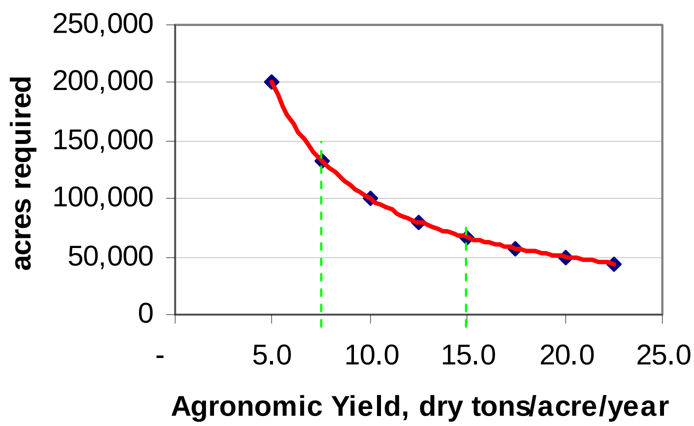
Figure 10: Acreage of Primary Ag Crops in the Study Region (in millions of acres)



Additional Analyses Regarding Dedicated Energy Crops

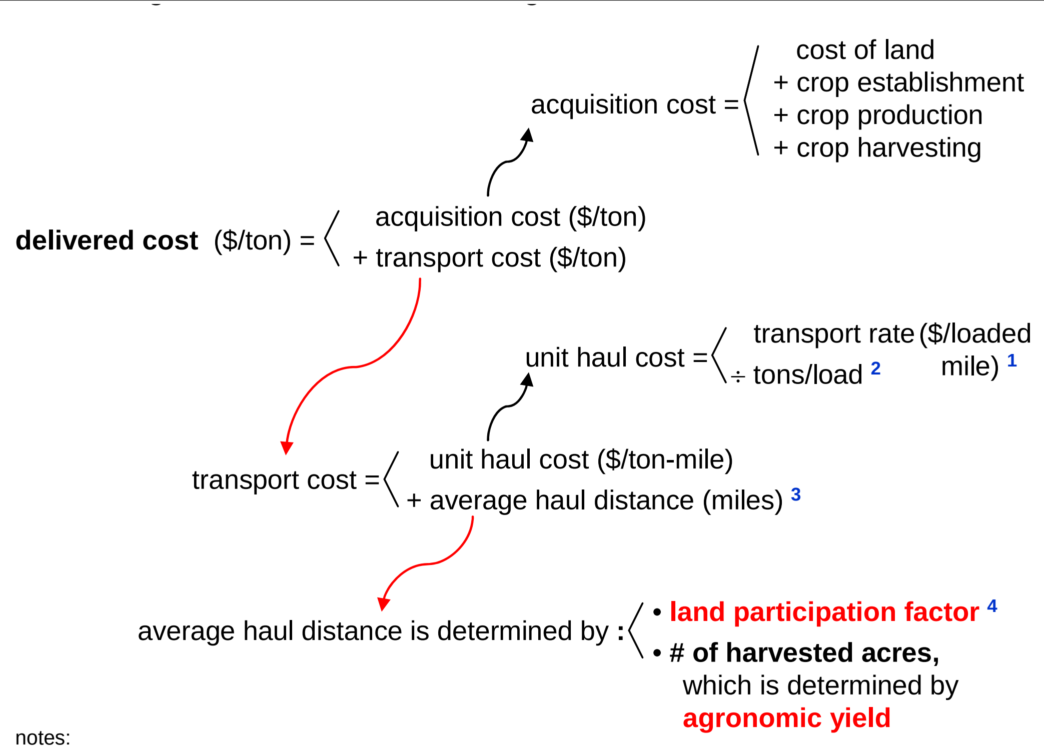
Required production acreage vs. agronomic yield: Agronomic yield is the most sensitive variable affecting estimated biomass crop production. Figure 11 shows the basic relationship between required production land area vs. agronomic yield for a given amount of crop production (in this example, for 1 million tons per year).

Figure 11: Production Land required vs. Crop Yield



Transport economics: The delivered cost of biomass to a processing facility is the sum of acquisition cost plus transport cost. The cost of transporting biomass from the harvesting sites to a processing facility is determined by the cost per load times the average haul distance (AHD). In turn, the AHD is determined by the crop's agronomic yield and the land participation factor (LPF), which is the portion of potential production lands in the vicinity of the bioenergy facility that participate in the production of energy crops for the facility. Figure 12 shows how *delivered* cost is determined, in part, by agronomic yield and land participation factor.

Figure 12: Delivered Cost vs. Agronomic Yield and Land Use

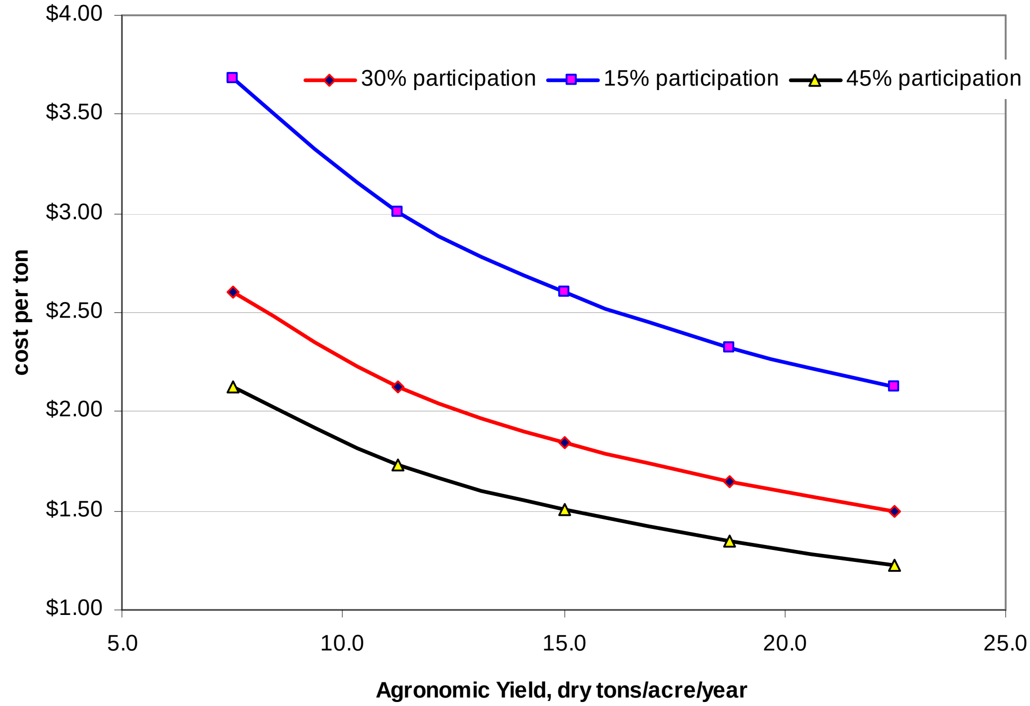


notes:

1. cost per loaded mile is typically a fixed rate, reflecting the cost of transport equipment and labor (e.g., in March 2009, the "rule-of-thumb" rate was $2.80/mile (assuming a full load).
2. although biomass has low bulk density, transport units should be used that have sufficient capacity so that the transport is weight-limited (the maximum allowable net weight is approximately 24 tons/load).
3. Average Haul Distance (AHD) is a critical figure that should be estimated as accurately as possible during project planning (note: AHD is <u>not</u> the same as *maximum* haul distance, which is the furthest distance an enterprise would have to transport biomass to achieve the total target quantity of material).
4. field participation level refers to the percentage of potential production lands in the vicinity of a bioenergy enterprise on which the energy crops are grown; for example, the AHD for an area in which 80% of the farmlands participate in growing energy crops would be far less than an area with a 20% participation level).

Figure 13 illustrates how transport cost can be affected by yield and land participation factor. For this analysis, the base case yield is assumed to be 15 tons/acre/year, with variance plus-or-minus 50%. Three participation levels are analyzed, with the base case assumed to be 30% and variations plus-or-minus 50%.

Figure 13: Haul Cost vs. Agronomic Yield and Land Participation



This biomass transport analysis indicates that, all else being equal, reducing the base case yield (*or* the land participation factor) by half results in an increased haul cost of 41%, whereas increasing the base case yield (*or* the land participation factor) results in a reduced haul cost of 18%. This analysis further indicates that reducing the yield from 15 to 7.5 tons/acre/year *and* reducing the participation factor from 30% to 15% results in a doubling of the total haul cost, i.e., from $1.84/ton to $3.68/ton.

Since the average haul distance affects a project's operating costs, detailed site-specific analyses should be performed during a project's planning stage to determine the estimated AHD for transporting the harvested biomass. GIS-based analyses can more accurately determine AHD costs based on specific targeted production fields and based on the actual road system in the target harvest area.[34] Such analyses can lead to a feedstock supply curve, which estimates quantities of target feedstocks versus distance from the facility.

Land-Use Considerations

Some of the factors that should be considered when estimating how much [and what types of] land might be used for production of dedicated energy crops in the study region include:

- Net income to landowners/farmers will need to meet or exceed other land use options available (e.g., from crop production, recreation, CRP, and/or other revenue sources).
- Land use and production commitments will be determined by attractive economics (net income/acre/year) combined with acceptably low levels of perceived risks.

[34] For more information regarding detailed transport cost projections, refer to: www.biofeedstat.com

- High participation levels of production lands will be needed in the vicinity of bioenergy facilities in order to minimize the *average* haul distance[35] of the biomass and thereby keep biomass transport costs to affordable levels.
- Long-term biomass supply contracts will likely be needed to minimize market risks (since there are no alternate markets for the cellulosic materials).
- Economic returns will be fundamentally affected by agronomic yield.
    - The average haul distance (and, therefore, the delivered cost per ton of biomass) will be higher for lower-yielding lands, since more lands (and, therefore, greater average haul distances) will be required for a given amount of biomass produced.
- Lower haul distance—resulting from higher yields and/or participation levels—will reduce the ecological footprint (the required production area) for a given amount of biomass production, which, in turn, will result in reduced greenhouse gas emissions associated with transport of the harvested biomass.
- Herbaceous energy crops have significantly higher projected yields than short rotation woody crops for the same type of Delta farm land considered (e.g., 10–20 tons/acre/year compared to 4–8). In comparison, forest residue biomass sustainably harvested from upland forest lands would yield less than 0.5 tons/acre/year.[36]
- Decisions to irrigate dedicated energy crops will be driven by cost-benefit analyses used for traditional crops (e.g., cotton or soybeans).
- As previously discussed, the categories of farm lands potentially available for energy crops production in the region include crop land (14.3 MM acres), idle land (0.8 MM acres), pasture land (2.5 MM acres), CRP lands (1.0 MM acres enrolled), and/or "marginal" lands. Regarding potential use of marginal lands: There are three types of farm lands considered marginal in the Delta:
    - Flood-prone lands, on which there is economic risk from crop failure and the crop cannot tolerate the flood conditions.
    - Highly erodible lands, which exist in limited quantities in the alluvial plain, given the regions relatively flat topography (and may already be enrolled in CRP).
    - Economically marginal lands: farm lands that entail relatively high crop production costs and/or relatively low agronomic yields (for example, due to low soil fertility). It is assumed that most of the marginal lands in the study region that are potentially usable for energy crops production fall into this category, i.e., are economically marginal.

[35] The *average* haul distance should not be confused with the *maximum* haul distance, which is the maximum distance that the bioenergy/bioproducts facility would have to go to obtain the quantity of biomass needed to satisfy operational requirements. While the maximum haul distance provides a sense of the geographic scope of a facility's "feed-basket", the average haul distance is used to evaluate feedstock transportation costs (e.g., average haul distance X average cost/mile X average tons/load = average transport cost/ton).

[36] This assumes that medium or large diameter stem wood would be sold into higher value saw-timber or pulpwood markets.

Observations and Conclusions

For the region's primary agricultural crops during the period 1987 to 2007, acreage increased 12%, average yields increased 34%, and total production increased 45%. Total crop biomass production in the region in 2007 was 57.8 MM tons, of which 57% was residue.

It is assumed that harvested forest lands in the region (located primarily on the rolling uplands to the east and west of the alluvial plain) are already being managed for optimal biomass production (i.e., for saw-timber or pulp markets).

- It is further assumed that production of energy crops on such forest lands would essentially entail redirecting some of the existing biomass production to energy markets (i.e., said forest lands would not be planted with new tree species that would entail a major increase in biomass productivity).

Accordingly, it is concluded that dedicated energy crops (whether short-rotation woody crops or herbaceous perennial grasses) will likely be planted on some type of *farm* land.

- It is further assumed that such plantings would only occur on those farm land categories where the economic returns are considered favorable (relative to other crop options) and the various risks (technical, economic, environmental) are considered acceptable to the landowners/producers.

Categories of farm lands in the study region that were considered for production of energy crops include harvested crop lands, pasture lands, lands enrolled in CRP, and marginal lands. In the Delta, lands are considered marginal due to high flooding potential or highly erodible conditions, or economically marginal due to poor soil fertility or other factors.

- Unless it can be demonstrated that a particular energy crop can survive extended wet conditions, it is unlikely that said crop will be planted on highly flood-prone lands, given the economic risks associated with potential crop failure (of a crop that entails very high establishment costs) and/or potential field access limitations for harvesting equipment.
- Pasture lands in the region may be candidate lands for energy crops production, depending on a specific field's characteristics and potential energy crop yield.
- Most of the harvested cropland in the study region is in the alluvial plain; the relatively flat topography of the alluvial plain (compared to the forested uplands) limits the amount of highly erodible lands in the region, and much of this type of land has already been enrolled in CRP.
- The 2007 Agricultural Census reported 0.8 MM acres of idle land in the region (2.2% of the total land area); much of this land may be categorized as idle because it is economically marginal. Possible use of such lands for production of dedicated energy crops will depend heavily on crop yield on these lands.

Agronomic yield is a major factor in the production of biomass (for both woody and herbaceous energy crops, as well as for field residues from agricultural crops and forest-derived biomass). For any crop, doubling the yield will halve the acreage requirements for a given amount of production.

Decisions regarding the amounts and types of lands to be used for planting and production of dedicated energy crops will be based primarily on expected net income, and will therefore be fundamentally influenced by expected yields.

- Under Delta conditions, yields of herbaceous energy crops are projected to be in the range of 12–20 tons/acre/year (15 has been used in this assessment), whereas yields of short-rotation energy crops are projected to be in the range of 4–8 tons/acre/year.

B. Agronomic Considerations for New Crops

This summary is excerpted from the study sub-report "Commercial Production Opportunities and Issues for Alternative Crops" prepared by Entira. The full sub-report is available online at www.agbioworks.org.

Key Crops by Counties

While many crops can be grown in the Mid-South Mississippi Delta study area, current crop production is dominated by five major crops: soybeans, rice, wheat, cotton and corn. To minimize the short-term impact of commodity price fluctuations, a five-year average of the harvested crop acres was calculated for each of these crops in each targeted county. As the following table shows, the region is heavily dominated by soybean acres followed by cotton, rice, corn and wheat. Grain sorghum (milo) and hay are negligible crops in the current crop production system.

Table 3: Average harvested acres (000)

Soybeans	Rice	Wheat	Cotton	Corn	Sorghum	Hay*
6,396	1,873	1,182	2,894	1,823	298	235

*County level data was unavailable for Arkansas and Mississippi

Common Crop Rotations and Reasons Crops are Paired in the Rotation

Across the study area, the major crops were ranked by their acreage in each county as summarized in Table 4. These rankings show that soybeans are the largest crop in 70% of the counties and the second largest crop in 21% of the counties. The only other crop with significant strength as the primary crop in a county was cotton. Rice and corn both hold significant positions as the second and third most prevalent crop on a per county basis.

Soybean-Rice-Cotton Rotation

At the state level, there are three major cropping patterns. The first is the Soybean-Rice-Cotton production system with a heavy reliance on these major crops. This cropping system dominates Arkansas and parts of the Missouri Bootheel. In this cropping system, these three crops are grown in rotation with one another and with the other major crops. As can be seen in Table 4, for the Arkansas counties, soybeans are the number one or two crop produced in 87% of the counties in this study. Rice is in the top three crops produced in 83% of the counties, and cotton is in the top three crops in 50% of the counties. In the southern portions of this area, it may be possible to grow three crops in two years with a corn, wheat, double crop soybean combination.

Table 4: Common Crop Concentrations

Crop Ranking	Soybeans	Rice	Wheat	Cotton	Corn	Sorghum	Hay
ALL COUNTIES							
1	70%	1%	0%	20%	1%	0%	3%
2	21%	16%	1%	26%	30%	0%	2%
3	4%	14%	24%	14%	34%	2%	3%
Sum	**96%**	**32%**	**26%**	**60%**	**64%**	**2%**	**8%**
ARKANSAS COUNTIES							
1	70%	3%	0%	13%	0%	0%	0%
2	17%	50%	0%	20%	0%	0%	0%
3	0%	30%	27%	17%	13%	0%	0%
Sum	**87%**	**83%**	**27%**	**50%**	**13%**	**0%**	**0%**
KENTUCKY COUNTIES							
1	100%	0%	0%	0%	0%	0%	0%
2	0%	0%	0%	0%	75%	0%	13%
3	0%	0%	63%	0%	13%	0%	25%
Sum	**100%**	**0%**	**63%**	**0%**	**88%**	**0%**	**38%**
MISSISSIPPI COUNTIES							
1	68%	0%	0%	32%	0%	0%	0%
2	21%	0%	4%	43%	32%	0%	0%
3	11%	14%	11%	14%	50%	0%	0%
Sum	**100%**	**14%**	**14%**	**89%**	**82%**	**0%**	**0%**
MISSOURI COUNTIES							
1	64%	0%	0%	9%	0%	0%	27%
2	36%	9%	0%	18%	27%	0%	9%
3	0%	9%	27%	9%	55%	0%	0%
Sum	**100%**	**18%**	**27%**	**36%**	**82%**	**0%**	**36%**
TENNESSEE COUNTIES							
1	67%	0%	0%	29%	5%	0%	0%
2	29%	0%	0%	24%	48%	0%	0%
3	5%	0%	24%	19%	38%	10%	5%
Sum	**100%**	**0%**	**24%**	**71%**	**90%**	**10%**	**5%**

The dominance of these crops is due to the flat and fertile delta soils and the ready access to shallow irrigation water. Soybeans are grown in rotation with rice and cotton first because they are profitable but also to break pest cycles and to provide legume-produced nitrogen for the grass crops that follow in rotation.

Soybean-Cotton-Corn Rotation

The second major production system is the Soybean-Cotton-Corn system. As the name implies, there is a heavy reliance on these three crops. This system dominates the eastern delta area including Mississippi and Tennessee. In these areas, soybeans are rotated primarily with cotton and corn with little impact from rice. In the more intensive production rotations to the south, corn may be followed by winter wheat and then double crop soybeans for three crops in two production years. Cotton acres once dominated this area, but have fallen dramatically over the last several years.

Diversified Rotation (Cropping System)

The final major cropping system is the diversified cropping system based heavily on soybeans but with less emphasis on cotton and rice and more on corn, hay and wheat. This system is more prevalent in the northern counties and in those counties that have more rolling ground. While this system may not appear to be diversified in the number of crops, it does contain some perennial crop land in the hay crop and may also support a diversified livestock operation. In much of this area, a corn and soybean rotation or wheat followed by double crop soybeans are popular rotations. The wheat-soybean rotation can allow for two crops in a single year if the rainfall is adequate for the summer soybean crop.

Potential Replacement Points of an Annual Alternative Crop in the Rotations

Farmers use crop rotations to maximize production on their land. With this in mind, any new crop will need to improve the overall revenue on a per acre basis over a number of years. The easiest substitution will be the replacement of an existing crop with a similar crop. Sweet sorghum for corn may be the simplest substitution because they are both annual grasses with summer growing seasons. Sorghum can easily fit into the same rotations as corn, cotton, or rice. However, there may be production and revenue limitations that can hinder sorghum's competition with corn. These will be discussed in later sections of the document.

It is possible that annual oil crops such as canola or camelina, assuming that they can be grown during the winter months, can be inserted into the rotation as a double crop ahead of either corn or cotton. In the following example, the insertion of an alternate winter crop added one more growing season over a three season period for a total of four crops in three years.

Table 5: Crop Timing and Rotation

Timing	Conventional Rotation	Alternative Rotation
Year 1 – Spring/Summer	Soybeans	Soybeans
Year 1 – Fall/Winter	Dormant	Canola or Camelina
Year 2 – Spring/Summer	Cotton	Cotton (late spring)
Year 2 – Fall/Winter	Dormant	Dormant
Year 3 – Spring/Summer	Soybeans	Soybeans

Finally, the most aggressive replacement of an existing crop rotation system is the establishment of a perennial crop such as switchgrass or miscanthus for a multiple year commitment. For the purpose of this document, a period of six years will be used as the life of the perennial crop. However, to compete in the Soybean-Rice-Cotton or Soybean-Cotton-Corn geographies they must return net revenue greater than the equivalent number of years of the existing crop rotation.

The following table compares a traditional cropping system with switchgrass.

Table 6: Traditional Crop Timing and Rotation with Switchgrass

Timing	Example Conventional Rotation	Switchgrass
Year 1	Soybeans	Establishment
Year 2	Cotton	Harvest 1
Year 3	Soybeans	Harvest 2
Year 4	Corn	Harvest 3
Year 5	Cotton	Harvest 4
Year 6	Soybeans	Harvest 5

Another alternative is to establish the switchgrass or miscanthus on existing hay or pasture lands. While this appears to solve the issue of competing with existing higher value row crops, it has not been shown that these energy crops can produce economically acceptable yields on the lower productivity soils currently in pasture and hay. Additionally, there is not an abundance of those acres in much of the study area and in the diversified cropping systems they may be the foundation of a farmer's diversified livestock operation. It is estimated that the scenario to utilize 15% of pasture land for dedicated energy crops could result in an 80,000 head/year reduction in regional marketable beef cattle. If this is the case, then the switchgrass/miscanthus production would need to generate enough net revenue to offset the net revenue lost from the liquidation of the livestock herds.

Estimated Net Return Needed for Replacements to Occur

As there are no published budgets for sweet sorghum, cost estimates are based on the Mississippi State University (MSU) crop budgets for grain sorghum. Using this budget, sweet sorghum will need to generate $425 per acre in gross revenues. At an estimated yield of 30 wet tons per acre, the price will need to be about $14.20 per ton to match the MSU budget and generating net revenue of $143 per acre. As a comparison, the MSU budgets indicate that a 185 bushel corn crop will return only $96 per acre over expenses.

Using these budgets, one might assume that replacing corn or cotton with sweet sorghum would be an easy economic choice; however, issues such as market availability, marketing options and production practices for sorghum make this an unattractive option for most farmers at this time. These issues will be examined in a later section of the document.

The insertion of an additional crop such as canola or camelina will obviously need to return enough revenue to offset the grower's expenses if the new crop is not replacing winter wheat. If the crop is replacing winter wheat, it will need to return at least $57 per acre over fixed and variable expenses to remain competitive with wheat, based upon the MSU 2009 budgets.

The total replacement of a multi-year crop rotation with a perennial crop is a more complicated budgeting process. The MSU budgets were used to create a 6-year summary of crop performance based on 2009 budgets. For a variety of common crop rotations the net margin before land cost ranged from $334–$1,022 for the 6-year period. A 6-year switchgrass budget published in "The Economics of Biomass Production in the United States" ORNL returns $308 over the period, so there appears to be little value for a farmer to make the conversion to switchgrass. Even in the case of cotton production where the current budget loses money in 2009, it would be better for a cotton producer to convert to corn or wheat production rather than to switchgrass. *Details of these analyses are provided in the full sub-report.*

Key Agronomic Production Gaps for the Major Alternative Crops

The production of alternative crops will require a great deal more than economic returns to the farmer. Additional work is needed to determine the production needs for each of the crops, including: biotech traits, germplasm, seed production and distribution, fertility recommendations, chemical labels, crop harvesting and logistics, and transparent markets. Table 7 summarizes the status of key production issues for major alternative crops.

Table 7: Key Production Issues for Major Alternative Crops

	Switchgrass	Miscanthus	Sweet Sorghum	Canola	Camelina	Sunflowers
Biotech Traits	No	No	No	Yes	No	Yes
Midsouth Adaptable Germplasm	Yes	Yes	Yes	No	No	Yes
Commercial Seed Production & Distribution	No	No	No	No	No	Yes
Commercial Fertility Recommendations	No	No	No	No	No	Yes
Crop Protection Chemical Labels	No	No	Some	Some	No	Some
Planting Equipment	Yes	Yes	Yes	Yes	Yes	Yes
Harvesting Equipment	Yes, but requires capital investment	Yes, but requires capital investment	Yes, but requires capital investment	Yes, but may require modification	Yes, but may require modification	Yes, but may require modification
Primary Field Processing	Baling but not pelletizing	Baling but not pelletizing	Crushing facilities needed	NA	NA	NA
Crop Insurance	No	No	No	Yes	No	Yes
Marketing Tools	No	No	No	No	No	No
Obvious Consumption Point	No	No	No	No	No	No

Key Grower Concerns with the Major Alternative Crops

Growers tend to stick with crops and production practices they know and trust. New crops that are touted to farmers have often failed due to the lack of addressing grower concerns such as those listed in the following table, generated from market research completed in other areas of the U.S. and for other crops. These concerns are judged to be fairly universal and applicable to the Mid-South study region.

Table 8: Key Grower Concerns for Alternative Crops

	Switchgrass	Miscanthus	Sweet Sorghum	Canola	Camelina	Sunflowers
Proven Yields	No	No	No	No	No	Yes
Weed Control	No	No	Not Specific to Sweet Sorghum	Yes	No	Yes
Insect Control	No	No	Not Specific to Sweet Sorghum	Yes	No	Yes
Disease Control	No	No	Not Specific to Sweet Sorghum	Yes	No	Yes
Transportation Distance	No	No	No	No	No	No
Perceived Market Viability	No	No	No	No	No	No
Processing Plan	No	No	No	No	No	No
University Support	Yes	Yes	Limited	Limited	Limited	Limited
Ag Retailer Support	No	No	No	No	No	No
Crop Insurance	No	No	No	Yes	No	Yes
Marketing Tools	No	No	No	No	No	No
USDA FSA Acceptance	No	No	No	No	No	Yes
Proven Profit Opportunities	No	No	No	No	No	No

Some of these concerns can be addressed with innovative production contracts; others can be addressed with local test plots. However, others such as weed, insect and disease controls may take years to complete testing and obtain EPA approved labels. USDA support of these crops and acceptance under the FSA programs may take multiple sessions of Congress to approve. Even acceptance by the existing agricultural retailers may take several years as they find ways to service these crops in a manner that maintains the profit per acre they once received from traditional crops.

Observations and Conclusions

Alternative crops are needed and desired by Mid-South farmers, who are willing and able to adopt alternative crops into their enterprises. Soybeans were an alternative crop until the 1940s and now soybeans occupy the largest number of acres in the study region. However, for an alternative crop to succeed, it must meet some basic requirements:

- It must generate more net revenue than the lowest value crop competitor
- It must fit into an existing crop rotation without seriously detracting from the other rotation crops
- It must be produced with modern tools to control weeds, insects and diseases that can detract from yield and also cause longer term issues in subsequent crops
- It must have a local or regional delivery point and an obvious consumption market
- It will ultimately need risk mitigation tools such as crop insurance, marketing tools, and acceptance in any federal farm program

Alternative crops such as *sweet sorghum, sunflowers and canola* could meet many of these requirements for acceptance in the near future. These crops are already in some level of commercial production, so many of the production issues have been or are being addressed. The biggest hurdles for these crops are delivery points, processing and consumption plans.

Alternative crops such as *camelina, switchgrass and miscanthus* face a steeper acceptance path because in addition to the issues faced by the other crops, the viability of commercial production has not been fully demonstrated. For the perennial grasses in particular, the economic hurdle of competing with a diverse range of rotational crops that provide significant risk mitigation may be insurmountable. Until it is proven that perennial grass crops will provide a sustainable return of $90 to $100 per acre, prior to land costs for the life of the stand, producers will be discouraged from making a long-term commitment to these alternative crops.

C. Alternative Crops: Opportunities, Challenges and Strategies for the Mid-South Mississippi Delta Region

This overview contains thoughts and content from the document "Strategies for Commercializing New Crops" published by the Thomas Jefferson Agricultural Institute, a 501(c)3 non-profit education and research center based in Columbia, Missouri. The oilseed and algae information is excerpted from the study sub-report "West Tennessee Oilseed Diversification Project" completed by Frazier, Barnes & Associates in March 2009 under a grant by the Tennessee Department of Agriculture. The sweet sorghum information is excerpted from the study sub-report "Potential for Sweet Sorghum in the Delta Region," prepared by BioDimensions, Inc. Information on bamboo was provided by Boo-Shoot Garden LLC., of Mt. Vernon, Washington.
The full sub-reports are available online at www.agbioworks.org

> *"The greatest service which can be rendered any country is to add a useful plant to its [agri]culture."*
>
> *Thomas Jefferson*

Introduction

The development of biobased products and bioenergy in the Mid-South Mississippi Delta region will create a market for new, alternative crops that can be grown by the region's farmers. This will enable farmers to have increased options and value-added opportunities, and give new biobased product companies a range of new plant-based materials as manufacturing feedstock. Much information is needed by the companies developing biobased products concerning the potential range of possible crops in the region many of which have unique and valuable properties. Farmers need to understand the agronomic practices, risk mitigation strategies, and how they fit in the new supply chain partnering with biobased product companies. Finally, there are institutional hurdles such as crop discovery and breeding, interaction with farmer networks, government barriers and market development that need to be addressed.

Fortunately there are numerous new North American crop companies and institutions (Table 9) that have an interest in developing projects with ramifications for the Mid-South Mississippi Delta region. The resources and interest of these potential partners, collaborating with the region's research farms and farmers will help identify potential crops and the clearest pathway to commercialization.

Table 9: Selected New Crop Development Companies with Projects Underway in the Mid-South Mississippi Delta Study Region

Company / Organization	Location	Crop(s) Under Development	Status in Study Region
BioDimensions, Inc. / Memphis Bioworks Foundation	Memphis, Tennessee	Sweet sorghum, biomass and oilseeds crops	Demonstration and commercial trials underway
Boo-Shoot Garden, LLC / Delta Economic Development Center	Mt. Vernon, Washington	Bamboo	Technology transfer and business development discussions underway
Ceres, Inc.	Thousand Oaks, California	Switchgrass, sorghum, miscanthus, energy cane, woody crops	Demonstration and commercial trials underway
FutureFuel Chemical Co.	Batesville, Arkansas	Canola, sunflower, oilseeds	Commercial trials and product development underway
Infinite Enzymes, LLC.	Jonesboro, Arkansas	Corn-based industrial enzyme production	Product development and field trials underway
Kengro Corporation	Charleston, Mississippi	Kenaf for biomaterials, other alternative crops	Integrated crop production, processing, and product marketing since 1995
Mendel Biotechnology, Inc.	Hayward, California	Miscanthus, energy crops	Demonstration and commercial trials underway
Miles Enterprises	Owensboro, Kentucky	Canola, sunflowers	Demonstration and commercial trials underway
Monsanto Company	St. Louis, Missouri	Canola	Demonstration and commercial trials underway
Shoffner Farm Research, Inc.	Newport, Arkansas	Sunflower, oilseeds, biotech crops.	Demonstration and commercial trials underway
Stemergy	Delaware, ON, Canada	Agri-fiber crop processing	Technology transfer & business development discussions underway
Sustainable Oils, LLC.	Seattle, Washington	Camelina	Demonstration trials (2008)
Technology Crops International	Winston Salem, North Carolina	HEAR, HO Sunflowers, Oilseeds	Demonstration trials underway
Thomas Jefferson Agricultural Institute	Columbia, Missouri	Canola, new oilseed and grain crops	Demonstration and education support underway.

This section provides an overview of the challenges and opportunities associated with alternative crops in the Mid-South Mississippi Delta region, as well as information on other crops that have potential in the region. For a new crop industry to be successful in the region it will be important to develop a comprehensive approach to ongoing crop discovery, breeding, regional adaptation, managing expectations with farmers, and developing sustainable markets.

Benefits and Challenges

The Mid-South Mississippi Delta region has a combination of assets that make it a logical place to attempt new crop development. The region already grows a diverse group of commodity crops and farmers have access to a variety of equipment and knowledge that can be applied to alternative crops. The region also has some existing infrastructure and agricultural equipment that can be utilized. The Mid-South Mississippi Delta region further has excellent inbound and outbound logistics which can deliver specialty crops, processed components, and biobased products globally, as well as contribute to the development of sophisticated identity preservation systems.

There is a clear benefit for introducing new crops for farmers, biobased product companies, and the region as a whole. Farmers need strategies to increase options and offer new opportunities, while enhancing current crop production and management activities. The crops under consideration for the Mid-

South Mississippi Delta region are potentially less vulnerable to weather, pests and market forces, while distributing labor across the planting and harvest seasons more uniformly. Ideally, new crops offer higher returns, and, in rotation, will boost the yields of other crops already being grown. Many of the new crops under consideration require less water and fewer inputs than traditional crops. Additionally, the development of new crops can offer farmers the opportunity to participate in value-added companies and develop new relationships in the supply chain.

Biobased product companies are finding there are many novel properties that are available in new crops, which are cost prohibitive to make synthetically and/or are not present in commodity crops such as corn and soybeans. For example, some of the oilseed crops under consideration for the Mid-South Mississippi Delta region have unique long chain fatty acids, *not* available in soybeans. These fatty acids can be used as ingredients for cosmetics, health and home care products, lubricants, and other specialty biobased products. Biobased product companies are actively working globally to develop entirely new supply chains that could include an expanded role for farmers, processors, and logistics providers. Both small businesses and large multinational corporations have identified new relationships in the supply chain, access to a reliable supply of feedstocks and the potential to utilize unique new properties as major drivers for this new industry.

As a region, the Mid-South Mississippi Delta can benefit from new crop introduction through development of local value-added processing and the resulting job creation, as well as the potential to encourage entrepreneurial development and new global supply chain relationships. The introduction of new crops will also increase biodiversity and wildlife, potentially reduce harmful agricultural inputs, and encourage new approaches to sustainable agriculture and economic development.

In order to introduce one or more new crops to the Mid-South Mississippi Delta region, there are significant research, logistics, government and market barriers that must be addressed. For example, current Federal farm policy provides price supports and other crop protections such as federal crop insurance to major commodity crops, while mandated check off programs invest a portion of farmers' income directly into research and marketing programs to support the major crops. The inadvertent consequence of these policies is that alternative crops receive little research or market development funding, have little or no success at receiving crop insurance, and are not supported in developing export markets or replacing current imports. There is some positive movement in this regard through recent USDA programs focused on specialty crops. However, these programs are largely focused on new vegetables, fruits, nuts, and horticulture products.

A specific regional need to commercialize new crops is the expansion of crop discovery and breeding programs to improve production. This is an extremely costly and time-consuming process and will require significant private investment. However, a small amount of modern breeding work can go a long way toward improved commercialization potential. "For example, three publicly-funded plant breeders, each working part-time on pearl millet, were able to more than double grain yields and develop types much better suited to mechanical harvest."[37] There are already research farms (Table 10) and institutions (Table 11) across the Mid-South Mississippi Delta region that are working with alternative crops. There is an opportunity to work collectively with these organizations to attract funding, improve efficiencies, and engage more effectively in commercialization activities.

[37] Thomas Jefferson Agricultural Institute

Table 10: Key Research Farms in Mid-South Mississippi Delta Region

Research Farm	Location	New Crops	Key Relationships
Agricenter International	Memphis, Tennessee	Switchgrass, oilseeds, sweet sorghum, niche crops	BioDimensions, Inc.; Memphis Bioworks Foundation; Major crop research companies
Arkansas State University	Jonesboro, Arkansas	Biomass crops and niche crops	Arkansas Biosciences Institute
Delta Research Center, Agricultural Experiment Station, University of Missouri	Portageville, Missouri	Sweet sorghum, camelina, and other alternative crops	Donald Danforth Plant Science Center, University of Missouri
Delta Research & Extension Center, Mississippi State University	Stoneville, Mississippi	Niche crops	Mississippi State University
Murray State University	Murray State, Kentucky	Biomass crops and alternative crops	Major crop research companies
Phillips Community College	Dewitt, Arkansas	Variety of alternative crops	Companies and regional institutions
Research and Education Centers, University of Tennessee	Jackson and Milan, Tennessee	Switchgrass	Institute of Agriculture, University of Tennessee; Oak Ridge National Laboratory
Rohwer Research Station, University of Arkansas, Cooperative Extension Service	Desha County, Arkansas	Switchgrass, sunflower, sweet sorghum, woody crops	University of Arkansas; Major crop research companies
Shoffner Farm Research Inc.	Newport, Arkansas	Sunflowers, oilseeds, niche crops	Major crop research companies
University of Arkansas	10 research locations in study region	National canola trials	Major crop research companies

Table 11: Key Independent Companies and Institutions Involved in Agricultural Crop Research in the Mid-South Mississippi Delta Region.

Name	Location	Lab	Crop Discovery	Seed Bank	Breeding	Green-house	Research Farm	Trans-genics	Business Incubator
Arkansas Biosciences Institute	Arkansas State University, Jonesboro, Arkansas	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hornbeck Agricultural Group	Dewitt, Arkansas	Yes	No	No	Yes	Yes	Yes	Yes	No
Jamie Whitten Delta States Research Center, ARS, USDA	Stoneville, Mississippi	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Memphis Bioworks Foundation/Bio Dimensions Inc.	Memphis, Tennessee	Yes	Yes	No	No	No	Yes	No	Yes
Miles Enterprises	Owensboro, Kentucky	No	Yes	No	No	No	Yes	No	No
National Center for Natural Products Center & USDA ARS	School of Pharmacy, University of Mississippi	Yes	Yes	Yes	No	Yes	Yes	No	Yes
Shoffner Farm Research Inc.	Newport, Arkansas	No	Yes	Yes	Yes	Yes	Yes	Yes	No

Research is also needed concerning the development of economic models and marketing data, as well as a comprehensive understanding of the unique properties in plants that may be useful for biobased product companies. Finally, there is little understanding of the many benefits of new crops, therefore there is little political will to develop comprehensive policies supporting crop diversification. Often, the success of a new crop is based on whether it is grown on large acreage in the region. However, it is possible that success has just as much to do with how many new crops are introduced as it does with the volume of acreage for each crop.

Institutional barriers, lack of good planning, unmanaged expectations, and scaling up too early have all contributed to the pitfalls experienced by many farm groups and companies attempting to commercialize alternative crops. These mistakes and failures are primarily attributed to over-production due to excitement about a potentially lucrative new opportunity, unequal allocation of rewards and risks in the newly created value chain, and ultimately lack of and/or overstated demand for a new crop product.

An important consideration in introducing potential new crops in the Mid-South Mississippi Delta region is managing the expectations of farmers and developing methods to involve farmers early, while realizing that not all of the approaches and crops will be successful. It is key to include leading farmers early, in that many of the pitfalls can be avoided by bringing real world agricultural experience to help solve problems with new crop introduction. A pilot program launched by Memphis Bioworks Foundation and BioDimensions, Inc., with funding from Tennessee Department of Agriculture has formed the *25Farmer Network* in West Tennessee. This program includes leading farmers who are growing five acre commercial trials of new crops, working together on solving agronomic and logistics issues, and collaborating on pursuing potential value-added opportunities. This program, operating in conjunction with extension offices and rural development professionals, is helping get farmers involved in new crops, while mitigating risk and managing expectations. Similar programs could be implemented across the Mid-South Mississippi Delta region. It is very important to expose farmers and biobased product companies to on-farm new crop demonstrations through field days which are being conducted across the region.

Specialized Oilseeds

One of the most promising opportunities in the Mid-South Mississippi Delta region is for the development of new oilseed crops that could have a positive impact for farmers, industry and for the region. In order to develop the feedstocks for the “oleochemical” platform, the first step is to assist potential organizers in the cultivation, processing and utilization of products and byproducts from oilseed crops that are suitable for production in the region. In the short term these include winter canola and high-oleic, mid-oleic Nusun and traditional sunflowers. The medium-to-long term focus will include a wider variety of specialty oilseed crops that have unique and desirable properties including high-erucic acid rapeseed and camelina. These crops will not require acreage large enough to negatively impact the production of traditional crops in the region and the processing technology for oilseeds is well-known and established. The oilseed industry, however, is currently highly consolidated with only a few major players and the processing is largely located outside the region.

Table 12: Mid-South Mississippi Delta Region Oilseed Processing Infrastructure

Company	Location	Facilities
Arkansas Soy Energy	Dewitt, Arkansas	Mechanical, soybeans
England Dryer and Elevator	England, Arkansas	Mechanical, soybeans
Planters Cotton Oil Mill	Pine Bluff, Arkansas	Solvent, cottonseed
Producers Cooperative Oil Mill	Covington, Tennessee; Kennett, Missouri; Osceola, Arkansas	Drop-Point and storage only – cottonseed, canola, sunflowers
PYCO	Greenwood, Mississippi	Solvent, cottonseed
Riceland Foods	Stuttgart, Arkansas	Solvent, soybeans
Southern Cotton Oil Mill (ADM)	Memphis, Tennessee	Solvent, cottonseed
Suco2	Quilin, Missouri	Mechanical, CO_2, soybeans

Several groups in the Mid-South Mississippi Delta region are actively pursuing the development of alternative oilseed crops. A study conducted by Frazier Barnes & Associates funded by Tennessee Department of Agriculture concluded that an identity-preserved processing facility would allow for regionalized production and consumption of value-added industrial oil products from seeds versus traditional crops which are in large part exported or shipped to distant processors. An oilseed crush plant located in the study region would have to be appropriately sized to optimize identity preservation and diverse processing opportunities to serve specialized markets. The processing facilities will be sized small enough to facilitate short runs of identity preserved crop processing, with minimal switch times. The operation, however, should be large enough to provide an acceptable economy of scale, which would translate into lower fixed costs per bushel or ton of seed processed. The selected processing technology is scalable, allowing for incremental expansion of processing capacity as acreage is introduced. A 200 ton per day capacity is considered a benchmark minimum size for this type of operation. The proposed facilities are mechanical crushers with compressed CO_2 to increase efficiency.

In addition to the agronomic work and development of a multi-feedstock crushing facility, the study recommended the establishment of a research pipeline of alternative oilseed crops. It would include the production of novel oilseed plants at area research farms, harvesting the seeds, developing a bench scale processor at one or more area research institutions, and generating commercial samples of oils. In order to properly ascertain the viability of this business approach, the study team has conducted an exhaustive analysis of all potential oil bearing crops and narrowed the field of viable options to those crops that have proven production capabilities in the region and/or have the potential for relatively mid-term breeding potential. The presence of unique or special properties that may be enhanced by growing in this region and have valuable markets was also examined. The following table ranks oilseed crops based on their production potential in the study region. Soybeans and cottonseed have been omitted due to their current representation as primary oilseeds for the region. It is not the intent to reduce the production of existing oilseeds, but to supplement production with higher value oilseed products.

Table 13: Ranking of Near- and Mid-Term Potential New Oilseed Crops for the Mid-South Mississippi Delta Region

Rank	Crop	Fatty Acid / Oil Property
1	Sunflower	Oleic fatty acid: industrial and food oil use
2	Winter Canola	Polyunsaturated oil: industrial and food use, + biodiesel feedstock
3	High Erucic Acid Rapeseed	Erucic acid used in multiple industrial products
4	Camelina	Biodiesel and oleochemical refinery base feedstock
5	Flax	Linolenic acid; oleochemical and health food use

Demonstration plot of sunflowers at Agricenter International as part of a project initiated by BioDimensions, Inc. and Memphis Bioworks Foundation with funding from Tennessee Department of Agriculture.

Sunflowers have been successfully grown in several local locations including West Tennessee; Pine Bluff and Newport, Arkansas; and Portageville, Missouri. Sunflowers are planted in April-May and harvested in late August through September. Sunflower seed has approximately 42% oil content and the meal contains approximately 35% crude protein if the seed is dehulled or approximately 28% if not. An acre of sunflowers will yield about 720 pounds of oil, assuming typical yields (1,500–2,000 lbs per acre). Sunflowers are a fairly drought tolerant crop, establish a quick stand, contribute to breaking up weed cycles, and have a wide sowing window (April–May). Solvent extraction sunflower processing plants are currently located in Kansas, Oklahoma, Minnesota, Montana, and North Dakota. The Mid-South Mississippi Delta region is constrained by the strong presence of corn, soybeans, and cotton, as well as the lack of a processing outlet. Sunflower oils command a market premium over soybean oil in edible markets, with NuSun® and High-oleic varieties predominating over traditional varieties. Significant local customers in the Mid-South Mississippi Delta region have been identified and commercial trials are underway in East Arkansas and West Tennessee. Miles Enterprises of Owensboro, Kentucky; Shoffner Research Farms of Newport, Arkansas and FutureFuel Chemical Company of Batesville, Arkansas are some of the companies working to commercialize sunflowers in the region.

Winter Canola is a viable option for the Mid-South Mississippi Delta region. The crop is planted in late September through early October and harvested in late May through early June. Winter canola has the potential to outperform wheat with respect to yields and value of production. The crop can be rotated with wheat on an annual basis or double-cropped with a late soybean crop. The most notable research with regard to winter canola in the study region has been conducted by Dr. Robert Bacon at the University of Arkansas. The average yield at three sites in Arkansas—Marianna (located in the study region), Kibler and Fayettville—was 2,308 lbs per acre for the period of 1999 through 2004. Miles Enterprises is also scaling up canola acreage in the study region where commercial trials have been underway since 2007. They have produced yields as high as 3,000 lbs per acre. The crop is more risk intensive than wheat, with a significantly narrower window for harvesting. Shattering at harvest is a continuing problem for production in the region, particularly if bad weather occurs during harvest. In order to minimize shattering it is recommended to use a swather or canola pusher. There are commercial varieties available for the

Demonstration plot of Roundup Ready® Canola at Agricenter International. Canola trials are underway across the Mid-South Mississippi Delta Region.

region. Industrial uses currently include: food grade lubricants, hydraulic fluids, metal working fluids, steel casting lubricants, chain bar lubricants, and 2-cycle engine oil.

In the *mid-term*, the project team concluded that high-erucic acid rapeseed (HEAR) and camelina may offer a reasonable potential for commercialization in the region.

High Erucic Acid Rapeseed *(HEAR)*, or industrial rapeseed, is used for non-edible purposes such as lubricants, hydraulic fluids and plastics. HEAR oil is especially useful where high heat stability is required. HEAR oil has special properties which include: high smoke and flash points, stability at high temperatures, ability to remain fluid at low temperatures, and durability. One of the primary markets for HEAR is erucamide, a slip agent used in injection-molded plastics and polyethylene manufacturing. Erucamide is a large relatively complex molecule and consequently attempts to produce it synthetically from petrochemicals would be very expensive. Canola is essentially rapeseed that has been bred for low erucic acid and is therefore edible. Like canola, HEAR faces the same challenges and has similar growing procedures. Customers have been identified in the study region for HEAR, however it will be necessary to segregate HEAR from edible canola.

A significant push (50,000 acres) for producing rapeseed in the Mid-South Mississippi Delta region occurred in the mid-1980s. Much of this was driven by projects from Calgene, the biotechnology company, which was contracting for rapeseed including the modified high-laurate variety. Laurate is a modified 12 carbon fatty acid that is used as a cosmetic ingredient. This commercial effort was headquartered at the Agricenter International in Memphis. Farmers in the study region produced good yields of the crop in the first year, with varying results in years 2 and 3. Problems included weather, lack of proper planting and harvesting equipment, and eventually the loss of the market. It is believed by the study team that there have since been significant advances in knowledge, regionally adapted varieties, crop improvements, and equipment resulting in a higher likelihood of success.

Demonstration plot of camelina at Shoffner Research Farms, Inc. in conjunction with Sustainable Oils LLC., FutureFuels Chemical Company and BioDimensions, Inc.

Camelina thrives in marginal agricultural lands as a winter grown crop and could probably be adapted for production in the Mid-South Mississippi Delta region. Excessive moisture induces lodging and plant disease. However, due to its low-input requirements and very short maturation period (85–100 days) the crop has potential for the region. It is believed that varieties of the crop will be developed for regions with higher rainfall and there are companies currently pursuing this idea. Researchers at the University of Georgia have produced successful camelina stands. Camelina oil has unique properties—the oil contains about 64% polyunsaturated, 30% monosaturated, and 6% saturated fatty acids. Camelina is very high in alpha-linoleic acid (ALA), an omega-3 fatty acid which is essential in human and animal diets and has important implications for human health. The oil also contains high levels of gamma-tocopherol (vitamin E) which confers a reasonable shelf life without the need for special storage conditions. The unique properties of camelina oil could lead to the development of a wide array of high value markets for the oil and its components in foods, feeds, cosmetics and industrial products such as biolubricants. Camelina can also be altered to contain other interesting properties that add to its commercial value. *Flax (linseed)* can be produced in the region, but is not yet proven to be as competitive as other oilseeds. The linseed oil has unique properties that can be used as drying agents in various paint and adhesive products.

In the *long-term* there may be a range of crops that could have commercial potential in the region. These include flax (linseed), pennycress, crambe, coriander, cuphea, castor, lesquerella, and meadowfoam. All of these offer some potential based on having unique properties desired by biobased product companies, or having a potential rotational benefit for the region. The successful breeding and commercial development of these crops will require significant investments of time and money that will probably require the participation of a major commercial company.

Of these, castor has been studied the most in the region, with programs initiated by Mississippi State University over the last decade. Castor is an interesting crop that has 55% oil content with yields of up to 2,200 lbs per acre. Its key ingredients, ricinoleic and sebacic acids are in high demand as a raw ingredient in a number of industrial applications. The price of castor oil is approximately $0.80 per pound. The crop, however, contains a toxic substance (ricin) which means that current varieties of castor are not recommended for processing due to concerns with toxicity, the presence of allergens and difficulties with mechanical harvest. There is significant research being conducted in breeding varieties with reduced ricin such as the 'Brigham' variety which has 4% ricin content, a significant reduction.

One other potential oil source is *Algae* which is currently being explored throughout North America as a solution to supplying large quantities of raw materials for advanced biofuels. Interest in algae production is not new. Nearly thirty years ago the U.S. Department of Energy's National Energy Laboratory researched algae for nearly two decades. In 1996 the program came to a close under the general consensus that algae production technology was not economically feasible. Algae is currently cultivated commercially for human nutritional products around the world in what would be considered small-scale production systems, producing several hundred tons of biomass annually. Increases and volatility in energy prices have rejuvenated the interest in algae production for biofuels, which has again become an active area for R&D. However, algae production technology is generally considered to be developmental at this stage. Nonetheless, the significant potential may be best evidenced by the algae-to-fuel R&D joint venture, recently announced between ExxonMobil and Synthetic Genomics.[38]

There are several over-arching concepts being explored in the development of algal technology. One potential use of algae is the capture of CO_2 from coal-fired power plants or ethanol plants. Algae consume CO_2 and could be utilized to remediate waste while potentially benefiting from carbon trading income in the future.

One good example of an algae company is Solazyme, Inc. of San Francisco, California. Solazyme is reportedly the only company which has produced significant quantities of biodiesel using its photobioreactor. Solazymes system is considered a "closed system," which means that critical optimization parameters such as light, temperature, water circulation, nutrients and cross-contamination can be controlled. Photobioreactors have many designs, but tubular reactors are the most common. In contrast, an "open system" consists of large open pond systems. There is significant interest in open systems from companies, many of which are using fish waste, municipal waste, and animal litter to feed the algae. There is a lot of interest, funding, and venture capital support for the technology, in addition to

[38] http://www.businessweek.com/bwdaily/dnflash/content/jul2009/db20090715_064110.html

misperceptions. The study team concludes that algae is a viable long-term source of oil, but the technology is probably a decade away from commercial viability. The U.S. Department of Defense estimates that the current production costs for algae as a biofuel are over $20 per gallon. However, significant research and development funding throughout the country is underway, with support from newly formed trade organizations and startup companies. Southern Growth Policies Board is working with Danforth Plant Science Center to develop further collaborative opportunities for algae companies and to support algal research in the region.

Sugar Crops

The production of crops in the Mid-South Mississippi Delta region that produce high amounts of sugar should increase as the most direct and simple way to manufacture fermentable biobased products and biofuels. The likely short-term sugar crop in the region is sweet sorghum although other candidates could potentially include sugar beets, sugar cane and sweet potatoes, depending on whether varieties and production practices can be adapted to this area. As the leading potential bioenergy crop for the region, sweet sorghum offers the flexibility of an annual crop, with the potential to produce significant amounts of sugar and lignocellulosic biomass for process.

Native to Africa, sweet sorghum is a tall, leafy plant that looks similar to corn. Agronomic practices for several open-pollinated varieties of sweet sorghum are well established in the study region, where the crop requires low inputs, is drought tolerant, and offers a good rotation option with other commodity row crops. Sweet sorghum has a very efficient, strong root system that allows it to produce under low water requirements. It is currently produced without irrigation or pesticides and utilizes approximately 60 lbs/acre of nitrogen. Adoption of sweet sorghum as a biobased product and bioenergy feedstock in the U.S. has been limited by availability of mechanized harvest and milling equipment, as well as market demand for the raw materials. Sweet sorghum is often noted for its photosynthetic efficiency as a C4 photosynthetic plant. It is a warm season plant, with the CO_2 first being incorporated into a 4-carbon compound. Other examples of C4 plants are corn, sugarcane, switchgrass, and bermuda grass. The advantage of C4 plants is their efficiency in nitrogen as well as carbon fixation allows for more efficient use of water. According to Blade Energy Crops, a brand of Ceres, Inc., C4 plants are the “most efficient engines of photosynthesis,” through which they store solar energy in the form of carbohydrates.

At the current time, there are no commercial harvesters designed specifically for sweet sorghum. Several harvest prototypes for dedicated sweet sorghum were developed in Italy between 1980 and 1990 but the result indicated the best solution was the adaptation of sugarcane harvesters. Two harvesting methods are being used today for sweet sorghum: harvesting the crop in-field with transport to a separate location for crushing or harvesting and crushing the crop with one machine and pass through the field. Sweet sorghum will typically average over 10 dry tons/acre in the southern United States, based upon a wet crop yield of 30–40 tons/acre and 70% moisture content. [39]

Efficient juice extraction can yield between 400–600 gallons ethanol/acre (gpa) from the sugar, while the crushed stalks (bagasse) represent a cellulosic feedstock, with the potential to produce an equal quantity of ethanol per acre. Louisiana Green Fuels, LLC (Lacassine, LA) is installing the nation’s first large industrial scale facility, which will share an existing sugar cane diffusion extraction unit for seasonal processing of 10,000 tons/day sweet sorghum to 25MM gpy ethanol, utilizing only the juice sugars.

[39] Fred L. Allen and Richard Johnson. “Corn Hybrid & Sweet Sorghum Silage Tests in Tennessee 2008.” The University of Tennessee Institute of Agriculture, available at http://www.utextension.utk.edu/publications/spfiles/SP618-2008.pdf.

Lignocellulosic Biomass

There are several new lignocellulosic biomass crops that have potential in the Mid-South Mississippi Delta region, on 25% of the region's idle land, 25% on Conservation Reserve Program (CRP) lands and eventually into broader use as markets for lignocellulosic biomass crops are expanded. These crops include switchgrass, miscanthus, biomass sorghum, and energy cane. It is probable that annual crops such as sweet sorghum will be a bridge crop that fits within traditional production practices, while developing a feedstock stream that can be augmented with lignocellulosic biomass crops.

Demonstration plot of University of Tennessee's Alamo variety of switchgrass at Agricenter International.

Switchgrass is a warm season perennial grass that is native to North America. It has an extensive root system and can reach heights up to 10 feet. First year establishment of switchgrass is critical. After establishment, switchgrass can be harvested for the next 10 to 20 years. Even though switchgrass competes strongly with weeds within the stand, it is not considered an invasive plant. Switchgrass is useful for livestock feed, the production of biomass pellets, and eventually for advanced biofuels. It also has a growth structure within the field that provides a healthy wildlife habitat. Switchgrass can be harvested with conventional baling equipment. Large rectangular bales tend to be easier to handle and store. For ethanol production, yields can be expected to be about 6–8 tons annually per acre with target yields of 12–15 tons per year, which could equate to upwards of 500 gallons of ethanol per acre. University of Tennessee is involved in a pilot project with Dupont-Danisco Cellulosic Ethanol LLC., located in Vonore, Tennessee to grow and harvest up to 6,000 acres of switchgrass for a pilot cellulosic ethanol facility. Ceres Inc., a California-based biotechnology company, is applying technology learned from sequencing the human genome to plants and in particular bioenergy crops such as switchgrass, high biomass sorghum, sweet sorghum, miscanthus and energy cane. Activities include: increased biomass yield, reduction of fertilizer requirements, drought tolerance, salt tolerance, and changing the plant composition to make bioprocessing more effective. Metabolix, Inc., of Cambridge, Massachusetts, a bioscience company is now developing a proprietary platform technology for co-producing plastics, chemicals and energy, from crops such as switchgrass, oilseeds and sugarcane.

Miscanthus species originate in Asia and are perennial, rhizomatous grasses with lignified stems resembling bamboo. Once the plants are established, which typically requires 2–3 years, some genotypes have the potential for very high rates of growth sometimes growing stems that are over three yards within a single growing season. Miscanthus is planted in the spring and, once planted, can remain for as many as fifteen years. The miscanthus leaves fall off in the winter, contributing to the development of soil humus and nutrient recycling. Miscanthus produces bamboo-like canes during late spring and summer, which are then harvested in late winter, or early spring. This growth pattern is repeated every year for the lifetime of the crop. Miscanthus spreads naturally by means of underground storage organs known as rhizomes. However, their spread is slow and there is little risk of uncontrolled invasion of hedges or fields. These rhizomes can be split and the pieces re-planted to produce new plants. All propagation, maintenance and harvest operations can be done with conventional farm machinery. In the UK, long-term average harvestable yields from a mature crop after the first three years have exceeded eight (8) dry tons per acre at the most productive experimental sites. Mendel Biotechnology, a California-based company is applying its technology developed to supply genetic traits and technology to major crop companies toward improving energy crops with a focus on miscanthus.

Sorghum-sudangrass hybrid grasses have been used for forage and cover crops and are increasingly grown as biomass feedstocks. Beyond high biomass yield, sorghum-sudangrass hybrids have the additional benefit of weed suppression, nematode control and the reduction of subsoil hardpans with their extensive root structure. As such, sorghum-sudangrass hybrids are great at increasing soil organic matter content. Since sorghum-sudangrass hybrid plants are largely sterile, they are bred to produce biomass and not seed and are unlikely to become weeds in future plantings. Sorghum-sudangrass hybrids are summer annual plants that can grow anywhere from five to twelve feet tall. The long, slender leaves and stalks tend to become more woody as they mature. Since they share the same C-4 photosynthetic pathway as corn and sugarcane, sorghum-sudangrass hybrids are fine-tuned to make use of soil moisture and sunlight to produce large quantities of biomass. Reported dry matter yields vary by agronomic practice and intended use, but yields ranging up to 15–20 tons per acre have been reported and newer varieties bred solely for biomass production are expected to yield more. Other crops being explored for bioenergy use include energy cane, miscanes (combination of sugar cane and miscanthus), and short rotation woody crops.

Agricultural Fibers

The development of crops which supply agricultural fibers is not new to the Mid-South Mississippi Delta region, as cotton, hardwoods and softwoods have been grown and processed in the region for centuries. There is, however, an increasing focus on the development of various biobased composite products and other novel uses for agricultural fibers that may increase demand for fiber. One of the agricultural fiber types with the greatest potential is “bast fiber” crops. Bast fibers include crops such as kenaf, industrial hemp, and flax. Although they are different species, they share the commonality of having a tall central stem which has long outer fibers (“bast”) and short, generally absorbency inner fibers (“hurd” or “core”). These crops offer potential opportunities in producing a range of biobased products including absorbant materials, composites, and specialty pulps.

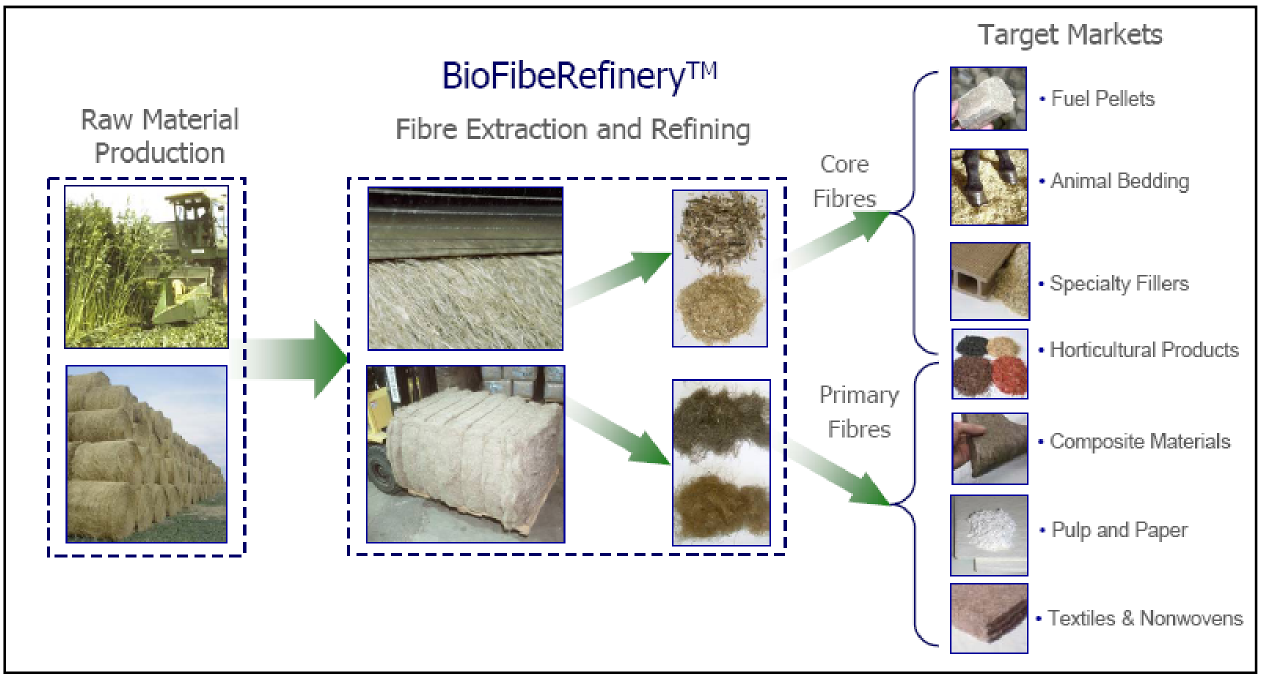
Brent Brasher, President, Kengro Corporation in Charleston, Mississippi, a leading producer, processor and marketer of kenaf and other alternative fibers.

Kenaf, is a relative of cotton and okra, and is native to Africa. The crop is an annual and is planted at the same time as cotton. There are several commercial varieties of the crop available. Mississippi State University is one of the key research institutions in the U.S. working with the crop. There are multiple harvesting methods including a modified cotton system which uses a forage chopper, cotton boll buggy, and module builder. Other systems harvest the crop in large square bales. There has been interest in growing and processing bast fibers such as kenaf in the study region over the last twenty years, much of it stimulated by progressive companies such as Kengro Corporation and work at Mississippi State University.

During the mid-1990s, 40 farmers were involved in the formation of the Mississippi Delta Fiber Cooperative which included the construction of a processing facility based in Charleston, Mississippi (Tallahatchie County) in partnership with Agro-Fibers, Inc. to develop a nonwoven facility at the site. The Mississippi processing facility is now owned by Kengro Corporation, a company founded by two leading farmers originally part of the processing cooperative. This processing facility was one of three constructed during the early/mid 1990s in the U.S. Over the years, thousands of acres of kenaf have been grown in states including California, Georgia, Louisiana, Mississippi, North Carolina, and Texas. A combination of overproduction, lack of processing knowledge, and inadequate market development has led to many failures, with only a few notable successes.

Kengro Corporation is currently the primary player in the 98-county study region commercializing bast fibers. The company is producing a branded line of absorbency products for the petroleum industry that is sold through a dealer network in the U.S. and Canada. Kengro is actively involved in looking at other potential fiber and biomass crops and developing higher value markets such as composites and insulation. Additionally, Vision Paper of Albuquerque, New Mexico has performed yield trials in the region to examine possibilities for a potential site for a small specialty pulp mill.

Mississippi State University is the leading institution that has researched kenaf. Additionally, a group centered at Clemson University has researched the commercialization of flax as a fiber crop in the southeastern United States. This has led to the construction of a processing facility in South Carolina and expanded collaborations with Canadian and European stakeholders. According to the Saskatchewan Flax Commission, there are 751,000 tons of flax bast fiber produced globally, while there are 83,000 tons of industrial hemp bast fibers. The focus of flax fiber production in the United States has focused on application in the textile industry which has suffered the same fate as the cotton textile industry.



Stemergy's BioFibeRefinery™ proprietary process offers a technology pathway for separating bast fibers into their valuable components.

According to Stemergy, a leading technology developer for agricultural fiber separation technology, the markets for bast fibers in North America are estimated in excess of $4 billion and growing. The long, slender fibers on the outside of annual stem fiber plants are used to replace synthetic fibers in composites for the automotive, construction and consumer products industries. These fibers also are used to make specialty pulp and paper, packaging, nonwovens, insulation, stuffing, and many other materials. The core of the stem fiber plants is extracted, screened, packaged and sold as animal bedding, garden mulch, and plastic and concrete fillers. Many new applications are being developed by various companies and research institutions, including heating and fuel pellets, liquid fuels, biofilms and biopolymers, industrial biochemicals, adhesives, gels and thickening agents, natural antioxidants, loose-fill insulation, and market pulps for paper. The two different fibers in the stalks of both of these plants, namely the core fiber on the inside and the primary fiber on the outside, are separated and then refined into different sizes and quality levels and packaged according to specific industry or customer needs. In the case of the primary fiber, the level of core remaining in the primary fibers, and the length of the fibers can be adjusted according to specific applications. The core fibers come in different particle sizes, and the largest size available is a function of the stalk diameter.

The use of natural fiber composites in automotive applications was launched in the early 1990s by Mercedes Benz and has since expanded to all major automotive producers in Europe and North America. As an example, the last generation of the Mercedes S Class vehicle used 55 pounds of natural fiber composites, whereas the new version now contains almost double this figure at 95 pounds per vehicle. Despite the current downturn in the domestic automotive industry, global demand will increase over the next decade and there remains a growing demand for lightweight composite technologies in many applications.

Bamboo is another potential fiber crop that is being considered in the Mid-South Mississippi Delta region. This fast growing perennial crop can be used to make composites, textiles, flooring, and a range of other biobased products, as well as applications for biofuels and bioenergy. An active group organized by the Delta Economic Development Center in Washington County, Mississippi is developing a network of participating companies, farmers, and industrial supply chain partners to develop a bamboo industry in the region. The development of new cloning technology to produce bamboo for large scale planting presents the opportunity to grow the crop for fiber and/or as a dedicated energy crop in the region.

Phyllostachys edulis 'Moso' is the species of bamboo suitable for introduction into the region. This species of bamboo is responsible for all of the bamboo products currently being imported into the U.S. The U.S. is the largest importer of bamboo products in the world. 'Moso' comes with an impressive set of statistics that are well documented by studies dating back to the early 1900s and backed by scientific publications as recent as this year. Moso produces more biomass per acre than any other plant in the world averaging 80 dry tons per acre annually. Thirty percent of this can be sustainably harvested annually for 100 years or more. Moso sequesters more CO_2 than any other plant in the world and because bamboo acreage is harvested sustainably it continues to act as a serious carbon sink that not only helps the U.S. achieve its reduction goals but brings significant value to the farmer on the emerging carbon cap and trade markets. Moso has the lowest sulfur content, lowest moisture content, low ash and is one of the most extraordinary co-firing materials available on the biomass scene today. Bamboo may represent a promising feedstock for cellulosic ethanol, bio-oil, and biodiesel.

Niche / Alternative Crops & Agricultural Biotechnology

A range of low volume, high value crops may have potential across the Mid-South Mississippi Delta study region. For example, Dr. Valtcho Jeliazkov, and his staff at the North Mississippi Research and Extension Center in Verona, Mississippi have worked extensively with new oilseed crops such as sunflower, canola, mustard, crambe and flax as part of the Mississippi Specialty Crops Research Program through Mississippi State University. The oilseed program has extended across six locations in Mississippi and includes cultivars, planting dates, multi-crop systems and nutrient management. An excellent example of a potential high value alternative crop is American mayapple which contains podophyllotoxin, the precursor used for the semi-synthesis of various chemotherapy drugs used as a treatment for cancer. Besides mayapple, the Specialty Crop Research Program is evaluating many medicinal and aromatic crops at four locations in Mississippi. Over forty different crops have been tested including evaluation of production methods, increased growth and production of secondary metabolites. Much of this work is being conducted through the leadership of The National Center for Natural Product

Arkansas Bioscience Institute at Arkansas State University and other regional institutions are working to develop novel, niche crops that would offer the region's farmers high value options.

Research (NCNPR) at the School of Pharmacy at University of Mississippi. NCNPR conducts basic and applied multidisciplinary research to discover and develop natural products for use as pharmaceuticals, dietary supplements and agrochemicals, and to understand the biological and chemical properties of medicinal plants. Research is also conducted on medicinal plants so that they may be developed as crops for the region's farmers.

Significant work is being developed at Arkansas Biosciences Institute at Arkansas State University in Jonesboro developing small volume, high value crops. Work within the ABI includes the development of plants for production of therapeutic and vaccine proteins, transgene expression strategies, protein processing in plants, and the commercialization of these technologies. In particular, researchers are developing agrobacterium-mediated transient expression systems in tobacco, industrial enzymes in corn seed, working with Arabidopsis (a model plant), and developing systems for using hairy roots and algae as protein expression systems.

Although this report focuses on industrial uses for farm crops and forestry resources, there is a significant local food industry growing in the region that is connecting local farmers directly with consumers. This niche industry, although low in volume and acreage, is serving to introduce new crops to the region, while providing an entry point for new entrepreneurial projects. Each of these niche opportunities serve to encourage local economic development, crop diversity, innovation, development of regional niche markets, and increased job creation for the region.

The potential for small niche crops in the region should be encouraged and the necessary institutional, financial and research support put in place for a concerted effort at regularly identifying new crops that may have a promising future in the region.

The Role of Agricultural Biotechnology in Current and Future Agriculture

Agricultural biotechnology offers many potential benefits to the Mid-South Mississippi Delta Region. Currently, biotechnology traits used to reduce farmers' costs and increase profitability ("input traits") are widely deployed in corn, cotton, and soybeans grown in the region, as well as in canola, which is being introduced as a winter rotation crop with winter wheat. In 2008, the global biotechnology crop area grew by 9.4%, or 26.43 million acres, to reach a total of 309 million global acres. More than 13 million farmers in 25 countries currently use agricultural biotechnology crops. Between 2007 and 2008, the U.S. increased its biotechnology crop acreage from 143 million acres in 2007 to 154 million in 2008. This is tremendous sustained growth considering the first biotechnology crops were not introduced until the mid 1990s.[40]

In addition to input traits in commodity crops, new crops have been generated for bioenergy and pharmaceutical applications using plant biotechnology to increase yield, efficiency of fertilizer use, and even to grow new products in the plants. Other rapidly commercialized output traits focus on improving

[40] International Service for the Acquisition of Agri-Biotech Applications, ISAAA Report for 2008.

edible oils, nutritional properties, and novel health benefits in traditional commodity crops. Not all of these technology improvements are created through gene transfer. Some use mutation, breeding and other novel techniques to create new crop performance. *These technologies will dramatically improve the quality and quantity of agricultural production in the 98-county study region.* Agricultural biotechnology will likely have a major role in enabling a vibrant bioeconomy in the study region.

It is expected that modern breeding with the aid of molecular markers and biotechnology will increase yields for existing crops, facilitating increased productivity. This productivity gain will allow the output of current crops primarily for food and feed to remain the same (or even increase) while reducing the amount of productive land needed. This can potentially make available good land for producing other alternative crops for biomaterials and/or bioenergy. It is also expected that biotechnology will increase yields for new crops that will be used for biomaterials and/or bioenergy. These dramatic increases in productivity will be similar to what has been observed in corn over the last fifty years, as modern technology is applied to crops that have had little or no modern breeding. Some of the most promising technologies include increased drought tolerance and nutrient use efficiencies in current and future crops. Gene stacking technology, the ability to introduce multiple genes into a plant at one time instead of breeding them individually, will bring multiple traits to market quicker and offer benefits to producers, processors and end users.

New relationships are being developed with farmers that involve direct contracts and identity preservation. This creates exciting new opportunities and income for farmers willing to develop relationships and partner in new ways. Output traits (first health and then industrial) will be brought to market which will further drive new relationships with farmers and end users of the farm-grown products. There are opportunities for small volume crops which are genetically engineered to produce pharmaceuticals or industrial proteins.

Observations and Conclusions

- New crops can offer farmers many benefits including increased options, enhanced agricultural practices, and potential to be involved in value-added processing. New crops under consideration in the region are potentially less vulnerable to weather, pests and market forces, while requiring less water and fewer inputs than traditional crops.
- Biobased product companies are finding that there are many novel properties available in new crops, that are cost prohibitive to make synthetically and/or are not present in commodity crops such as corn and soybeans.
- Biobased product companies, including both small businesses and large multinational corporations, have identified new relationships in the supply chain, access to a reliable supply of feedstocks and the potential to access unique new properties as major drivers to introduce new crops.
- In order to introduce one or more new crops to the Mid-South Mississippi Delta region, there are significant research, logistics, government and market barriers that must be addressed. These include the need for breeding programs, increased incentives from federal farm programs, and the ability to insure new crops. A comprehensive effort to deal with these institutional barriers must be part of a new crops strategy for the region.
- An ongoing effort at continued crop discovery, breeding, agronomic development, and deployment will be important to continue adding potential new crops to the regional development pipeline.
- Specialty crop programs and funding from USDA should be expanded to include any noncommodity crops that can be grown by farmers in the Mid-South Mississippi Delta region despite their physiological makeup and intended end use.

- Greater collaboration and alignment with the region's research farms, education and research institutions, and private companies to commercialize new crops will help drive programs that will benefit the region.
- An important consideration in introducing potential new crops in the Mid-South Mississippi Delta region is managing the expectations of farmers and developing methods to involve farmers early. Farmers and new crop promoters will need to realize that many of the approaches and crops under development may not ultimately be successful. It is key to include leading farmers early in the commercialization process, in that many pitfalls can be avoided by bringing real world agricultural experience to help solve problems with new crop introduction.
- The expansion of the automotive industry in the 98-county study region and surrounding states may offer significant opportunity for the expansion of the production and use of agricultural fibers for industrial textiles, fiber reinforced composites and other automotive related applications. Besides existing markets, likely new markets are filtration mediums, structural components, and the application of nanotechnology to the improvement of fiber strength.
- Conducting due diligence on technology and developing collaborations with experienced partners will be necessary to capitalize on new crop opportunities in the region. The history of new crop commercialization is littered with failures, and it will be crucial to align regional projects with the few proven success stories and existing knowledge base.
- The allocation of risks and rewards must be done equally among participants in the new value-chain. One way to do this is to incorporate public-private partnerships with business and organization plans, resulting in appropriate and sustainable roles for each partner in the commercialization effort.
- The development of supply chain management systems will be very important, so that sufficient product is available at a time and price when buyers want it, and to avoid overproduction and market saturation.

III. Biomass Conversion Technologies and Products

This summary is excerpted from the study sub-report "Biomass Conversion Technologies and Products," prepared by BioDimensions, Inc. and Biowa. The full sub-report is available online at www.agbioworks.org.

A. Introduction and Feedstocks Summary

The chemical composition of biomass is diverse and many plant species produce complex organic components which have historically been extracted and processed as dyes, drugs, flavorants and other useful end products. Despite these unique specialty components, biomass intended as a feedstock for downstream processing contains one or more of the constituents shown in Table 14, in commercially useful quantities. Bioprocessing technologies seek to convert these components into other useful downstream products such as fuels and chemicals, which can displace finite fossil-fuel derived materials.

Table 14: Major Biomass Feedstocks

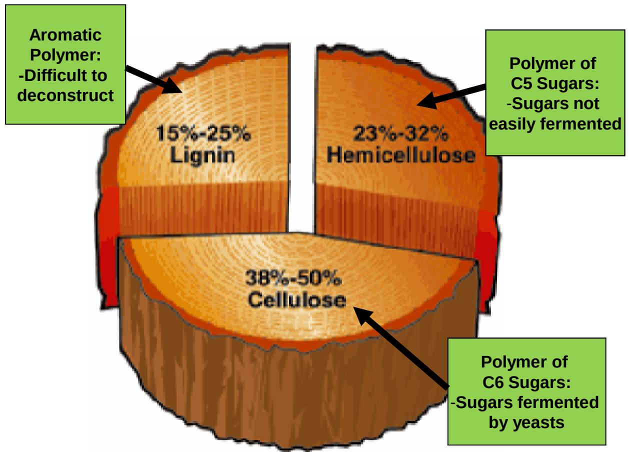
Feedstock	Key Chemical Component(s)	Crop Examples
Oils	Plant oils: triglycerides	Soybeans, Canola, Camelina, Algae
Starch	Glucose polysaccharide	Corn, Barley, Grain Sorghum (Milo)
Sugar	Disaccharides, glucose, fructose	Sugar Cane, Sugar Beets, Sweet Sorghum
Lignocellulose	Lignin, cellulose, hemicellulose	Wood, Crop Residues, Miscanthus, Switchgrass

Oils are triglycerides, which are esters comprised of three long-chain fatty acids with glycerol, derived from both plant and animal (fats) sources. Starch is the primary component in the grain of crops such as corn and barley. It is a sugar polymer, or polysaccharide, and the individual sugar molecules must be hydrolyzed or cleaved from the polymer by the action of enzymes, prior to yeast fermentation. Monomeric 6-carbon sugars, such as glucose and fructose or the two-unit disaccharide sucrose, are produced by certain sugar crops, and are readily fermentable by yeasts to ethanol, without hydrolysis or other pre-treatment.

Woody and herbaceous biomass—often referred to as lignocellulosic biomass— is the subject of significant technology development due to its abundance and potential as a bioprocessing feedstock.[41] It is primarily comprised of three components—lignin, cellulose, and hemicellulose—along with varying amounts of many other specialty and trace constituents. While the proportion of these major components varies by species and type of biomass, they generally fall within the ranges shown in Figure 14. Cellulose and hemicellulose are polysaccharides or sugar polymers—comprised of repeating monomer sugar units bonded together into long chains, much like rail cars are coupled together to form a train. Combined with lignin, these biopolymers comprise the structural components of plant matter and are produced by the photosynthetic process, whereby atmospheric carbon dioxide (CO_2) is absorbed by the plant, chemically transformed, and "fixed" into these other useful chemical materials.

[41] DOE and USDA (2005). *Biomass as Feedstock for A Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*. Retrieved from www1.eere.energy.gov/biomass/pdfs/final_**billionton**_vision_report2.pdf.

Figure 14: Lignocellulose Composition



Lignin is a natural polymer found in all plant materials which combines with cellulose and hemicellulose to provide structural strength to the plant and direct water flow. It is not a sugar polymer, but rather an aromatic polymer, meaning its component phenylpropenyl molecular units contain the highly stable benzene-ring chemical structure, which is also the basis for many commercially useful materials produced from petroleum. The aromatic chemical structure also imparts a high calorific value to the lignin molecule, which is valuable for combustion (heat) and also chemical transformations. Lignin can have significant variability in its chemical structure, often differing based upon the biomass source, with softwoods containing the highest proportion (27–33%) and hardwoods/grasses containing lower levels (17–25%).[42]

Cellulose and hemicellulose are referred to as carbohydrates because they are aliphatic polymers comprised only of carbon, hydrogen, and oxygen. Cellulose is the most abundant biopolymer on earth and is made of six carbon or C-6 glucose ("sugar") monomers. Cellulose obtained from wood pulp, cotton, and other plants has been used for centuries to produce paper and cardboard, as well as derivative products. Often referred to as dietary fiber, it is not digestible by humans, but with recent technology developments can now be commercially de-polymerized (hydrolyzed) by enzymes to its monomer sugars, which can then be readily utilized as feedstocks for bioprocessing. Yeast fermentation of C-6 glucose sugar to ethanol has been practiced for centuries, and other natural and genetically-modified organisms can convert these sugars to various useful chemical molecules. Hemicellulose is a polymer comprised of various five carbon, or C-5 sugar monomers. Unlike cellulose, it is an amorphous polymer with little structural strength and is easily hydrolyzed to its monomeric C-5 sugars with acid/base or enzymes. Unfortunately, C-5 or xylose sugars cannot be fermented using natural yeasts, although aggressive R&D programs are developing new organisms and genetically-modified yeasts to utilize these readily available C-5 sugars as bio-processing feedstocks.

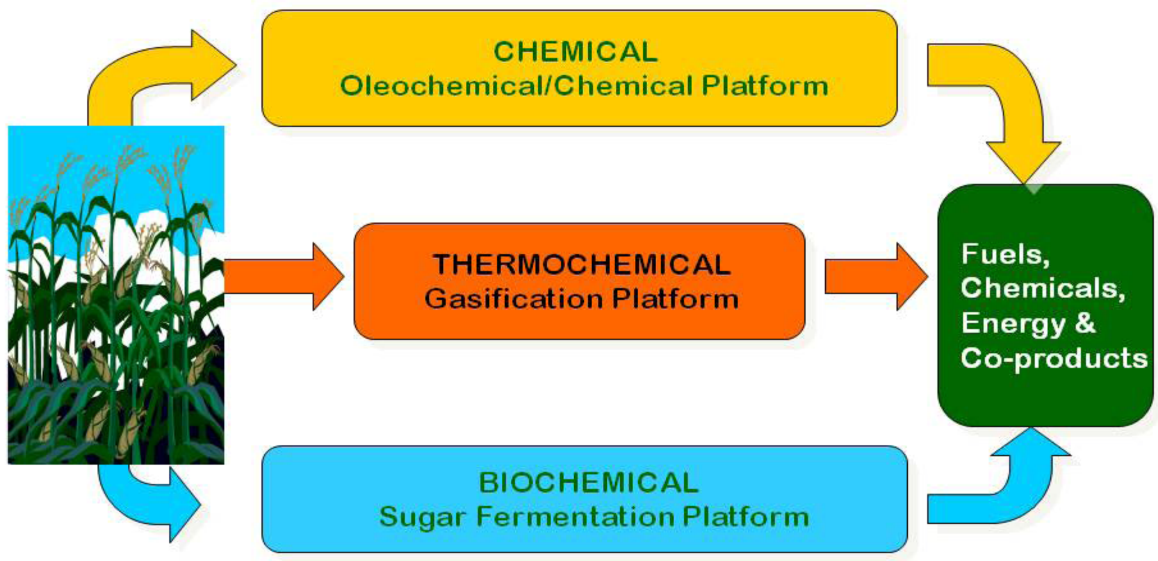
B. Overview of Technology Platforms

Biomass or components of biomass can be used as feedstocks by chemical modification of the constituents, often referred to as bioprocessing. There are three distinct technology platforms for these

[42] DOE (2007). *Top Value-Added Chemicals from Biomass; Volume II – Results of Screening for Potential Candidates from Biorefinery Lignin.* Retrieved from www1.eere.energy.gov/biomass/pdfs/pnnl-16983.pdf.

molecular transformations—chemical, thermochemical, and biochemical—as shown in Figure 15. Each platform has specific characteristics for commercial processing, including: range of feedstocks and products; co-products; cost; scale; and stage of technology development.

Figure 15: Biomass Conversion Technologies



Chemical Platform

Transformation of biomass materials by classical chemical and catalytic reactions has been practiced commercially for over a century, although focused on a relatively narrow range of products. The most significant processing sector is the pulp and paper industry, which uses lignocellulosic feedstocks (mostly wood) to produce paper and cardboard products. Chemical wood pulping involves the digestion of wood chips at elevated temperature in a basic water solution to dissolve the lignin and hemicellulose, while leaving the cellulose intact, for purification and processing into paper. The extraction solution, referred to as "black liquor," contains lignin, hydrolyzed hemicellulose (C-5 sugars), and other decomposition products resulting from the harsh processing conditions. Historically black liquor has been concentrated, the process chemicals recovered, and the residual biomass components combusted for fuel value. More recently, thermochemical technologies (described later in this sub-report) have been developed to gasify black liquor to higher-value downstream products. In addition, several academic and private-sector groups are developing technologies to fractionate lignocellulose, allowing more cost effective options for downstream processing of each component. These technologies to enable an "Integrated Forest Products Biorefinery" or IFPB have not yet been significantly demonstrated at commercial-scale facilities.[43] The industry is characterized by large capital-intensive facilities, with highly integrated chemical and heat recovery systems, which complicates retrofitting for more efficient processing of all biomass components.

The other significant sector employing chemical processing of biomass feedstocks is the oleochemical industry. Oleochemical manufacturing facilities are mature biorefineries. This industry sector has its roots in the saponification (base treatment) of fats and oils to produce soap. The acid or base-catalyzed hydrolysis chemical reaction is the basis of the oleochemical industry, producing fatty acids and glycerol,

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[43] Agenda 2020 Technology Alliance; American Forest & Paper Association. *Integrated Forest Products Biorefinery.* Retrieved from www.agenda2020.org/PDF/IFPB_Brochure.pdf

which are purified and used directly or reacted further to downstream derivatives. Such derivatives include fatty acid methyl esters (FAME or biodiesel), fatty alcohols, fatty amines and amides, alcohol ethoxylates and sulfates, and acylglycerols. These products find many industrial and end-use applications in areas such as coatings, surfactants, lubricants, detergents, and consumer products. Major oleochemical manufacturers include: ADM, Akzo Nobel, Arkema, Cargill, Cognis, Croda (Uniquema), P&G Chemicals, and PMC Biogenix (formerly Chemtura). This industry is characterized by significant global infrastructure and highly integrated processing facilities.[44] [45]

Recent increasing demand for chemical products with biobased content has resulted in renewed R&D efforts and new commercial products derived from oil feedstocks by traditional chemical processing technologies. Vegetable oils, notably soybean oil, can undergo various chemical reactions to introduce hydroxyl groups, forming polyols used in polyurethane foam production. Epoxidized soybean oil (ESO) is a commodity product used in polyvinyl chloride plastic.[46] The glycerol co-product from biodiesel production is now being converted to intermediates such as propylene glycol, epichlorohydrin, and propanediol in demonstration or commercial facilities. While most commercial transformations of fatty acids are directed toward the acid group,[47] Elevance, a partnership between Cargill and Materia is applying new olefin metathesis technologies to the double bonds (unsaturation) in feedstock oils to produce a range of biochemicals and waxes.[48] [49] Segetis is developing patented technology to combine biomass-derived carbohydrates to form bifunctional or "binary" monomers, as precursors to proprietary polymers. An example patented chemical family, glycerol levulinate ketals, is said to be produced entirely by synthetic chemical, rather than fermentation, technologies.[50]

R&D efforts to convert lignocellulose biomass to liquid fuels have predominantly focused on the Thermochemical and Biochemical technology platforms described below. Nevertheless some programs, such as the Energy Biosciences Institute (EBI), a collaboration between research institutes and oil company BP, are also investigating new chemical catalysts to accelerate the depolymerization of polysaccharides and lignin.[51] Virent Energy Systems, Inc. is developing novel technologies to convert plant sugars to hydrocarbon mixtures, which could be used as renewable liquid fuels. The approach integrates a patented Aqueous Phase Reforming step, which partially deoxygenates sugars with catalytic processing to afford non-oxygenated hydrocarbons. Catalysts and conditions can be selected to produce fuel mixtures for various applications. The technology can utilize mixed sugar feedstocks, but would require fractionation of lignocellulosic biomass to remove the non-carbohydrate lignin component.[52]

Thermochemical Platform

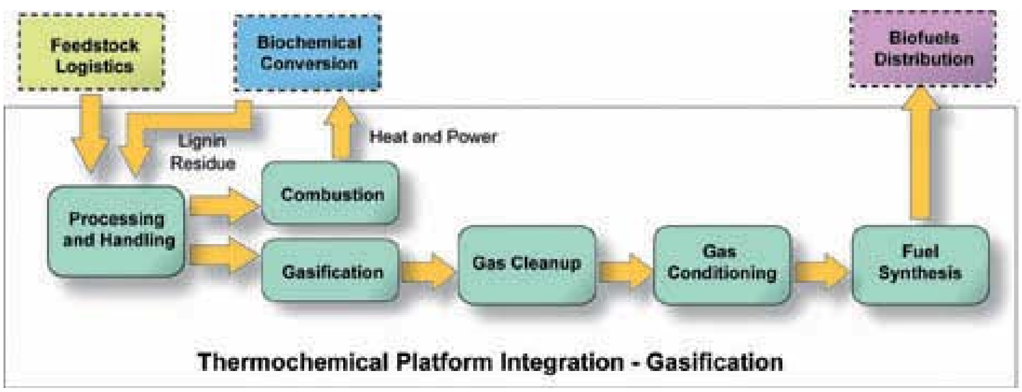
Thermochemical technologies use thermal, or high temperature, processes to break down carbon-containing feedstocks into other usable products. These technologies have been practiced in the chemical process industry for many years, mostly using fossil fuel feedstocks. However, the processes can generally use a variety of feedstocks including biomass, municipal waste, and petrochemical wastes such as plastics. Two major process variations—gasification and pyrolysis—use limited oxygen compared to

[44] NREL Technical Report (2004). *Biomass Oil Analysis: Research Needs and Recommendations.* Available at http://www.osti.gov/bridge
[45] Bergstra, Ray. February 2007. *Emerging* Opportunities *for Natural Oil Based Chemicals*. Plant Bio-Industrial Workshop, Saskatoon, Canada. Retrieved from www.mtnconsulting.ca/Oleochem%20Final%20rjbergstra.pdf
[46] Bergstra, Ray. February 2007. Emerging *Opportunities for Natural Oil Based Chemicals*. Plant Bio-Industrial Workshop, Saskatoon, Canada. Retrieved from www.mtnconsulting.ca/Oleochem%20Final%20rjbergstra.pdf
[47] Bozell, Joseph J. 2006. *Oleochemicals in the Biorefinery,* Growing the Bioeconomy Conference, Iowa State University. Retrieved from www.bioeconomyconference.org/images/Bozell,%20Joe.pdf.
[48] Chemical and Engineering News, March 31, 2008.
[49] www.elevance.com
[50] www.segentis.com
[51] Energy Biosciences Institute (EBI) Annual Report, 2008. Bioenergy: Exploring the Applications of Modern Biology to the Energy Sector. Retrieved from www.myvirtualpaper.com/doc/Institute-for-Genomic-Biology/EBIAnnualReport2008/2009030302/

incineration, to produce gas, solid, and liquid product streams. The **pyrolysis** process thermally degrades carbon-containing feedstocks—such as coal, solid wastes, and biomass—in the absence of oxygen to produce liquid and gaseous products. Pyrolysis oil or "bio-crude" is a potential substitute for petroleum, but contains oxygenated products and other chemicals, and is therefore different from hydrocarbon petroleum products. Such pyrolysis oils require further purification and refining to produce liquid transportation fuels. Flash or fast-pyrolysis is a process variation that uses finely divided feedstock which can be decomposed at high temperatures with short residence times. The **gasification** process exposes the feedstock to some oxygen—but not enough to allow combustion to occur—to produce syngas, which is a mixture of carbon monoxide and hydrogen (about 85%), with smaller quantities of other gaseous products.

Syngas can be combusted for energy but has been used as a feedstock in the chemical process industries for many years, where the gases are reacted in secondary chemical or biochemical processes to produce methanol, ethanol, and other chemicals. An important secondary process for possible liquid fuel production is the Fisher-Tropsch synthesis, which reacts syngas over metal catalysts to produce mixed hydrocarbon products.[53] [54] An essential gasification process step is the purification of syngas to remove impurities—often feedstock specific—which can deactivate the catalysts used for downstream processing. Organisms have also been developed that convert syngas to ethanol and other chemical products, resulting in a hybrid thermochemical/biochemical process. Dr. James Gaddy, formerly of the University of Arkansas, has been a leading developer of this technology.[55] A generic thermochemical process schematic is shown in Figure 16.[56]

Figure 16: Thermochemical Process Flow



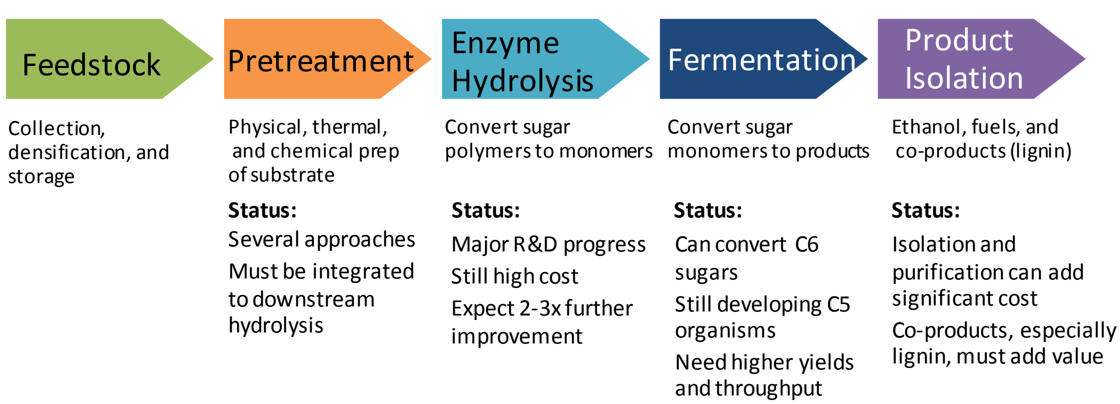
[53] NREL Technical Report (2003). *Preliminary Screening – Technical and Economic Assessment of Synthesis Gas to Fuels and Chemicals with Emphasis on the Potential for Biomass-Derived Syngas.* Retrieved from www.nrel.gov/docs/fy04osti/34929.pdf
[54] Perry, Alex. *Time,* September 15, 2008.
[55] www.brienergy.com and BRI Energy, Inc. Report, 2006. *The Co-Production of Ethanol and Electricity from Carbon-based Wastes.* Retrieved from www.energy.ca.gov/bioenergy_action_plan/documents/2006-03-09_workshop/.../BRI_ENERGY_STEWART_JAMES_CMNT.PDF
[56] EERE, http://www1.eere.energy.gov/biomass/biochemical_conversion.html.

Biochemical Platform

Biochemical processing, sometimes referred to as the "sugar" platform, seeks to convert six-carbon (C-6) and five-carbon (C-5) sugars derived from biomass to fuels and chemicals through the use of enzymes and microorganisms. Most of the recent R&D, with significant support from the Department of Energy, has focused on the development of pretreatment systems and enzymes which can de-polymerize cellulose and hemicellulose into their monomeric sugars followed by yeast fermentation to "cellulosic" ethanol. As a second generation biofuel, ethanol derived from lignocellulosic feedstocks eliminates the food-fuel issue and has also been shown to have a much more favorable net energy balance and lifecycle GHG reduction than starch-based ethanol. Also within the biochemical platform, other research is developing new bacterial organisms and genetically modified yeasts to convert both C-6 and C-5 sugars to other products, with perhaps the most advanced efforts directed at butanol, an important industrial chemical and possible second generation biofuel, and succinic acid, a multi-functional platform chemical.

Significant progress has been made in developing biochemical technologies to use lignocellulosic feedstocks. The overall process requires several steps as depicted in Figure 17: feedstock pretreatment, enzymatic depolymerization, sugar fermentation and distillation/product isolation. Several pretreatment methodologies have been developed, generally combining heat, pressure, and chemical reaction to make the cellulose and hemicellulose polymers more accessible to enzymatic attack. Pretreatment processing must be designed to minimize introduction or formation of contaminants that would be toxic to the downstream enzymes and organisms. While significant hydrolysis of the hemicellulose can occur during pretreatment, cellulase and other enzymes are next added to convert the more recalcitrant cellulose to its component C-6 sugars and complete conversion of hemicellulose to C-5 sugars. Remarkable advancements in cellulase enzyme cost and effectiveness have been made in the last 5 years, due to work done by Genencor and Novozymes, supported by DOE. While C-6 sugars are readily fermented to ethanol by natural yeasts, current R&D programs seek to develop new organisms that can effectively convert the C-5, as well as the C-6 lignocellulosic sugars to ethanol and other chemical products. Some R&D programs are pursuing organisms that can both hydrolyze cellulose and hemicellulose and ferment the resulting mixed sugars to ethanol, referred to as consolidated bioprocessing. An alternative approach being pursued by several leading technology developers seeks to fractionate lignocellulosic feedstock into its 3 components—lignin, cellulose, and hemicelluloses—and apply targeted downstream processing technologies for each component.

Figure 17: Biochemical Process Flow



C. Characteristics of the Technology Platforms

Overview

Traditional chemical processing of biomass feedstocks is often overlooked in technology discussions in preference to the thermochemical and biochemical technology platforms being developed for lignocellulosic feedstocks. However, significant opportunities exist for conversion of plant oils and other biobased precursors to new and useful chemical materials, which generally command higher value than fuel products. Fatty Acids obtained from plant oils are generally multi-functional, containing both olefinic (unsaturation) and acid functionality, which makes them particularly useful as chemical intermediates for polymers and other complex molecules with desired properties. Application or enhancement of conventional reactive chemical technologies, within existing oleochemical or specialty chemical processing industries, also offers a lower-risk route to these biobased chemicals and intermediates. In addition to new conversion technologies such as olefin metathesis, genetically modified oilseed crops offer enhanced compositional traits as feedstocks. These specialty oilseed feedstocks may require new supply chains, including dedicated or identity-preserved oil extraction. Economic disposition of co-product meal will also be a factor in producing specialty oil feedstocks.

The thermochemical and biochemical technology platforms are primarily focused on conversion of lignocellulosic biomass-to-liquid (BTL) fuels and chemicals. Generally speaking, gasification and pyrolysis are known technologies presenting fewer technical challenges, although these are still being adapted to the use of biomass feedstocks. Downstream chemical catalytic conversion of syngas to fuels leverages existing knowledge, while conversion by bioorganisms represents novel technology being developed by several groups. Thermochemical processes have the advantage of converting all the carbon-containing components—lignin, cellulose, and hemicellulose—into products. However, secondary processing of syngas generally requires efficient removal of impurities, which can vary according to feedstock. Liquid pyrolysis products are generally complex mixtures which must be purified to afford downstream fuel products or chemical intermediates. Historically, due to the temperature and pressure requirements, thermochemical processes have required economy of scale for commercial viability. This could present a challenge in sourcing sufficient quantities of biomass feedstock at an acceptable delivered cost to support a large industrial-scale facility. Several groups are attempting to develop smaller modular gasification and downstream processing units to address this issue. Thermochemical technologies appear to be particularly well-suited for production of liquid fuel products from lignocellulose feedstocks, most commonly mixtures of alcohols, hydrocarbons, or other monofunctional compounds at commodity volumes, from large dedicated facilities. This product range of longer-chain aliphatic compounds would be better suited for replacement of diesel and aviation fuels.

While substantial progress has been made in recent years in developing biochemical technologies, challenges still remain, including: optimizing pretreatment systems with adequate throughput; improving efficiency and reducing cost of enzymes; enhancing value of co-products; and achieving overall process integration. A key distinction between the two technology platforms is that the biochemical route affords lignin as a residue or co-product, which can be used for process heat and/or power generation. Lignocellulose fractionation to remove lignin prior to the hydrolysis and fermentation could afford a purer and more consistent feedstock for downstream processing to higher value aromatic chemical derivatives. In fact, while sulfonated lignins from the Kraft paper process have found rather limited market applications, low-sulfur and low-ash lignin from lignocellulose fractionation, coupled with novel biochemical depolymerization, has the potential to offer a non-petrochemical route to the important higher-value aromatic chemical platform.

Lignocellulose Fractionation

Thermochemical technologies can effectively convert a range of carbon-containing feedstocks, including both the carbohydrate (cellulose and hemicellulose) and lignin components of lignocellulosic biomass. However, biochemical and other chemical technologies (e.g. Virent's aqueous phase reforming) are designed to utilize only carbohydrate or sugar raw materials. Recognizing this compositional diversity of lignocellulosic feedstocks, several leading technology developers have pursued fractionation, or separation, of these components, in order to facilitate more efficient and targeted downstream conversion of each component. Early development of these technologies originated in the pulp and paper industry, where processes are designed to remove hemicellulose and "de-lignify" wood pulp in order to obtain a purified cellulose fraction for paper manufacturing. Unfortunately, the primary Kraft pulping process accomplishes this separation through aggressive chemical processing that degrades and modifies the unwanted components, which are then largely usable only for their fuel value. More recent approaches have used a combination of physical and thermal pre-processing, followed by aqueous and/or solvent extractions, to afford substantially purified fractions of hemicellulose (and C-5 sugars), lignin, and cellulose for further processing specific to each component. These fractionation technologies offer the potential for bolt-on or new pulping processes that can extract higher value from pulpwood feedstocks, and some technologies are being developed for that purpose. Lignocellulose fractionation may prove equally valuable as an integrated component of biochemical processing, providing sugars for fermentation and also a purified lignin stream with potentially greater value as an aromatic chemical platform feedstock. Unlike lignin by-product from Kraft pulping, fractionated and purified lignin will be unsulfonated; of higher purity and consistency; and can be produced to desired molecular weight ranges.

Economic Comparison of the Biochemical and Thermochemical Platforms

According to a recent report by the International Energy Agency (IEA), the thermochemical and biochemical routes have comparable potential energy yields, converting dry biomass at about 20 GJ/ton to about 6.5 GJ/ton of biofuels, for a conversion efficiency of about 35%.[57] The report further projects potential ethanol yield of about 80 gallons/dry ton from biochemical processing and a synthetic diesel yield of 53 gallons/dry ton from thermochemical conversion. Experience with each platform, utilizing biomass feedstocks, is limited to pilot and pre-commercial scale at present, so accurate production cost information remains to be confirmed. Furthermore, leading private-sector technology developers do not generally publish proprietary process cost information. IEA has estimated production costs of second generation biofuels to be in the range of $3.02–3.79/gallon for ethanol and at least $3.79/gallon for synthetic diesel, comparable to the wholesale petrochemical fuel prices when crude oil is in the range of $100–130/bbl. The IEA report concludes that there is presently not a clear commercial or technical advantage between the platforms, and that widely fluctuating crude oil prices impart high risk to investment in second-generation biofuels.

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57 IEA (2008). *From 1st- to 2nd Generation Biofuel Technologies: An overview of current industry and RD&D activities.* Retrieved from www.iea.org/Textbase/Publications/free_new_Desc.asp?PUBS_ID=2074

D. Profile of Key Products

Fuels

First generation biofuels produced from food crops (such as corn and other grains), sugar cane, and oilseeds have utilized well known technologies to produce liquid fuel products generally compatible with existing mature markets, namely **ethanol** and **biodiesel** (fatty acid methyl ester or FAME). After much analysis, it is generally accepted that these products afford net benefits in terms of GHG emission reduction and energy balance relative to petroleum-based fuels. However, R&D and commercial focus has now shifted toward development and commercialization of more sustainable second generation biofuels which can be produced from non-food feedstocks and achieve more substantial environmental benefits. DOE has defined such "Advanced Biofuels" as fuels derived from renewable biomass other than corn kernel starch, including: sugar, starch (other than ethanol derived from corn kernel starch), cellulose, hemicellulose, and lignin, among other materials.

The U.S. renewable fuel industry to date has produced primarily first generation biofuels—starch-based ethanol and biodiesel. Over the past eight years, biofuel production has grown both in absolute terms and as a percentage of gasoline and diesel fuel consumed. Until recently, high oil prices, firm government support, growing environmental and energy security concerns, and the availability of relatively low-cost corn (starch) and soybean (oil) feedstocks provided favorable market conditions for these biofuels. However, current market prices for petroleum-based fuels, as well as feedstock costs, now present a very challenging environment for first generation biofuel producers. Producers with multiple product lines and early entrants who retired significant debt during the boom cycle of 2005–06 may still be profitable in this environment, but bankruptcy and idle capacity are plaguing many businesses solely dependent upon biofuels.

Ethanol: Ethanol is a 2-carbon alcohol produced by mature yeast fermentation technologies, using either sugar or starch feedstocks. Sugars obtained from sugar cane, sweet sorghum, or sugar beets are more easily converted to ethanol than starch, being readily fermented by yeast without pre-processing. Brazil has developed a mature ethanol industry based upon sugarcane, but ethanol production from sugar crops in the United States has been limited. In 2007, 7.6 billion gallons of ethanol were made in the U.S., more than 98% from corn.[58] Ethanol can be blended with gasoline in concentrations up to 10% as an oxygenate. Oxygenates are oxygen-containing compounds such as alcohols and ethers which improve combustion and thereby reduce automotive carbon monoxide emissions. EPA regulations mandate oxygenate blending in many areas of the country to reduce smog and other airborne pollutants. Ethanol has become the primary compound of choice for oxygenate blending, replacing MTBE (methyl tertiary butyl ether) which poses groundwater contamination issues from leaks and spills. Ethanol can also be blended with gasoline at higher concentrations, up to 85 percent ethanol, for use in Flex Fuel Vehicles (FFVs). Nearly half of the gasoline sold in the United States today is a 10 percent blend of ethanol. [59] Since 142 billion gallons of gasoline were consumed in the United States in 2007, the potential oxygenate blend market (or E10) is approximately 14 billion gallons. Current production levels are expected to approach 12 billion gallons by the end of 2009, so this 'blend wall' is being approached. Current studies are being conducted by the EPA to determine if higher blend levels can be approved for unmodified gasoline engines, which could create additional ethanol demand through the existing fuel distribution network.

Biodiesel: Biodiesel (also referred to as FAME for "fatty acid methyl ester") is produced from vegetable oils and animal fats (lipids) by reaction with an alcohol, typically methanol, and a base catalyst, through a relatively simple chemical reaction known as transesterification.

[58] EIA (2007). Biofuels in US Transportation Sector. Available at http://www.eia.doe.gov/oiaf/analysispaper/biomass.html
[59] Hunt, Suzanne. Biofuels, Neither Savior Nor Scam. *World Policy Journal*, Spring 2008, pp 9-17.

Approximately 1 pound of co-product glycerin is produced for every gallon of biodiesel. Pure biodiesel is designated as B100 (100% biodiesel) and can be burned in unmodified diesel engines; however, lower blends with petrodiesel in the range of B5 (5% biodiesel) to B20 (20% biodiesel) are most common. While the transesterification chemical reaction is straightforward, commercial production of fuel grade biodiesel that meets the 20 quality parameters of ASTM D6751 revision 08 can be challenging, especially using lower quality feedstocks. Cold weather operability ("cold flow") is a key issue and is affected by the residual glycerin and glyceride levels, the fatty acid profile of the oil/fat feedstock, and other feedstock impurities. Biodiesel produced from soy or canola/rapeseed oil generally exhibits enhanced cold flow properties, and often commands a higher price than animal fat biodiesel. With the growth of the worldwide biodiesel industry, oil and fat prices have become highly correlated with crude oil prices, as feedstock cost comprises 70–75% of biodiesel production cost. A key issue for growth of biodiesel as an alternative fuel is feedstock supply. The total available U.S. supply of plant oils and animal fats is approximately 5.1MM gpy, which would equate to about 10% of U.S. diesel demand.[60] [61] However, most of this supply is committed to higher value food and oleochemical applications and will not be diverted to biofuel production.

Competing technologies have emerged for production of biobased hydrocarbon fuels from oil and fat feedstocks. A recent report by the California Environmental Protection Agency has provided a comprehensive profile of these technologies.[62] Referred to as hydrogenation-derived renewable diesel (HDRD) and Fatty Acid to Hydrocarbon (FAHC-Hydrotreatment), these processes use existing petroleum refining hydrotreatment processes to convert triglycerides to so-called "renewable" diesel—a hydrocarbon, not an ester mixture—essentially identical to petroleum-based diesel. Renewable diesel from these processes has better cold weather characteristics than FAME biodiesel and glycerol is not produced as a side-product. A number of firms, including ConocoPhillips, UOP, and Petrobras, have demonstrated the technology at existing petroleum refineries. In the U.S., Syntroleum and Tyson have formed Dynamic Fuels LLC, a partnership which is building a 75 MM gpy facility in Geismer, LA to produce renewable diesel and jet fuel, using animal fat feedstock.[63] Neste Oil has announced plans to build Europe's largest renewable diesel plant in Rotterdam, NL, using plant oil and animal fats.[64] Renewable diesel production facilities will likely be larger than FAME biodiesel facilities in order to achieve production scale benefits from the more complex process technology.

Butanol: Butanol is a 4-carbon alcohol widely used as an industrial solvent and intermediate, produced primarily from fossil feedstocks by the oxo process, comprising hydroformylation of propylene with synthesis gas. Prior to development of this lower-cost petrochemical synthetic route, biobutanol was produced by bacterial fermentation of sugars using the ABE process, which yielded a mixture of acetone, butanol, and ethanol. Only a few plants, mostly in China, currently practice the ABE process, which is plagued by low productivity and high cost for separation of the co-products. As a second generation biofuel, butanol has several advantages over ethanol, including higher energy density, lower vapor pressure, and it is less hydrophilic (water-seeking) making it potentially suitable for transport in pipelines. Technology efforts are primarily focused on the biochemical platform, with several companies and academic research programs actively

[60] NREL Technical Report (2004). *Biomass Oil* Analysis*: Research Needs and Recommendations.* Available at http://www.osti.gov/bridge
[61] Bozell, Joseph J. 2006. *Oleochemicals in the Biorefinery,* Growing the Bioeconomy Conference, Iowa State University. Retrieved from www.bioeconomyconference.org/images/Bozell,%20Joe.pdf.
[62] California Environmental Protection Agency, Air Resources Board (2009). *Proposed Regulation to Implement the Low Carbon Fuel Standard, Volume II Appendices.* Available at www.arb.ca.gov/fuels/lcfs/030409lcfs_isor_vol2.pdf
[63] Schill, Susanne. *Biomass Magazine*, July 2008.
[64] www.renewableenergyworld.com, May 27, 2009

pursuing enhanced bacterial organisms to improve the fermentation process productivity, selectivity, and cost.

Butanol used in chemical applications generally commands a price premium compared with fuel products, and would therefore be the initial market for a biobased substitute. Total U.S. and European capacity for petrochemical butanol is reported to be in excess of 2.1MM tons/year, with stable or slightly growing demand.[65] Technology and process optimization, coupled with fossil feedstock pricing, could result in competitively priced biobutanol as a second generation fuel. Based upon anticipated process similarities, much of the infrastructure at ethanol fermentation facilities may be adaptable to produce biobutanol.

Biobutanol blends of up to 11.5% with gasoline can currently be sold in the U.S. under a special waiver of Clean Air Act rules granted by the Environmental Protection Agency, under the presumption that the blend is similar to a 10% ethanol blend. However, mixtures with a higher butanol blend ratio would require additional testing and registration with EPA.[66]

Renewable gasoline, diesel, and jet fuels: Gasoline, diesel, and aviation fuels derived from petroleum are predominantly mixtures of hydrocarbons, containing many straight-chain, branched, and cyclic alkanes (paraffins); alkenes (olefins); aromatics such as benzene and toluene; and other compounds and contaminants. The refining process isolates mixtures that differ in the range of carbon compound chain length and composition, which define the boiling range, energy content, and other properties of the final fuel. Petroleum refining typically produces gasoline with a C-5 to C-12 carbon chain range; jet fuel in the intermediate C-9 to C-16 range; and diesel at the highest liquid range of about C-10 to C-20. Mixtures containing carbon chain lengths above C-20 are generally waxy materials.

Second generation biofuels, particularly those produced by some thermochemical processes, are typically mixtures of many chemical compounds. Since lignocellulosic feedstocks contain a much higher proportion of oxygenated compounds than petroleum, these biomass-to-liquids (BTL) technologies must often be designed to reduce the oxygen composition of the resulting product mixtures. The pyrolysis and syngas-Fischer Tropsch technologies are capable of producing longer-chain hydrocarbon and oxygenated compounds, often requiring downstream reforming and refining. The resulting mixtures may be particularly suitable for diesel and aviation fuels, but can differ compositionally from the petroleum-derived fuels and require testing and qualification for the designated end-use. In addition to product acceptance, the current early-stage BTL projects must demonstrate reliable gasification of biomass and production of consistent downstream fuel products.

Chemicals

Despite prominent federal programs to promote biofuels, there are significant opportunities to produce higher-value chemicals from biomass feedstocks. New organisms offer the potential for selective biochemical transformation of the highly-functionalized cellulose and hemicellulose-derived sugars to a range of multi-functional chemical intermediates, with higher value than commodity fuels. These C-3 through C-6 chemicals form the basis for a new biobased platform of chemical building blocks, which coupled with aromatics derived from lignin, has the ultimate potential to fully replace petrochemical intermediates. Technology development and deployment is at an early stage, but is accelerating rapidly as strategic partnerships are forming to assemble the complementary competencies necessary to achieve commercial success.

[65] *ICIS Chemical Business*, March 9, 2009, pp 37
[66] *Kiplingers Biofuels Market Alert*, Vol. 1, No. 1; July 2007

Sugar-derived Chemicals: Two comprehensive reports have detailed the potential to produce biobased chemicals: the "Top Value-Added Chemicals Report" produced by NREL and the Pacific Northwest National Laboratory for the Department of Energy;[67] and the "BREW Project Report" produced by a collaboration of academic and private-sector partners for the European Commission's GROWTH Programme.[68] Both reports have documented the potential to produce important platform or building block chemicals from biochemical and chemical processing, to replace current petrochemical products.

The DOE report identifies 12 Target "Building Block" chemicals accessible from sugars (with the exception of glycerol, a biodiesel co-product) through biochemical technologies, as well as a comprehensive range of derivatives which may be produced from these platform intermediates. Building Block chemicals are defined as molecules containing multiple functional groups which allow them to be transformed into downstream families of chemical intermediates. Active R&D and commercialization efforts have been announced for several of these platform chemicals and their derivatives, as well as a limited number of other commodity chemicals. Technology developers for these early biobased chemical products are summarized in Table 15. Four of the DOE report building block chemicals—succinic acid, levulinic acid, itaconic acid, and 3-hydroxypropionic acid—are not readily available from petrochemical processing and may be preferred strategic targets for early commercialization, as they will not compete directly with petrochemical analogs and could offer enhanced product properties over conventionally available materials.

Table 15: Key Chemicals Technology Developers

Chemical	Feedstock	Developer	Status
1,3-Propanediol (PDO)	Sugars	DuPont/Tate&Lyle	Commercial plant-Tennessee
Propylene glycol	Glycerol	Dow, Cargill, ADM, Huntsman	Commercial plants
Epichlorohydrin	Glycerol	Solvay, Dow	Commercial plants-France, Thailand
Succinic Acid	Sugars	Diversified Natural Products (DNP)	Demo plant-France
Levulinic Acid	Cellulosics	Biofine, NREL	Pilot plant-New York
Ethylene	Ethanol	Braskem SA, Dow	Commercial plants announced
3-Hydroxypropionic Acid	Sugars	Cargill/Codexis	R&D
Acrylic Acid	3-HPA	Cargill/Novozymes	R&D

The BREW Report identifies 4 factors which will affect the commercialization of biobased chemicals:

- Substantial technological breakthroughs in the bioprocessing step
- Major progress in downstream processing
- High fossil fuel prices
- Low fermentable sugar prices

Lignin-derived Chemicals: The DOE Lignin Report, prepared by Pacific Northwest National Laboratory, describes the potential to use lignin as a renewable feedstock in three categories: fuel

[67] DOE (2004). *Top Value Added Chemicals from Biomass; Volume 1 – Results of Screening for Potential Candidates from Sugars and Synthesis Gas.* Available at www1.eere.energy.gov/biomass/pdfs/35523.pdf
[68] European Commission GROWTH Programme (2006). The BREW Project: *Medium and Long-term Opportunities and Risks of the Biotechnological Production of Bulk Chemicals from Renewable Resources. Available at www.chem.uu.nl/brew/BREW_Final_Report_September_2006.pdf*

or syngas feedstock; macromolecules; and aromatics & monomers.[69] The first category encompasses the lowest-value, and primary current use of lignin, as a carbon source for fuel. Gasification, rather than combustion, affords the potential to produce higher-value fuels and chemicals from syngas processing.

The other two categories recognize the potential to produce higher-value functionalized aromatic polymer and chemical products from lignin, which could displace petroleum-based products. Historically, most commercial lignin products have been by-products of the pulp and paper industry, and are generally sulfonated, high ash content, and/or contain impurities such as sodium, which derive from the pulping process. These traditional lignosulfonates have found only niche market applications, while most pulp and paper lignin by-product in the "black liquor" is combusted for fuel value to generate process energy. Purified and functionalized lignin macromolecules and de-constructed lignin-derived aromatics will be accessible as new supplies and forms of lignin become available from emerging lignocellulosic biorefineries, especially those employing fractionation technologies. Due to enhanced solubility, solvent-based fractionation processes are particularly effective in extracting lignin. So-called organosolv pulping processes have been developed, but not widely commercialized, to separate wood components using organic solvents.

Initial lignin biorefinery products will likely be partially depolymerized lignin macromolecules, rather than purified chemical compounds. These materials will not be direct petrochemical materials analogs, but rather new—and potentially cost advantaged—compositions to develop novel products and formulations. Lignol Innovations, Inc. is developing the Allcel solvent fractionation process, and has announced a line of high-purity ("HP-L") lower molecular weight lignin macromolecules.[70] Pure Power Global Limited is also developing a commercial solvent-based fractionation process.[71]

The domestic aromatic chemical supply chain comprises approximately 45 billion pounds annually of chemical intermediates.[72] With its functionalized aromatic polymer structure, lignin contains monomeric components which could serve as building blocks to eventually displace most, or all, of the petrochemical aromatic intermediates. However, technologies must still be developed to deconstruct lignin's polymeric structure, and convert the resulting components to usable chemical intermediates, considered to be a longer-term objective by the DOE report.

Polymers

Fossil-based polymers and plastics are typically inexpensive, durable, and can be manufactured to exhibit a broad range of properties. They are ubiquitous to modern life and find application across many market segments, where performance and permanence is required. As specialty products, polymers generally command a price premium compared to commodity fuels and chemicals, so it is not surprising that several new biobased polymers have found early commercial acceptance, as profiled below.

Polylactic acid (PLA): In 2002, a joint venture of Cargill and The Dow Chemical Company began production of polylactide polymer at a 140,000 metric ton plant in Blair, Nebraska. In 2005, Cargill acquired Dow's interest and renamed the venture NatureWorks LLC, which

[69] DOE (2007). *Top Value-Added Chemicals from Biomass; Volume II – Results of Screening for Potential Candidates from Biorefinery Lignin.* Retrieved from www1.eere.energy.gov/biomass/pdfs/pnnl-16983.pdf.
[70] www.lignol.ca/
[71] Private communications to BioDimensions Inc.
[72] DOE (2007). *Top Value-Added Chemicals from Biomass; Volume II – Results of Screening for Potential Candidates from Biorefinery Lignin.* Retrieved from www1.eere.energy.gov/biomass/pdfs/pnnl-16983.pdf.

subsequently formed a new 50/50 partnership with Teijin Limited of Japan in 2007.[73] PLA is produced by fermentation of plant-based sugars to lactic acid, which is subsequently polymerized to polylactic acid (also known as polylactide). NatureWorks uses corn grain as the glucose source for PLA production, but is also developing organisms to convert pentose sugars, derivable from lignocelluloses, into PLA.[74]

Polyhydroxyalkanoates (PHAs): PHAs are polyesters produced naturally by bacteria from sugars or fats, to store carbon and energy in their cells. Since the 1970's a number of companies have pursued industrial processes to optimize conditions for polymer growth and the subsequent extraction and purification of PHA polyesters. PHAs are thermoplastic resins that can be produced with a broad range of properties and are biodegradable, making them suitable for a large range of applications. In 2007, Metabolix and Archer Daniels Midland Company formed a joint venture to commercialize Mirel™ branded PHAs. A 110 million pound annual capacity production facility under construction adjacent to ADM's wet corn mill in Clinton, Iowa is scheduled for start-up in 2009.[75]

A potentially lower-cost route to PHAs is genetic modification of plants to directly produce PHA polymers. In collaborative work cofunded by the US Department of Energy (DOE), Metabolix is pursuing genetic modification of switchgrass to allow it to produce PHAs, which would then be extracted from the plant material and processed to obtain desired material properties. The residual plant material remaining after the PHA extraction could be used to produce fuels, power, or other products.[76]

Polytrimethylene terephthalate (PTT): In 2004, DuPont and Tate & Lyle formed a joint venture to produce biobased 1, 3-propanediol (PDO) from corn using a fermentation process that was developed in collaboration with Genencor. Start-up of a 100m lbs/year Bio-PDO™ facility using corn sugar feedstock at the Tate & Lyle wet milling site in Loudon, Tennessee followed in 2006. PDO can be reacted as a monomer with terephthalic acid to produce polytrimethylene terephthalate, a polymer with unique properties. Use of biobased PDO results in a polymer identical to fossil-based products, but containing over 30% renewable content, which DuPont has branded as Sorona.™ Bio-PDO is also marketed as an industrial solvent and intermediate into numerous market applications.[77]

Natural Oil Polyol (NOP) plastics: Vegetable oils such as soybean oil can be chemically modified to introduce multiple hydroxyl groups, resulting in natural oil polyols. These can serve as reactants to produce polymers, the most significant of which is polyurethane. Urethane polymers are used in various market segments such as construction, transportation, carpet, and coatings. Several companies have commercialized biobased polyols, including Cargill, under the BiOH™ brand; Urethane Soy Systems of Volga, SD; and BioBased Technologies of Rogers, AR.[78]

Biobased Polyethylene (PE): Polyethylene, produced by polymerization of fossil-based ethylene, is a commodity polymer which is manufactured with a wide range of physical properties for diverse end-use applications including packaging, bottles, and pipes. Over 60MM tons/year are produced globally. In 2007, Braskem SA, Latin America's largest petrochemical company announced plans to build a 200,000 ton PE facility in Brazil, utilizing ethylene

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[73] www.natureworksllc.com
[74] *Carole,T. M. et al.* Opportunities in the Industrial Biobased Products Industry*, Applied Biochemistry and Biotechnology, Vol.113-116, 2004*
[75] www.mirelplastics.com
[76] *Carole,T. M. et al.* Opportunities in the Industrial Biobased Products Industry*, Applied Biochemistry and Biotechnology, Vol.113-116, 2004*
[77] www.duponttateandlyle.com
[78] www.unitedsoybean.com/UploadFiles/Library/pdf_%2025241M%20Plastics.pdf

produced from sugar-derived ethanol.[79] This was followed by announcement of a joint venture between Dow Chemical Company and Brazilian ethanol producer Crystalsev to construct a 350,000 ton PE facility in Brazil, also using biobased ethylene.[80] Bioethylene is produced by catalytic dehydration of ethanol, and the resulting PE has the same properties and performance as fossil-based polyethylene, because the ethylene monomer molecules are identical. In its announcement, Dow has commented that Biobased PE project economics will be competitive with hydrocarbon-based projects, but is dependent upon low-cost sugar-derived ethanol feedstocks.

Materials

While recent R&D attention has focused on chemical conversion or functionalization of biobased feedstocks to develop an ever-broadening range of downstream products, a limited but significant group of products is available by applying only physical or purification processes to biobased feedstocks. Historically, the production of natural fiber, notably cotton in the Delta region, has been economically significant. Other fiber products, for example those derived from Kenaf, are also finding new commercial applications as structural component materials, insulation materials, and absorbents.

Products based upon chemically unmodified natural oils are also important in some applications, especially environmentally sensitive uses, where biobased content, biodegradability and/or low-toxicity are desired. Such vegetable oil based products have been developed for diverse markets, including lubricants, greases, plasticizers, emulsifiers, crosslinkers, and cosmetics. In particular, vegetable oil lubricants compete with mineral-based oils in a number of application areas. The United Soybean Board has developed a Market Opportunity reports which summarize soy-based lubricant and surfactant opportunities.[81] [82] The lubricant report describes vegetable oil lubricant advantages as enhanced lubricity, lower evaporation loss, and higher viscosity index, while noting performance limitations such as thermal, oxidative, and hydrolytic stability. Performance issues can be addressed by chemical modification of the feedstock oils—most commonly hydrogenation—or by formulation with additives and stabilizers. However, recent R&D efforts have also focused on development of enhanced oil output traits in several crops to provide improved feedstock chemical composition, such as high oleic acid sunflowers and soybeans and high erucic acid rapeseed. Continued genetic modification of oilseed crops to produce specific fatty acid profiles and specific levels of fatty acid unsaturation promises to produce a new generation of specialty oilseed products, specifically tailored to the downstream application.[83] [84] Many of these specialty oilseed crops may be particularly suited for cultivation and processing in the Delta region.

Regional Bioprocessing

The strategy region includes a number of companies operating in the established pulp and paper, olechemicals, and fiber (cotton) processing industries. Despite centralization of significant oilseed crushing capacity outside the region, there are still several regional facilities in operation, including smaller mechanical crushers which could process new oilseed crops. Within the past five years, the biodiesel industry has grown to at least 11 regional operations, although many of these are not currently

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[79] www.braskem.com.br/
[80] Rocha, Euan. Update 3 – Dow Chemical in tie-up with Brazil's Crystalsev. *Reuters*, July 19, 2007.
[81] USB (2006). Market Opportunity Study: Soy-Based Lubricants. Available at www.unitedsoybeam.org/FileDownload
[82] USB (2009). Market Opportunity Study: Surfactants. Available at www.soynewuses.org/downloads/Surfactants%20MOS%20Jan%202009.pdf
[83] Bergstra, Ray. February 2007. *Emerging Opportunities for Natural Oil Based Chemicals*. Plant Bio-Industrial Workshop, Saskatoon, Canada. Retrieved from www.mtnconsulting.ca/Oleochem%20Final%20rjbergstra.pdf
[84] Schmidt, Monica et al 2006. Biotechnological Enhancement of Soybean Oil for Lubricant Applications. In *Synthetics, Mineral Oils, and Bio-Based Lubricants: Chemistry and Technology*, CRC Press

operating, due to unfavorable economics. There are also several specialty bioprocessing facilities and a growing number of projects seeking to demonstrate new technologies. Table 16 summarizes regional bioprocessing businesses and projects that have been identified by the project team.

Table 16: Regional Bioprocessing Businesses and Projects (non-food)

Business/Industry	Description/Project	Location	Feedstock	Comments
Pulp and Paper	Multiple companies	Various	Wood	Established industry
The Price Companies	Feedstock supplier	Monticello, AR	Lignocellulosics	Established company
PMC Biogenix	Oleochemicals	Memphis, TN	Oils	Established company
Buckeye Technologies	Specialty cellulosics	Memphis, TN	Cotton Linters	Established company
Oilseed crushers	5 Solvent; 3 mechanical*	Various	Soybeans	Established industry
Ethanol Grain Processors	Ethanol	Obion, TN	Corn	New industry
Bluegrass Bioenergy, LLC	Ethanol	Fulton County, KY	Corn	Initiated construction
Fiber Resources, Inc	Pellets	Pine Bluff, AR	Wood	New industry
Biodiesel	FAME Biodiesel	11 Locations*	Oils, fats	New industry
Kengro Corporation	Fibers and absorbents	Charleston, MS	Kenaf	New industry
Four Rivers BioEnergy	Biodiesel	Calvert City, KY	NA	Announced
Enerkem Inc.	Ethanol – gasification	Pontotoc, MS	Municipal waste	Announced
Colusa Biomass Inc.	Silica, ethanol	Stuttgart, AR	Rice hulls	Announced
Burton's Sugar Farm	On-farm ethanol	Michigan City, MS	Sweet sorghum	Under development
DSSE, LLC	Ethanol	Lake Village, AR	Sweet sorghum	USDA VAPG Feasibility Study
Sorzoom	Ethanol	Piggott, AR	Sweet sorghum	Business Plan
PurePower	Lignin, ethanol, other	TBD	Wood (fractionation)	Exploring regional facility
International Silica Technologies, LLC	Silica, process heat	TBD	Rice hulls	Assessing sites
Infinite Enzymes, LLC	Corn-based enzymes	TBD	Corn	Under development
Associated Physics	Biomass gasification	Greenwood, MS	Lignocellulosic biomass	Equipment/technology

*Source: Regional Strategy Sub-Report "West Tennessee Oilseed Diversification Project," Frazier Barnes & Associates, March 2009. Some facilities may not be in operation.

Observations and Conclusions

The Mid-South Mississippi Delta region currently produces crop and forestry biomass comprising all four feedstock components—oils, sugars, starches, and lignocellulose. Decentralized rural biorefineries will utilize the described technologies for the conversion of locally-sourced biomass feedstocks to advanced biofuels and value-added chemicals. Early commercial demonstration projects, and ongoing technology development, will continue to clarify the preferred technologies and products for rural, as well as centralized biorefineries. Nevertheless, some general observations can be made, based upon the current state of technology, and applicability to rural biorefineries in the Mid-South Delta region, as follows:

- Despite significant progress in recent years to advance the technologies necessary to produce second generation biofuels, the leading technologies are just reaching the commercial demonstration stage. These early demonstration projects carry significant commercial risk, as they generally seek to validate and optimize new technologies and processes. The International Energy Agency concludes that large-scale demonstration projects will provide the needed comparative data to determine the "best technology pathway" between the thermochemical and biochemical lignocellulosic conversion routes.

- Little biomass conversion technology is being innovated in the Mid-South Delta region; however, technology providers are pursuing business strategies to implement, or make technologies available, to biomass-rich regions such as the Mid-South Delta.
- The production of higher-value *chemical products* with fuel and power output could significantly enhance biorefinery economics; however, this will increase facility complexity and technical support requirements, and may be most appropriate for larger centralized, rather than rural, facilities.
- Oil-based products and opportunities—particularly for lower-value fuels—will be constrained by availability of appropriately priced feedstocks. Production of higher-value chemical products from oils, including genetically-modified specialty oils, will be limited by the lack of regional oilseed crushing capacity. Algae oils represent the most significant opportunity for a fundamental shift in plant oil supply, but are still at an early developmental stage.
- Lignocellulosic feedstock storage stability will be a significant factor in both crop and processing technology selection. Thermochemical processing can potentially use a range of feedstocks (assuming effective gas purification) including decomposed materials. Biochemical processing will require relatively pristine feedstocks of consistent composition.
- Thermochemical processing of lignocellulosic feedstocks is best-suited to produce renewable *fuel products*, both shorter-chain alcohols such as ethanol and methanol, as well as longer-chain hydrocarbon mixtures from Fisher-Tropsch and other downstream catalytic reforming. Unfortunately, gasification technologies have historically depended upon economics of scale, which may not be well-suited to early rural decentralized biorefineries due to capital, scale, and feedstock proximity. Several technology providers are attempting to demonstrate viable smaller-scale gasification processes that would be amenable to rural biorefineries, but these technologies remain to be commercially proven.
- Biochemical processing of sugars is best-suited to produce *fuel alcohols* and also *multi-functional chemicals*. Fermentation infrastructure requirements favor rural biorefineries, whose more limited technology capabilities may be best focused on a limited portfolio of fuel and energy products, rather than chemicals. Lignocellulosic fractionation technologies would provide the opportunity to produce value-added lignin products.
- Traditional chemical processing of biomass, rather than fossil-derived feedstocks, is receiving renewed R&D attention, leading to new commercial biobased products. Oilseed crops with enhanced or specialty output traits—such as high oleic, erucic, or ricenoleic acid—are particularly interesting, as is the creation of higher value chemical intermediates from bioprocessing co-products, such as glycerol.

IV. Regional Supply & Demand for Biobased Products

A. Introduction: From Feedstocks to Products to Markets

Biomass is useable in multiple forms. In first-generation biofuels, starches and sugars have been converted via fermentation into alcohols (most frequently ethanol) for use as liquid fuels in transportation and other applications. Another first generation biofuel, biodiesel, is predominately produced using plant oils and animal fats—again resulting in a liquid fuel used in transportation applications. Biomass is also used directly in minimal processed form in direct combustion or for co-firing with fossil fuel resources to generate heat and electricity. To a lesser degree biomass has also been used in the production of biogas (mostly via anaerobic digestion of waste organic materials such as livestock manure and mixed municipal waste) and syngas (synthesis gas), a versatile gas comprised of carbon monoxide and hydrogen that may be used directly as a combustion fuel or further refined into other useful chemicals such as methanol, synthetic diesel and hydrogen. With current technology biomass is already being used in the production of liquid fuels, gaseous fuels and solid fuels for transportation, electricity generation and direct heat generation applications—plus it is being used in the generation of intermediates used in the specialty chemicals industry. In addition, biomass has a direct use as plant fibers in various materials applications.

There are multiple issues associated with first-generation applications of biomass. The starches and sugars used in ethanol production are derived from crops that are also used for food and feed. Competition for their use in fuels versus foods has resulted in significant price volatility. Likewise, oilseed crops used to derive biodiesel also have food and feed applications and are subject to the same issues as starches and sugars. Biogas, which is primarily methane, is a potent greenhouse gas, and thus has significant environmental issues attached to it. Syngas is a versatile material but expensive to produce with current technologies. Direct combustion of biomass is basic technology, but a comparatively inefficient use of biomass which may have a higher and better use in the future.

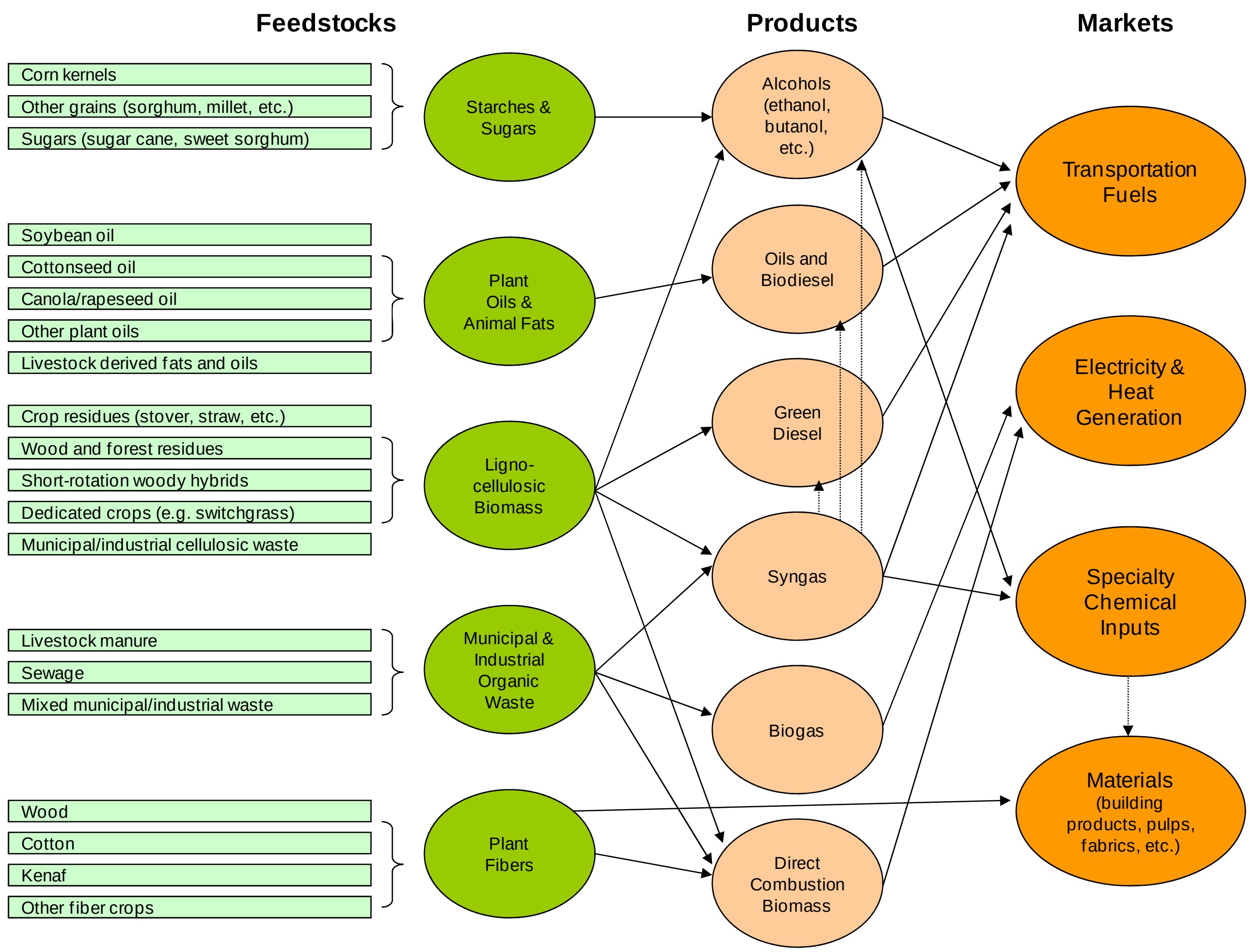
On the horizon is the promise of second-generation biofuels, most notably in the form of fuels derived from lignocellulosic biomass (crop residues and woody biomass predominantly). The use of lignocellulosic biomass, which is unusable as a food product (although it does have some livestock feed value) provides access to a resource that should have less price volatility. Furthermore, projections by the National Renewable Energy Laboratory show that cellulosic biofuels will have high net energy efficiency values and require relatively minor fossil fuel resources in their production (when compared to other energy sources such as gasoline, coal, or starch/sugar based ethanol). Lignocellulosic processing technology development is a key to unlocking a much higher and better use of currently underutilized biomass and offers the potential to spur significant biobased economic development.

It is evident that both current and future technologies will be used in four primary applications: liquid fuels; electricity and heat generation; intermediate chemicals and specialty chemicals, and biobased materials. The biobased products feeding into these four primary applications will be:

- Alcohols
- Oils (vegetable oil and biodiesel)
- Syngas products (including green diesel)
- Biogas
- Direct combustion of solid biomass material
- Fiber.

In many instances the actual products can be derived along multiple current and developing biomass pathways. Figure 18 provides an illustration of some of the potential pathways and the complexity of the biomass to market equation.

Figure 18: Process Flow of Biomass Feedstocks to Biobased Products to Market Applications



It should be noted at the outset that the question is not "will biobased products be used in the market" but rather "what volume of biobased products will replace competing products from non-biobased sources." Each of the four macro markets shown in Figure 18 already see a portion of that market supplied by biobased products:

- Transportation Fuels → Currently nominally penetrated by ethanol and biodiesel.
- Electricity and Heat generation → Multiple facilities using wood and residual organic matter in the firing or co-firing of boilers.
- Specialty Chemical Inputs → There is an established base of oleochemical manufacturers, and synthesis gas products and alcohols are being used in chemical manufacturing processes.
- Materials → Large scale industries exist within which major feedstocks are biobased, including the lumber industry, paper industry and textiles industry. Additional opportunities are growing in the use of biobased chemicals for the production of industrial materials such as plastics, resins and composite materials.

If a biobased input can compete successfully on price, availability and quality with a non-biobased input, the market has already shown it may adopt it. Given growing environmental pressures, carbon caps, emerging consumer preference for green products, etc., other considerations come into play that will favor the adoption of biobased products in the marketplace.

B. The Mid-South Mississippi Delta Regional Market

Covering 98 counties, the Mid-South Mississippi Delta region contains 3,659,000 people—representing 1.2% of the total U.S. population. Containing both urban and rural populations, a broad range of industries, and significant economic activity, the region constitutes a substantial market in its own right.

While some data are available on a county-by-county basis from existing statistical sources, certain data on energy demand and associated consumption data need to be extrapolated based on national consumption statistics (using the assumption that average use of resources would be proportionate to the population size of the Mid-South Mississippi Delta region).

From an oil and energy consumption perspective, national demand in the U.S. is extremely large. The nation annually consumes 7.55 billion barrels of oil, 653 billion cubic meters of natural gas and 3.9 trillion kilowatt hours of electricity. On a proportionate basis, the Mid-South Mississippi Delta region, containing 1.2% of the U.S. population will likely consume oil, natural gas and electricity at the levels shown in Table 17—constituting an estimated consumption of 91.6 million barrels of oil per year, 7.9 billion cubic meters of natural gas and 47.2 billion Kwh of electricity.

With 71.4% of electricity generated in the U.S. coming from fossil fuels and oil and natural gas being derived from fossil resources, the vast majority of energy resources being consumed in the U.S. and in the Mid-South Mississippi Delta are fossil fuel-based.

Table 17: Study Area Extrapolated Energy Demand

Study Area Counties	Population of Study Area Counties	Percent of U.S. Population (Census 2007 Estimate = 301,621,157)	Oil Consumption National = 7.548 billion barrels/yr.	Natural Gas Consumption National = 652.9 billion cubic meters/yr.	Electricity Consumption National = 3.892 trillion Kwh/yr.
Arkansas (30)	842,301	0.28%	21,078,389	1,823,275,026	10,868,718,642
Kentucky (8)	163,425	0.05%	4,089,673	353,755,630	2,108,771,501
Missouri (11)	304,236	0.10%	7,613,436	658,560,183	3,925,740,899
Mississippi (28)	851,331	0.28%	21,304,362	1,842,821,689	10,985,238,187
Tennessee (21)	1,497,373	0.50%	37,471,415	3,241,267,428	19,321,508,391
Total (98)	**3,658,666**	**1.21%**	**91,557,274**	**7,919,679,956**	**47,209,977,621**
			91.56 million barrels/year	**7.92 billion cubic meters/year**	**47.2 billion Kwh/year**

Data source: https://www.cia.gov/library/publications/the-world-factbook/print/us.ht

Liquid Fuels

When considering the markets for biobased fuels one of the key applications will be in liquid transportation fuels—primarily biobased substitutes for gasoline and diesel fuels. First-generation biofuels predominantly in the form of ethanol from grains, and biodiesel from oilseeds and animal fats, have already penetrated the marketplace in a limited fashion. Into the future, second generation fuels, especially those based on the conversion of lignocellulosic biomass feedstocks, hold significant potential for replacing substantial fossil-fuel based liquid fuel volumes.

Locally grown biomass provides the opportunity to feed locally-based biofuel production operations. In turn, these local biofuel production facilities can avoid significant costs in shipping their output if much of their product can be absorbed in the local liquid fuels marketplace.

The market for liquid transportation fuels within the Mid-South Mississippi Delta is significant. Just in terms of highway registered motor vehicles (passenger cars, motorcycles, trucks and buses) the region contains over three million vehicles[85]. These vehicles, operating on either gasoline or diesel fuels require significant fuel resources. Based on Energy Information Administration published data, it is projected that the 98-county region will have the level of fuel demand shown in Table 18. This table provides estimates of gasoline demand and diesel fuel demands in on-highway and off-highway applications.

Table 18: Study Area Gasoline Demand

Study Area Counties	Population of Study Area Counties	Percent of U.S. Population (Census 2007 Estimate = 301,621,157)	Estimated Gasoline Consumption (national = 9,286,000 barrels/day)	Estimated Gasoline Consumption (gallons/day)
Arkansas (30)	842,301	0.28%	25,932	1,089,139
Kentucky (8)	163,425	0.05%	5,031	211,317
Missouri (11)	304,236	0.10%	9,367	393,393
Mississippi (28)	851,331	0.28%	26,210	1,100,816
Tennessee (21)	1,497,373	0.50%	46,100	1,936,182
Total (98)	**3,658,666**	**1.21%**	**112,639**	**4,730,847**

Source: Energy Information Administration

The 98-county study region has an estimated annual gasoline consumption of 1,726,759,274 gallons or 4,730,847 gallons per day.

The region has an estimated annual gasoline demand of almost 1.73 billion gallons. This is equivalent to 472 gallons per person.

[85] U.S. Department of Transportation data show that there are 250,851,833 Registered Highway Vehicles in the U.S. (http://www.bts.gov/publications/national_transportation_statistics/pdf/entire.pdf). With 1.21% of national population the Mid-South Mississippi Delta should contain circa 3,042,834 vehicles on an extrapolated basis.

In terms of on-highway diesel fuel the region uses an estimated annual total of 482,795,335 gallons equivalent to a daily demand for 1,322,727 gallons.

Off-highway diesel fuel is used in applications such as farming and construction. The Mid-South Mississippi Delta region uses an estimated annual total of 30,475,351 gallons which equates to 83,494 gallons per day.

The region has an estimated annual on-highway diesel fuel demand of almost 483 million gallons.
The region has an estimated annual off-highway diesel fuel demand of 30.5 million gallons.

Taken together the on-highway and off-highway transportation demand for diesel fuel in the Mid-South Mississippi Delta region equals 513.5 million gallons per year.

There are, of course, other applications to liquid fuels beyond the fueling of wheeled transportation vehicles. While the overwhelming majority of gasoline is used in vehicle fueling applications, distillate fuel oils (which includes diesel) and kerosene are used in more varied transportation and non-transportation (energy and heat generation functions).

Overall the region has the following estimated annual demand totals for petroleum products:

- Total for All Petroleum Products = 3,836,065,372 gallons (3.84 billion gallons)
    - Natural Gas Liquids and LRG's = 406,475,131 gallons (406.5 million gallons), the majority of which comprises Liquified Petroleum Gases (386.7 million gallons).
    - Finished Petroleum Products = 3,423,723,580 gallons (3.42 billion gallons)
    - Other Liquids = 5,866,661 gallons (5.9 million gallons)

Finished Petroleum Products	Gallons
Motor Gasoline	1,722,426,506
Aviation Gasoline	3,180,316
Kerosene-Type Jet Fuel	300,941,302
Distillate Fuel Oil	778,312,366
Residual Fuel Oil	134,094,160
Petrochemical Feedstocks	119,384,311
Special Naphthas	7,556,934
Lubricants	26,261,235
Waxes	2,008,915
Petroleum Coke	90,986,652
Asphalt and Road Oil	91,672,165
Still Gas	129,324,703
Miscellaneous Products	11,703,338

Liquid Fuels, Petroleum Products and the Biomass Equation

Lignocellulose, derived from woody biomass, crop residues, and agricultural processing residues, presents the most promise as a sustainable, high availability feedstock for liquid fuels development and petroleum substitution in the region. Analysis performed for this project indicates that the 98-county Mid-South Mississippi Delta region may have the following level of lignocellulosic biomass availability on an annual basis (Table 19).

Table 19: Sustainable Regional Lignocellulosic Biomass Availability

Biomass Source	Total Production, million tons/year	Theoretical sustainable usable quantities, million tons/year
Agricultural field residues	31.5	7.2
Agricultural processing residues	1.3	1.3
Forest residue biomass	9.8	6.4
Forest stem wood biomass	12.7	12.7
Totals	**55.3**	**27.6**

Regional Lignocellulosic Biomass Supply

Agricultural field residues represent only a modest supply which may be undesirable to recover.

Key available supplies are estimated to include:

- 7.2 million tons of crop residues
- 1.3 million tons of agricultural processing residues
- 6.4 million tons of forest residues
- 12.7 million tons of forest stem wood

Harvested crop production in 2007 was 25.0 million tons on a dry matter basis, with total production of field residues from these primary crops (not including hay) totaling 31.6 million tons, of which 7.2 million tons (23%) is estimated to be sustainably removable based on the 1:1 corn stover-to-grain ratios.[86] Corn stover and rice straw comprise the primary crop residues in the study region by volume. The Billion Ton Report's estimates for crop residues may not convert readily to the Mid-South Mississippi Delta region given the difficulties in harvesting and handling rice straw (due to its high silica content) and the potentially lower stover to grain ratio in the region (versus the high-yield Upper Midwest production zones). These regional variables are acknowledged in the Billion Ton Report, which points out that the grain-to-residue ratio (or the inverse, harvest index) is effected by grain yield, regional differences, technology improvement, crop density and other factors.

In the near-term, corn cobs may represent the most accessible crop residue for the region. Harvesting of corn cobs in a one-pass system is feasible and is being developed by the Midwest corn ethanol industry. There is already an existing market in some regions for corn cobs at approximately $80.00 per ton to be used in the production of chemicals such as furfural. Companies such as POET Biomass, a division of POET, and DuPont Danisco Cellulosic Ethanol LLC, are developing conversion technologies specifically targeting corn cobs as feedstocks for biochemical conversion using enzymes. Given the agronomic characteristics of the region and the uncertainties in collection of crop residues, all residue sources are included in the overall inventory of lignocelluloseic biomass potential, but are not considered by the study team to be the most attractive near-term option.

Agricultural processing residues are available in the study region, with an estimated production of 1.3 million tons (predominantly comprising cotton gin trash and rice hulls), and there may be opportunities to utilize these processing residues in a variety of biobased products.

The region contains significant forest land resources, in addition to farm-generated biomass. Standing forest-based lignocellulosic biomass in the region is 624 million tons (95 million tons of branches and tops, 105 million tons of rough and rotten material, 22 million tons of small diameter stem wood, 87 million tons of medium diameter stem wood, and 316 million tons of large diameter stem wood). It should be noted that, for highest-and-best economic value reasons, the harvest and utilization of stem

[86] "Biomass as a Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply"; Oak Ridge National Laboratory for USDA and USDOE; April 2005. (Page 25)

wood from medium- and large-diameter trees is expected to continue to occur primarily for saw timber and pulp markets (it is important that development of a new biomass-based economy be developed in a manner that does not disrupt existing biobased industries which add value to biomass). **In calculations herein, only 10% of the medium- and large-diameter stem wood is considered available for new industrial biomass applications.** Based on an assumed harvest cycle of 28 years, the estimated amount of average potentially removable forest residue biomass would be 6.4 million tons per year, and the estimated amount of average potentially removable medium- and large-diameter stem wood would be 12.7 million tons per year.

In addition to currently available biomass there is significant regional potential for the growth of an expanded regional lignocellulosic feedstock supply using agricultural crop lands. There is, however, a balance to be struck between having enough biomass available for development of a significant industrial bioproducts industry while at the same time assuring nominal negative impacts on existing agricultural products and markets. **The project team sought to identify dedicated biomass expansion options that could be accomplished with limited effects on existing production—especially where food commodities are concerned.**

The team's conclusions are that the following additional *dedicated energy crop*[87] (DEC) production opportunities may be sustainably and realistically pursued:

- Production of DECs, such as switchgrass or miscanthus, on 25% of the region's idle lands at 12.0 tons per acre per year—for a total annual production of 2.4 million tons.
- Production of DECs on 25% of the region's Conservation Reserve Program (CRP) lands at 12.0 tons per acre per year—for a total annual production of 3.1 million tons.
- Production of DECs on 10% of the region's cropland. While more aggressive expansion of DECs on crop land is possible, this planning scenario was selected with the intent to minimize any impact on land currently used to produce food crops. This scenario would utilize 1.43 million acres of cropland, or about 60% of the 2007 cotton acreage, the region's primary non-food crop and the crop most generally under economic pressure for substitution. Expressed as lignocellulosic biomass at an estimated 15.0 tons per acre this represents annual production of 21.4 million tons.

Regional Lignocellulosic Biomass Supply Expansion Opportunities via Dedicated Energy Crop Production

- 2.4 million tons on idle land
- 3.1 million tons on CRP land
- 21.4 million tons on crop lands

The project team has identified *sweet sorghum* as the preferred near-term dedicated energy crop for the study region, as compared to switchgrass or miscanthus. As an *annual crop*, sweet sorghum will achieve its full production yield in the season of its planting and may be incorporated into rotations with other Delta crops. However, dedicated energy *perennial crops*, such as switchgrass and miscanthus, require upfront establishment costs that have to be reclaimed over the life of the crop (5–8 years). Perennial energy crops commit the land to a single crop over an extended time period, significantly increasing market risk, which is particularly unattractive for Delta farmers with diverse crop options and agronomic requirements. It is likely that the drivers for producing perennial dedicated energy crops will have to be long-term contracts which share a percentage of carbon trading revenue, and possibly opportunities for value-added processing ownership. In the highly productive Delta study region, there will need to be a clear demonstration of how these crops mitigate risk for an overall farm operation. The study team believes that perennial dedicated energy crops represent a longer-term feedstock option for Delta farmers.

[87] Dedicated biomass crops are frequently referred to as Dedicated Energy Crops (DECs). They constitute crops (such as switchgrass, miscanthus, sweet sorghum, and woody crops) grown specifically for biomass applications, as opposed to use in food and feed applications.

Sweet sorghum, on the other hand, is a highly productive annual crop which produces readily-fermentable sugars in the juice as well as significant biomass yield, typically over 10 dry tons/acre in the southern U.S.[88] Regional farmers are experienced with several open-pollinated varieties which require low inputs, are drought tolerant, and are grown in a variety of soil types. Efficient juice extraction can yield the equivalent of 400 gallons ethanol/acre from the sugar, while the crushed stalks (bagasse) represent a lignocellulosic feedstock with the potential to produce an additional quantity of ethanol. While developing countries with abundant labor have been pursuing sweet sorghum sugars as a rural biofuel feedstock, adoption of sweet sorghum as a feedstock in the U.S. has been limited by availability of mechanized harvest and juice extraction equipment. Several groups, including project collaborator BioDimensions, are actively pursuing the development of suitable harvest and pre-processing equipment to demonstrate sweet sorghum as a viable dedicated energy crop for the Delta region and the United States. A more detailed description of sweet sorghum as a dedicated energy crop is provided in Section II. B. of this report.

Based upon the above scenario for use of agricultural crop land for dedicated energy crop production, the total regional biomass availability, *expressed as lignocellulosic biomass*, is summarized in Table 20.

Table 20: Total Sustainable Lignocellulosic Biomass Availability including DECs

Biomass Source	Total Production, million tons/year	Scenario sustainable usable quantities, million tons/year
Agricultural field residues	31.5	7.2
Agricultural processing residues	1.3	1.3
Forest residue biomass	9.8	6.4
Forest stem wood biomass	12.7	12.7
Dedicated energy crops	31.5	31.5
Totals	**86.8**	**59.0**

As will be discussed, the individual industrial products that can or potentially could be made from biomass feedstocks are extremely diverse, and it is not possible at such an early stage in the development of the bioeconomy to determine the percentages of biomass that will be directed to each individual use.

However, it is possible to estimate the product potential for the Delta study region lignocellulosic biomass resource by calculating an estimated ethanol yield, representing the potential production of this biobased liquid transportation fuel. This calculation makes it readily apparent that the Mid-South Delta region can contribute significantly to the national demand for commodity liquid transportation fuels and biobased products.

[88] Sweet Sorghum Silage Tests in Tennessee, Univ. of Tennessee, 2008

Delta lignocellulosic biomass conversion to ethanol

The production of ethanol from lignocellulosic biomass is in the initial commercial demonstration stage. The current consensus is that a realistic near to mid-term yield target would be 80 gallons of ethanol per dry ton of lignocellulose, either herbaceous or woody biomass.[89] University of Nebraska and USDA-ARS researchers also consider 80 gallons to be a realistically achievable goal, with 200 gallons of ethanol per ton of switchgrass being an approximate theoretical maximum (dependent upon feedstock). **For the scenario calculations in this study 80 gallons of ethanol per dry ton of lignocellulosic biomass assumption is used.**

59 million dry tons of lignocellulosic biomass ***x*** *80 gallons of ethanol per dry ton* ***=***
4.7 billion gallons of ethanol*.*

At current spot price for ethanol of $1.65(July 2009) this is a $7.75 billion value.

Sweet sorghum sugar biomass conversion to ethanol

While lignocellulosic biomass conversion to ethanol is still an emerging technology, fermentation of sweet sorghum sugars (contained in the juice) is readily accomplished by well-known yeast fermentation. Applying the 10% DEC land scenario to sweet sorghum results in the following projection of ethanol production; *1.43 million acres of sweet sorghum:*

400 gallons of ethanol per acre production of juice ***= 572 million gallons of ethanol****.*

800 gallons of ethanol per acre production from bagasse (80 gallon x 10 dry tons/acre) *=*

1,144 million gallons of ethanol

Assuming comparable lignocellulosic conversion rates, sweet sorghum produces the same estimated total ethanol production as switchgrass or miscanthus, resulting in 4.7 billion gallons of ethanol, from all regional biomass feedstock sources. It is important to note that in addition to the more favorable characteristics of sweet sorghum as an annual DEC crop for the region, fermentation of sweet sorghum sugars to ethanol is commercially demonstrated technology. In addition, the assumed sweet sorghum lignocellulose yield of 10 tons/acre has been demonstrated in field trials by the University of Tennessee and other groups, whereas the assumed 15 tons/acre for herbaceous DECs such as switchgrass and miscanthus is at present an optimistic future goal. Finally, until lignocellulose-to-ethanol conversion technologies are demonstrated to be commercially viable, sweet sorghum sugar-derived ethanol could be produced with known technology, with the bagasse used for process energy, solid fuels for co-firing (see below), animal feed, or soil enrichment. **In summary, the 4.7 billion gallons of ethanol (or other liquid fuel) potential from biomass feedstocks exceeds the 3.42 billion gallons in total regional consumption of finished petroleum products, making the Delta study region a future net exporter of liquid transportation fuels under this scenario.**

The calculations above provide indications of the basic potential in ethanol commodity production from available and sustainable non-food regional biomass. While significant biomass volumes may indeed be

[89] University of Nebraska-Lincoln (2008, January 14). Biofuel: Major Net Energy Gain From Switchgrass-based Ethanol. *ScienceDaily*. Retrieved June 6, 2009, from http://www.sciencedaily.com /releases/2008/01/080109110629.htm

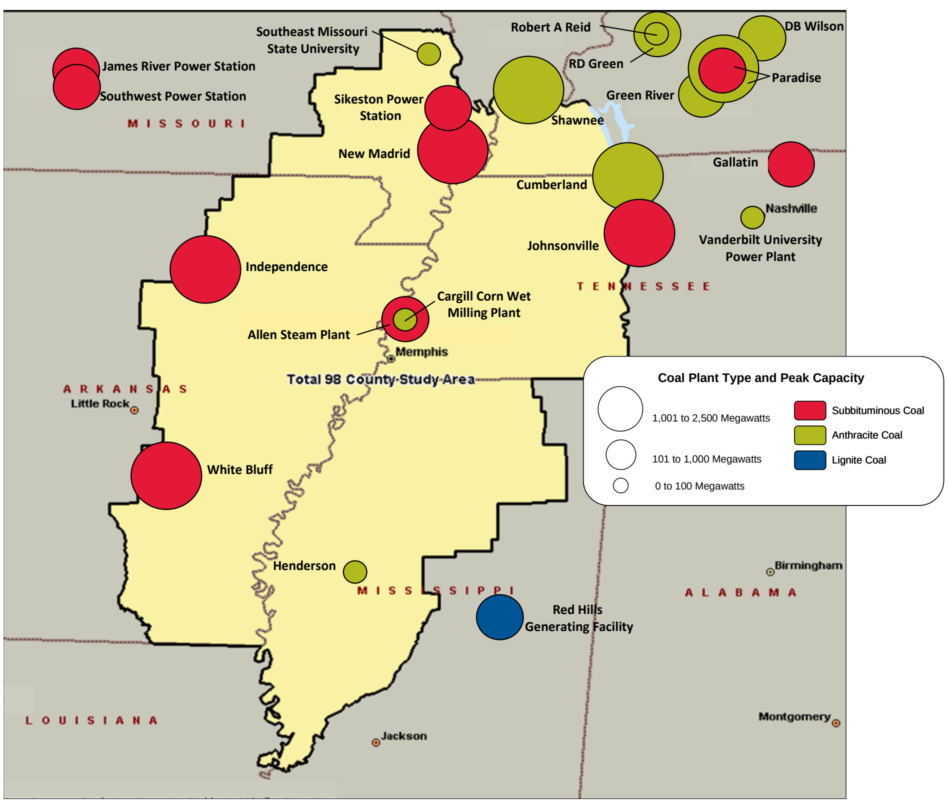
used for the production of cellulosic ethanol or other liquid fuels, the potential exists for production of additional higher value specialty products.

Energy (Heat and Electricity)

As noted earlier, the 98 counties in the Mid-South Mississippi Delta region have an estimated demand for 47.2 billion Kwh of electricity on an annual basis. In terms of power generation capacity the Energy Information Administration maintains data on major power plants (those with over 100MW of generating capacity) on its website at http://tonto.eia.doe.gov/state/.

Within the 98-county study region there is a total generating capacity of 19,362 MW, with 18,672MW (96.4%) of this generated by fossil fuels (coal and natural gas). Amongst the fossil fuel generating capacity, coal accounts for 6,775MW (36.3% of fossil fuel electricity generation) while natural gas accounts for 11,897MW (63.7%). In counties outside of the 98-county study region, but in close proximity to it, there is an additional generating capacity of 18,887MW, with 17,473 (92.5%) of this generated by fossil fuels (coal and natural gas). Amongst the fossil fuel generating capacity, coal accounts for 10,550MW (60.4% of fossil fuel electricity generation) while natural gas accounts for 6,923MW (39.6%).

Figure 19: Coal-Fired Electricity Generation in the Mississippi-Delta Region and Immediate Surrounding Environs



Of particular interest from a biomass perspective are coal-fired power plants because biomass can be co-fired with coal in the production of electricity (either in the form of the direct combustion of the biomass or combustion of syngas produced via biomass gasification. The National Renewable Energy Laboratory reports that:

Cofiring is a near term, low-cost option for efficiently and cleanly converting biomass to electricity by adding biomass as a partial substitute fuel in high-efficiency coal boilers. It has been demonstrated, tested, and proved in all boiler types commonly used by electric utilities. There is little or no loss in total boiler efficiency after adjusting combustion output for the new fuel mixture. This implies that biomass combustion efficiency to electricity would be close to 33%–37% when cofired with coal. Extensive demonstrations and tests also confirmed that biomass energy can provide as much as 15% of the total energy input with only feed intake system and burner modifications. The opportunities for biomass cofiring are great because large scale coal-powered boilers represent 310 gigawatts of generating capacity. Cofiring biomass with coal offers several environmental benefits. Cofiring reduces emissions of carbon dioxide, a greenhouse gas that can contribute to the global warming effect (see picture on the reverse side). Also, biomass contains significantly less sulfur than most coal. This means that cofiring will reduce emissions of sulfurous gases such as sulfur dioxide that will then reduce acid rain. Early test results with woody biomass cofiring showed a reduction potential as great as 30% in oxides of nitrogen, which can cause smog and ozone pollution.[90]

Within the 98-county study region there are six major coal-fired electricity generating plants having a combined total output of 6,775 megawatts (MW). Based on average national data from the Energy Information Administration, 1MW of electric power generating capacity produces 4,384 megawatt hours of electricity on an annual basis.[91] Therefore, it may be extrapolated that the 6,775MW capacity of the coal-fired power plants in the Mid-South Mississippi Delta study region should produce circa 29,701,600 megawatt hours of electricity annually. Full operational capacity of 6,775MW of power generation on an annual basis would be 59,349,000 megawatt hours (6,775MW x 8,760 hours in a year)—however, electricity generation plants do not run at full capacity non-stop all year.

National data show that 0.52 short tons of coal are consumed, on average, to produce 1 megawatt hour of electricity (or 1 ton of coal produces on average 1.93 megawatt hours of electricity).[92] **On this basis, the generation of 29,701,600 megawatt hours of electricity by the study area coal fired generating plants should consume 15,418,877 tons of coal per year.**

The National Energy Technology Laboratory reports that extensive demonstrations and tests prove that as much as 15% of the fuel firing a coal-fired boiler can be replaced with biomass with only moderate feed intake and burner modifications.[93] Were biomass to be substituted at the 15% rate for direct combustion in the Mid-South Delta region's coal-fired power plants this would require 2,313,000 dry tons of biomass (equivalent to 4,626,000 green tons—assuming a standard 50% moisture ratio).

Within the 98-county study region there are 22 major natural gas-fired electricity generating plants having a combined total output of 11,897 megawatts (MW). Based on the MW to MWh calculations used above, it may be extrapolated that the 11,897 MW capacity of the natural gas-fired power plants in the Mid-

[90] National Renewable Energy Laboratory. "Biomass Cofiring: A Renewable Alternative for Utilities". Biopower Fact Sheet. DOE/GO-102000-1055 June 2000.

[91] Net summer capacity of electric utilities in the U.S. = 571,200MW and total megawatthours of electricity produced by electric utilities in 2007 = 2,504,130,899. Max annual energy output for 571,200 MW on an annual MWh basis would be 571,200(24*365) equaling 5,003,712,000 MWh. Therefore, power generation in the US runs at circa 50% of full capacity. http://www.eia.doe.gov/cneaf/electricity/st_profiles/us.html

[92] U.S. 2007 short tons of coal used for electricity generation = 1,046,795,000. Megawatthours of electricity produced from coal in the U.S. in 2007 = 2,016,456,000. U.S. Energy Information Administration.

[93] National Renewable Energy Laboratory. "Biomass Cofiring: A Renewable Alternative for Utilities". Biopower Fact Sheet. DOE/GO-102000-1055 June 2000.

South Mississippi Delta study region should produce circa 52,156,000 megawatt hours of electricity annually.

Biomass has some potential for use in gas-fired power plants. Biomass can be converted into syngas (primarily comprising hydrogen and carbon monoxide) which may then be used to directly fuel a gas-turbine generator—or syngas may be co-fired in a natural gas combustion boiler system or used in indirect co-firing based on separate parallel boilers (one using natural gas and the other syngas) with an integrated steam cycle. As Oak Ridge National Laboratory has noted:

Gasification offers greater flexibility, both in the range of possible biomass feedstocks and in the end-use of the energy. For example, as well as driving a gas turbine, the gas from a gasifier can power a fuel cell to generate electricity, or it can be used to generate steam in a gas boiler, sometimes in combination with natural gas.[94]

The application of biomass to gas-fired generation is more complex than the direct combustion of biomass typically deployed with coal-firing; it is also at a more embryonic stage of development. Gas applications require capital investment in biomass gasification equipment and gas cleaning/filtering equipment. They also require natural gas fired power operations to invest in biomass storage facilities, material handling and ash waste disposal operations—operations they do not need to have when firing natural gas alone. For these reasons it is unlikely that the biomass will be used in the foreseeable future in gas-fired power plants in the U.S.—especially those in the Mid-South Mississippi Delta region, which have excellent direct access to gas via pipelines from Gulf of Mexico gas resources.

Chemicals

One of the distinguishing factors of biobased renewable resources is that unlike wind, solar, geothermal and other renewable energy resources that produce electricity or heat, biomass can also produce materials, such as chemicals, plastics, and fibers (and, of course, food and feed). Biomass represents a highly flexible resource able to supply raw materials and feedstocks into a significant range of industries for processing into higher-value business-to-business and business-to-consumer products.

Unlike fuel markets which can be generally estimated via reference to regional population size (under the reasonable assumption that liquid fuels will be used proportionately in line with the general size of the population), industrial input markets are more location specific. In order to determine the market in the Mid-South Mississippi Delta study region, the project team instead conducted a detailed assessment of the types of industries that may be able to produce or use biobased inputs (defined by NAICS codes) and then worked to identify specific industry locations within the 98-county study region with operations in these NAICS code industries.

Using the specified NAICS codes, Battelle contracted with *Harris Selectory* for provision of business location data for each county in the study region. Table 21 summarizes the resulting data for the 98-county region by NAICS code (sorted on total employment) for only those sectors comprising chemicals operations. It is evident from this data that there are:

- 199 individual business locations in "chemicals"
- A total chemicals sector employment of 10,879 personnel
- A total sales volume of $3.75 billion
- Over 6.5 million square feet of facilities space.

Table 21: Chemical Industry Sectors in Mid-South Mississippi Delta (Sorted by Total Employment)

[94] *http://bioenergy.ornl.gov/faqs/index.html#tech1*

No of Sites	Plant or Facility Size	Sales Amount	Jobs Here	Primary NAICS	Primary NAICS Description
30	1,477,300	$449,890,755	2,763	326151	Urethane & Other Foam Product (Except Polystyrene) Mfg
14	295,700	$757,814,223	1,661	325200	All Other Basic Organic Chemical Manufacturing
26	1,029,700	$260,572,334	1,287	325999	All Other Misc. Chemical Product & Preparation Mfg
19	751,500	$451,314,818	1,178	325212	Plastics Material & Resin Manufacturing
9	463,400	$151,719,276	891	325612	Soap & Other Detergent Manufacturing
14	404,300	$212,948,783	737	325511	Paint & Coating Manufacturing
17	529,600	$289,715,390	603	325321	Pesticide & Other Agricultural Chemical Manufacturing
11	176,200	$213,818,987	444	325312	Nitrogenous Fertilizer Manufacturing
13	692,500	$122,515,586	369	324200	All Other Petroleum & Coal Products Manufacturing
11	109,600	$585,947,473	339	324111	Petroleum Refineries
8	253,900	$80,541,970	212	325521	Adhesive Manufacturing
5	44,150	$56,220,408	166	321115	Wood Preservation
4	34,100	$65,692,532	66	325111	Petrochemical Manufacturing
4	81,200	$9,283,088	48	325315	Fertilizer (Mixing Only) Manufacturing
4	36,700	$30,503,360	46	325313	Phosphatic Fertilizer Manufacturing
4	18,800	$1,780,000	30	325412	Medicinal & Botanical Manufacturing
1	9,900	$1,200,000	15	312121	Breweries
2	82,400	$777,000	12	325192	Gum & Wood Chemical Manufacturing
2	8,600	$4,958,102	7	325193	Cyclic Crude & Intermediate Manufacturing
1	3,200	$390,000	5	325194	Ethyl Alcohol Manufacturing
199	**6,502,750**	**$3,747,604,085**	**10,879**		

Certainly not all of these chemicals sectors could use biomass as feedstocks in their chemicals production, but there is evidence to suggest that a majority could. There are already multiple biobased chemicals, chemicals replacing petrochemicals in applications including plastics, coatings, adhesives and solvents to name a few. Major chemical industry multinationals are engaged in the development, production and sales of biobased chemicals including Dupont, BASF, Eastman, Proctor and Gamble and Cereplast.

Indicative of the kind of market opportunity available is the product penetration being achieved by NatureWorks LLC, a joint venture between U.S.-based Cargill and Teijin Limited of Japan. NatureWorks has a family of commercial biobased polymers on the market derived from 100% renewable resources with cost and performance competitive with petroleum based products. NatureWorks bioplastic is branded as Ingeo™ and is produced via the processing of natural sugars to create a polylactide biopolymer used in consumer products, packaging and the manufacture of fibers and textiles.

Other bioplastics are also on the market. The biopolymer poly-3-hydroxybutyrate (PHB) is a polyester produced by bacteria processing glucose or starch. Its characteristics are similar to those of the petrochemical derived polypropylene. The South American sugar industry is producing PHB on an industrial scale. Polyethylene is also being produced via bio-based pathways. Bio-derived polyethylene is chemically and physically identical to traditional polyethylene and has a well-established production pathway:

Biomass → (fermentation) → Bioethanol → Ethene → Polyethylene

Cereplast is marketing its Biopropylene™ family of products as the world's first "sustainable polypropylene" using cornstarch, tapioca and other starches as feedstocks. They are also producing Cereplast Compostables™ which are fully biodegradable and compostable BPI approved resins. It should be noted that hybrid plastic resins have also been developed that derive part of the resin mix from petrochemicals but substitute starch or other biobased components as part of the mix—thereby partially displacing petrochemical feedstocks in the marketplace. Some additional examples of biobased chemicals product development include:

Table 22: Examples of Chemical Companies Active in Production of Bio-Based Chemicals

Company	Products
Ashland Composite Polymers	ENVIREZ 1807, a soybean oil- and corn ethanol-based unsaturated polyester resin for SMC use.
BASF	Blends of PLA with biodegradable copolyester. Also nylons and polyols derived from castor oil.
Dupont	Thermoplastic elastomers partially derived from corn sugar and nylon partially derived from castor beans.
Ex-Tech Plastics Inc.	Film and sheet products extruded from NatureWorks PLA.
Kingfa Science & Technology Co. Ltd.	PLA and polybutylene succinate (PBS) bioplastic resins.
Merquinsa North America Inc.	Thermoplastic polyurethane elastomers with plant-oil content as high as 60%.
PolyOne Corp.	Compounds based on polyhydroxybutyrate valerate (PHBV) and plant-derived TPUs. Also modifiers and colorants for bioplastics.
Polyvel Inc.	PLA masterbatches for impact modification, melt strength, mold release, antiblock and other functions.
Urethane Soy Systems Co.	Produces SoyMatrix, a soy-based polyurethane marketed for pultrusion and filament winding applications.
Vertec Biosolvents Inc	Using ethyl lactate in soy oil-solvent blends.

In looking at the key categories of chemicals being produced in the Mid-South Mississippi Delta region it is evident that many may have the option to deploy biobased feedstocks in their manufacturing:

- **Urethane & Other Foam Products** (Except Polystyrene) manufacturing employs 2,763 personnel across 30 facilities in the region. Both rigid and flexible urethane foams are available in the market produced from biobased polyols and Cargill is active in the supply of commercial volumes of soy-based polyols into the urethane foam market.
- **Plastics Materials and Resin** manufacturing employs 1,178 personnel within the region across 19 facilities. As noted earlier there are multiple biopolymers, resins and plastics already on the market.
- **Soap and Other Detergent** manufacturing employs 891 regional personnel in nine facilities. Soap production obviously has a long history in the use of biobased inputs, while multiple manufacturers are producing biobased detergents and industrial and consumer cleaning agents from biobased feedstocks.
- **Paint and Coatings** manufacturing employs 737 personnel in the Mid-South Mississippi Delta region across 14 plants. Several manufacturers are actively producing biobased paints (mostly derived from soy) and other coatings used for a diverse range of applications such as concrete waterproofing, wood preservation and roof sealing.

The above represent just some of the existing chemicals industries operating within the study region that have potential to use biobased inputs to produce biobased specialty chemicals.

The full range of chemicals used as commodity chemicals, secondary chemicals and intermediates is expansive as is the variety of finished products and commercial goods made from chemicals. Determining the market within the Mid-South Mississippi Delta region for all chemicals and chemical derivatives would be close to an impossible task. It is fair to say, however, based on the analysis of companies contained within the Mid-South Mississippi Delta region that there is significant potential for existing chemical process industry to use biobased feedstocks and/or intermediates as cost-effective, renewable inputs for future production.

Materials and Niche Product Opportunities

The Mid-South Mississippi Delta region, more than most agricultural regions in the U.S., has a long track record of biomass production for fiber and textile applications. As a leading cotton production region for the nation, the Delta has a major vertically integrated supply chain with a significant (albeit declining) base of farmers growing cotton and a substantial base of cotton gins and processing operations. While most of the cotton is now exported for conversion into textiles the region does contain a major producer of cotton fiber from cotton linter, and companies using cotton seed in oleochemical applications. The cotton production environment may continue to change as other agricultural commodities increase in value and gain production acreage.

The region does have an opportunity to encourage the development of a broad range of diverse, niche and specialty products. These include agricultural fibers, smaller acreage crops with unique properties, and specialty crops with output traits. A great example of this is in the development of agricultural fibers in the region. The growing, processing and utilization of agricultural and forestry fibers is an important component of building a future bioeconomy for several reasons. Those center around the fact that plants have created, through photosynthetic processes, a naturally-occurring molecular system that can be used to increase the strength and performance of many products, and can be used as a foundation material for the creation of products such as textiles, composites, and paper.

The presence of the automotive industry and associated suppliers in the 98-county study region and the surrounding states may offer significant opportunity for the expansion of the production and use of agricultural fibers for industrial textiles, fiber reinforced composites and other automotive related applications. Additional opportunities exist in new markets with filtration media, structural components, and the application of nanotechnology to the improvement of fiber strength. There are clear rotational benefits for increasing acreages of annual bast fiber crops such as kenaf in the study region, including reduced chemical use, weed suppression, and less water consumption.

There are also product opportunities in the region for small acreage crops that offer novel health or industrial properties for specialty applications. Some small scale oilseeds including crops such as lesquerella and castor possess highly desirable fatty acid profiles that have markets in cosmetics and specialty lubricants. Work at several of the regional institutions is identifying naturally occurring chemicals in plants that may have commercial potential in health and in natural crop protection products.

A strong potential also exists for the development of enhanced or new output traits in crops. These are traits which allow the crop to produce certain characteristics desired by food, health or industrial customers. Unlike input traits in which the value proposition is directed to the farmer by reducing production costs, output traits are directed to those making products from the crops and ultimately to the consumer. Enhanced output traits will allow crops to have higher protein, stronger fibers, enhanced components, or other properties that will improve the development of agricultural products. There are numerous examples of these products in development or already commercialized for food, feed and industrial applications. Some of these will be in large commercial applications such as the recently deregulated Amylase producing corn by Syngenta, but some of these will be small, niche crops which require specialized handling.

Using modern biotechnology tools, and often referred to as Plant-Made-Pharmaceuticals (PMPs) crops such as tobacco can be developed to directly produce medicine, industrial enzymes or other desirable products. Ongoing efforts to deregulate these crops could potentially offer a shorter and less costly path to market that may open the way for numerous companies to commercialize PMP technology. There is an increasing interest in PMPs within the study region driven by programs at Arkansas Biosciences Institute and other institutions.

Each of these niche opportunities serve to encourage entrepreneurial development, crop diversity, innovation, development of regional niche markets, and increased job creation for the region.

Observations and Conclusions

Biomass presents an opportunity for providing sustainable, more environmentally-friendly feedstocks versus fossil fuels for the production of liquid fuels and the generation of electricity. Biomass also provides a renewable feedstock with applications in the displacement of crude oil and petrochemicals in the production of specialty chemicals and various industrial materials, such as plastics, composite construction materials and fibers.

Current levels of biomass available within the region are significant. Under one scenario, production of dedicated energy crops on no more than 10% of current cropland, would more than double annual lignocellulosic biomass availability, to 59.0 million tons per year, sufficient to produce 4.7 billion gallons of ethanol annually, well in excess of the total regional consumption of finished petroleum products which stands at an estimated 3.42 billion gallons annually.

Sweet sorghum has been identified by the study team as the preferred near-term dedicated energy crop for development in the Delta region, compared to switchgrass and miscanthus, due to the relative ease of incorporation of an annual crop into existing rotations; yield potential and agronomic requirements; known technology to convert sugars to ethanol (or other higher-value fermentation products); and value-added disposition options for the bagasse.

The calculations above provide indications of the basic potential in ethanol commodity production from available and sustainable non-food regional biomass. While significant biomass volumes may indeed be used for the production of cellulosic ethanol or other liquid fuels, the potential exists for production of additional higher value specialty products. The application of biomass to specialty chemicals manufacturing has the potential to support and reinforce an existing industry within the region which currently employs nearly 11,000 personnel.

V. Regional Enablers for an Emerging Bioprocessing Industry

A. Logistics Infrastructure

This summary is excerpted from the study sub-report "Logistics Assessment of the Delta Region" prepared by Strata-G LLC. The full sub-report is available online at www.agbioworks.org.

Introduction

The Strata-G, LLC (Strata-G) logistics sub-report includes an assessment of the region's logistics infrastructure; an analysis of farm-to-factory logistics issues; and an assessment of strengths and weaknesses as applicable to movement of feedstock, biofuels, and bioproducts. The study process consisted of interviews with contacts including agricultural extension agents, farmers, and trucking companies in each state of the study region. Also included were document reviews, Geographic Information System (GIS), and government data searches, and the experience/knowledge of the reviewers.

Logistics Infrastructure of the Region

Road Infrastructure: The road transportation infrastructure within the 98-county region is centered on a good system of established primary, secondary, and connecting roads, as shown in Figure 20. There are eight Mississippi River road crossings in the study region, with several major Interstate and U.S. highways converging at Memphis, where there are two road crossings. It is expected that most low bulk density lignocellulosic biomass will move by truck from farms and forests to decentralized biorefineries over secondary and connecting roads. Primary roads and Interstate highways will most likely be used primarily to move products, such as liquid transportation fuels, from refineries to petroleum tank farms or blending stations.

Rail Infrastructure: Regional rail and port infrastructure is depicted in Figure 21. The significance of Memphis as the region's rail hub is readily apparent. The study region has five Class I railroads (annual revenue of over $250 million): Burlington Northern Santa Fe (BNSF), Union Pacific (UP), Canadian National/ Illinois Central (CN/IC), Seaboard Coastline Railroad (CSX), and Norfolk Southern (NS). BNSF and UP have bridge crossings over the Mississippi River at Memphis. Northwest Mississippi is served by four Class I rail lines: two Canadian National lines, a Kansas City Southern line, and Burlington Northern Santa Fe. The region is also served by two Class II lines (annual revenue of over $20 million up to $250 million): Columbus and Greenville and the Mississippi Delta Railroad. Although there are many smaller railroad sites within the region, these two are the primary movers of material within the Mid-South Mississippi Delta Region. Nationwide, rail has been the primary mode of transport for first-generation biofuels from refineries. As regional production increases, the demand on regional short-line rail may increase as well.

The 98-county study area contains 76 intermodal facilities, which are most likely to be used for exporting some biobased products outside the region. Intra-regional transportation requirements will predominantly be serviced by the road and trucking infrastructure.

River Port Infrastructure: Within the region, there are 17 public ports, all of which have the capability to ship and receive dry bulk commodities and most ship and receive general cargo. Of significant importance is the Port of Memphis, which handles over 19 million tons of cargo annually and is the fourth-largest inland port in the United States. Ten of the ports have direct rail access, connecting to the Union Pacific or Burlington Northern Santa Fe lines. Storage options vary widely between the ports and include open storage, storage on concrete pads, steel tanks for grain, metal and concrete storage buildings, and liquid fertilizer pipelines. Adequate storage space is essential for biomass related operations. Appendix B to the full report has descriptions of the capabilities at each port. River transport will likely not be economical for most low bulk density lignocellulosic biomass feedstocks, which will be processed in close proximity to production. However, barge transport of densified lignocellulosic biomass, such as pellets or briquettes, as well as high bulk density chemical and fuel products for export may represent a regional advantage.

Figure 20: Road Infrastructure

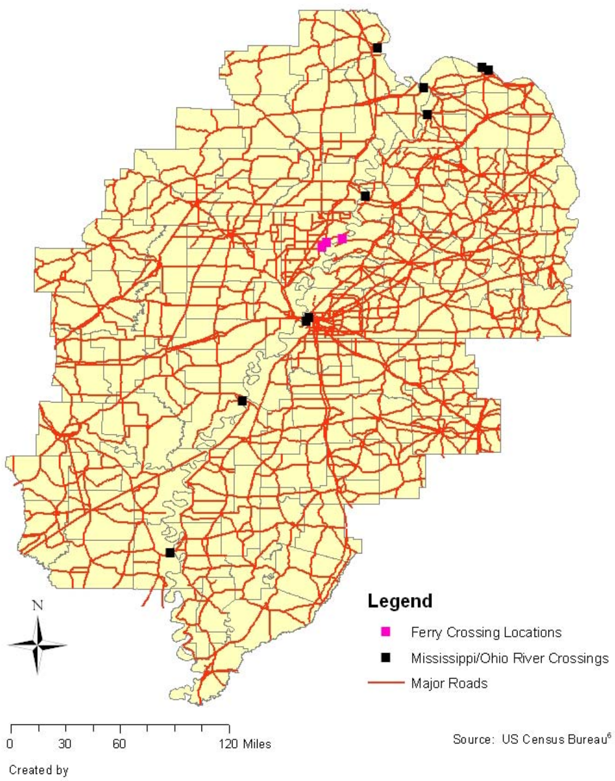


Figure 21: Rail and Port Infrastructure

Pipeline Infrastructure: Crude oil and refined petroleum pipeline infrastructure throughout the region allows movement of products from the Gulf Coast to major markets in the Midwest and on the East Coast. Major crude oil lines include the Shell Capline, which provides access for refineries to crude oil to two states in the study; the Mid-Valley Pipeline, owned by Sunoco, which crosses North Mississippi and West Tennessee and has trunk lines into Arkansas; and the ExxonMobil pipeline which has a crude line that travels from southwestern Arkansas into Missouri.

Major refined product pipelines include the TEPPCO Pipeline which supplies refined petroleum from Texas and Louisiana to the Northeastern U.S. and traverses Arkansas, with multiple trunk lines extending from the main pipeline. The Centennial pipeline carries refined product through north Mississippi, west Tennessee, and western Kentucky. For refined fuel products, pipelines are without question the most efficient and economical means of transportation; however, due to concerns about corrosion and compatibility, first-generation biofuels (ethanol and biodiesel) have generally not been shipped by pipeline. Major pipeline companies are actively researching how biofuels can be moved within their networks, and a key characteristic of second-generation biofuels will be pipeline compatibility. Proximity to refined product pipelines sets the Mid-South Delta region apart, giving it a strategic advantage for blending and export of compatible second-generation liquid biofuels. Pipelines will likely be the preferred option for outbound movement of compatible second-generation biofuels.

Farm to Factory Logistics of Biomass Feedstocks

Crop Residues and Oilseeds – Harvest, Storage, and Transport Scenarios

For the emerging bioprocessing industry, baling is currently the most common method for harvesting crop residues (corn stover, wheat straw, rice straw, and sorghum stover). These residues are typically windrowed and baled into large round (6 x 5 foot) bales or large rectangular (9 x 4 x 4 foot) bales. Once baled, the product is moved to storage via flatbed trucks, tractors pulling bale wagons, or over-the-road tractors. Flatbed trucks would also be used to transport the baled product to biorefineries. A small portion of the region's crop residues are handled as silage, chopped with a forage harvester, moved via silage wagons, and then stored in covered bunkers or piles until subsequent use, although very large commercial silage harvesters are available locally. Both the baling and the silage methods use existing equipment and have an existing transportation infrastructure, although they work within a limited transportation radius.

New attachments for combines are being developed and tested to merge grain and residue harvest into an integrated one-pass harvesting operation. In the future, the one-pass harvesting method could play a role in handling biomass. One-pass harvesting eliminates the need for multiple operations in the field (cutting, shredding, raking, baling) and allows for transportation and storage of the wet product at or near a biofuels plant. This method would eliminate handling costs on the farm and could reduce traffic into biofuels facilities if load weights could be increased.

Other methods of pre-processing at the farm, including pelletization and liquefaction, are possible steps in the supply chain; however, these steps will add cost to the feedstock and it is too early to know if these technologies will be adopted.

Cotton motes are cotton ovules that fail to ripen into mature seeds, developing instead into aborted structures which cause imperfections in ginned fibers and textile products from cotton. Motes are the by-product of the lint cleaning process after the seed has been removed from the cotton. In the past, motes had to be burned or hauled off as waste, but now there are new uses and outlets for motes. Cotton mote processors generate re-ginned bales of cleaned short-fiber cotton that are used in such applications as furniture, paper, nonwoven fabrics and coarse yarn spinning (e.g., hosiery, socks, draperies, rugs).

Oilseed crops, other than cottonseed, in the South are harvested with combines rather than swathers because the climate allows for better drying in the field. Once harvested, the product is moved to drying facilities, then (in the case of soybeans) to crushing facilities via gravity fed or dump trucks. One or more regional multi-seed oilseed crushing mills would greatly benefit the emergence and growth of new oilseed crops in the region. This could be a new mill or it could be developed by renovation of an existing mill or an existing industrial site. It should be located in close proximity to where there is already extensive production of soybeans, because it might need to crush soybeans as well as the new crops.

In assessing storage and transportation capabilities of residues and oilseed crops, interviews with agricultural extension agents in the region indicated that approximately twenty percent of farms have onsite storage for grains and soybeans with the remaining eighty percent transporting to dry bulk storage facilities. The density of crop residues affects the capacity and cost of transportation to these storage sites and can limit the mode of transportation used to move biomass in the region. Densities for most of the current crop residues average between 7 lbs/ft^3 to 9 lbs/ft^3, making movement by truck within 50 miles most economical.

There is a substantial existing infrastructure of farm-based tractor-trailer gravity-fed and dump trucks in the Delta region that could be used to haul crop residues for bioprocessing after grains have been harvested. It is interesting to note that where Arkansas farmers own most of their own trucks, farmers in Tennessee and Mississippi are transitioning from lease or for-hire trucking to individually owned trucks. Transport of agricultural crop residues to biorefineries could represent a new off-season opportunity to utilize farm-based rolling stock for revenue generation. Based on telephone interviews, trucking companies that service the Delta Region indicated they could meet the needs of increased biomass transportation. In contrast, a 2007 study by the USDAAMS indicated that truck freight is forecast to almost double from 2002 to 2020, while driver shortages are projected to reach 219,000 by 2015.

Woody Biomass – Harvest, Storage, and Transport Scenarios

Woody biomass consists of stem wood, as well as accumulated wood, bark and leaves of living and dead woody shrubs and trees. Based on 2002 reports from the U.S. Forestry Service Timber Products Output website, logging residue, which is typically left in the forest, represents a significant biomass resource within the region. Sawmill residue is often used for drying green lumber, therefore availability is limited. In addition, there is increased demand for wood chips and sawmill residue because renewable electricity goals are increasing the use of these products in each state.

Paper and pulp mills compete for woody biomass, but they do not use a significant amount of residues. As such, it may also be beneficial to locate a biofuels refinery between concentrated forestry activities and concentrated agricultural activities, so it can be close to multiple feedstocks.

Woody biomass harvesting operations typically involve the following phases, not necessarily in this order: harvesting or felling, skidding or forwarding, pre-processing and drying, transportation and delivery, and storage. These activities are performed either during conventional timber harvesting operations or as a separate operation. Woody biomass is harvested with various types of equipment depending on the conditions of the harvest area and the preference of the end user. Smaller-scaled harvesting utilizes equipment such as a tracked skid steer, farm tractor and various customized equipment are used to gather woody biomass material in thick forest areas. Larger-scaled operations utilize equipment such as feller bunchers, skyline yarders and forwarders in areas where the forests are more easily accessible.

Woody biomass can be harvested, stored and transported in one of three forms:

- *Unconsolidated Material* – woody biomass in its raw form after removal from the bole of the tree. Although not normally harvested, this unconsolidated slash can be transported in specialized containers on trailers to wood manufacturing facilities to be used as hog fuel.
- *Comminuted (i.e., reduced in size) Material* – currently the preferred form of woody biomass, it is generated using chippers, tub grinders or shredders. Comminution occurs in the woods, roadside, or at the end use facility.
- *Bundled Material* – logging residues that are compacted into cylindrical bales or bundles are also referred to as composite residue logs (CRLs). Processing requires specialized machinery, however, the biomass bundles can be handled and transported in the same way as traditional roundwood, which is an advantage because existing infrastructure and knowledge may be utilized. Also, bundles may be stored for longer periods of time than unconsolidated or comminuted materials.

Woody biomass in its raw form (e.g., slash, limbs, small trees with limbs, tree sections) has a low bulk density, which increases the cost of transportation. In the South, trucks are the predominant mode of transport, either via tractor-trailer or fixed truck type. There are multiple options for trucks and trailers, and the type and configuration selected depend on the method of pre-processing at the logging site. The tractor-trailer/bulk van combination is the most used and most cost-efficient mode. Fixed trucks with enclosed beds are used when needed to negotiate tighter and frequent turns. Storing of woody biomass is completed by gathering material and staging it in large piles.

Various types of specialized forestry residue bundling equipment have been used more readily in Europe. John Deere introduced the first bundling machine in the U.S., the 1490 Slash Bundler, and a study was recently published in which a John Deere 1490D Slash Bundler was tested for the first time in the South. The study was conducted in the summer of 2006 at pine harvest sites in Arkansas. Bundles from this machine are approximately two feet in diameter, and the operator can pre-select the length ranging from six to 16 feet. Bundles weigh approximately 100 pounds per foot of length when produced immediately after harvest.

The research concluded that these bundles can be produced economically (based on current markets), a delivery truck was not required to be present during processing, and the bundles could be stored for seven to eight months. The study included four independent case studies, each with a sample size of one. Researchers pointed out that all logging sites are different and present different challenges. They concluded that if this machine were to be used in the South, loggers would adapt their operations to ensure residues would be removed in the most efficient manner.

Dedicated Energy Crops – Harvest, Storage, and Transport Scenarios

Switchgrass and Miscanthus are both high yielding herbaceous grasses that can be used as lignocellulose feedstocks. The majority of research on switchgrass has been performed in the U.S. (primarily in Illinois and more recently in east Tennessee), and the majority of research on Miscanthus has been performed in Europe. Other potential dedicated energy crops include short rotation woody crops (SRWC) for production of cellulosic biomass for biofuels. Several species are being researched, including hybrid poplar, willow, sweetgum, American sycamore and loblolly pine. Most of these grow best in areas with modest to high soil moisture.

Switchgrass: Switchgrass is a perennial crop that reaches a yield plateau in year three and thereafter should sustain this yield until years 10–12. The yield is relatively low during the first two years (40 to 60% of plateau), and annual fertilization with nitrogen is required. Yields are expected to increase as agronomists develop higher yielding cultivars and as agronomic practices improve. Current yields are in the range of 4 to 8 tons per acre for a mature crop, but these yields may increase to 10 to 12 tons per acre with improved cultivars.

It is anticipated that switchgrass grown for biofuel will be harvested once annually, after a frost. Several harvest scenarios are being evaluated. For harvest of dry biomass, it can be mowed and dried to a moisture level of 14 to 16% in windrows. It can then be baled into large wrapped round (1000 lbs) or large rectangular (1500 lbs) bales. Current research being performed at the University of Tennessee shows that it is possible to create modules from chopped switchgrass using a cotton module builder. Bales would be stored on field-side pads and covered with tarps. Modules will be stored field-side and covered with tarps although significant degradation risks increase with time stored in this fashion. Material must be kept dry until processed at the biorefinery. Costs per dry ton are estimated at $52.92 for round bales and $60.81 for modules.

Alternatively, switchgrass could be harvested with a forage chopper and ensiled in bunker silos at the farm for subsequent transport in bulk to the refinery. Ensiled forage could be treated with enzymes or microorganisms that would initiate breakdown of cellulose in storage. Before processing, switchgrass would be ground on the farm, at storage sites or at the refinery to increase bulk density and improve flowability.

Transport from the farm to the biorefinery will occur in one or more stages, depending on the on-site storage capacity at the refinery. It may be cheaper to have a large storage site at the refinery because the bales, modules or chopped/ground material would have to be moved only twice (farm to refinery storage and then to bioprocessing) rather than three times (farm to off-site storage then to refinery and then to bioprocessing). However there is significant fire risk by putting all of the raw material in one location. Another solution that is used in the flax straw industry in Canada is the satellite “on farm” storage that can later be drawn into the plant. Standardized equipment for transporting bales, modules or ground material will need to be developed in order to improve efficiency of producing fuel from switchgrass. Several different production and transportation systems are being investigated to determine which are best suited for different regions of the country and different sizes of refineries.

As the lignocellulosic biofuel industry develops, it is expected that new equipment will be developed to speed harvesting and pre-processing, which should reduce the cost to the refinery. Nevertheless, new field harvesters, balers and pre-processors are likely to be more expensive than conventional balers and module builders; therefore, these might be owned and operated by custom harvest operators and alter the need for on-farm equipment. The potential harvest season for switchgrass region-wide may extend for four to five months, so custom harvesting is a good option for such an extended season.

Miscanthus: Miscanthus harvest typically occurs in late winter or early spring in Europe, but there is little or no experience with this crop in the Delta Region. Crop initialization takes time, and it is usually not harvested in the first year. The best potential for yearly harvesting miscanthus is between January and March. Research suggests higher yields if harvested in autumn, but could increase nutrient removal from soil. Miscanthus stands are estimated to last from 15 to 25 years before a crop rotation is necessary. Studies have shown that miscanthus can be chopped, baled, or bundled, however bundling is not recommended for bioenergy use. Mowing and chopping experiments have been done with a chopping self-propelled forage harvester used for harvesting maize or grass and a power take off (pto) driven flail type chopper pulled by a tractor. The density of the material after chopping is low and compaction should be completed before transport. Mowing tests have also been completed using a swath mower of the cutter bar or disc bar type, and a flail type mower-chopper attachment.

Baling of miscanthus has worked with a round baler and a high-pressure big baler. It is important to note that storage requires the crop to have moisture content below 15%. This moisture content cannot always be achieved naturally so the material may have to be dried during storage. Ambient-air-drying is possible for chopped and baled material with moisture contents below 30%. Other available methods include utilizing potato storage systems, batch grain dryers using solar energy collectors, floor ventilated storage, or ensiling. Miscanthus bales may be hauled on flatbed trucks or trailers. If they are chopped, they would be hauled in a dump trailer. If these are to be grown as dedicated fuel crops, it is essential that the biorefinery be within reasonable trucking distance—generally less than 50 miles.

Short Rotation Woody Crops: Short Rotation Woody Crops (SWRC) last between 20 to 25 years, but are only harvested every three to five years between November and April. The most significant cost in the harvest process for SRWC is drying; therefore the need for supply drives the production chain. Immediate supply chains have the trees harvested as chips, transported, and then thermally dried at the energy plant. Short term supply chains (within two months) have the trees harvested as chips, force convection dried at the farm, transported, and then stored. Medium term supply chains (2–5 months) harvest as chunks, naturally wind dry on the headland, force convection drying on the farm, transport, and size reduce to chips if required. Long term supply chains (six or more months) harvest as chunks or whole stems, naturally wind dry on the headland, transport, and size reduce to chips if necessary. The costs decrease in this order with the immediate supply chain the most costly. SRWC hardwoods will sprout after harvesting and can be harvested through a few sprouting cycles. Pine must be replanted after harvest. Logging equipment or specialized harvesting and chipping equipment is needed to harvest the biomass.

Effect of Feedstock Bulk Density on Transport Cost

Table 23 illustrates that low bulk density is a significant transportation cost issue. Materials with average bulk density greater than about 10 pounds per square foot can generally be transported by truck at maximum weight loads, optimizing transport costs.

Table 23: Effect of Feedstock Bulk Density and Transport on Cost per Mile

Material	Avg Bulk Density (lbs/ft3)	Transport	Actual Tons Per Truck	Cost Per Mile Per Ton of Feedstock
Pelletized Crops	70	Gravity Fed	25	$ 0.12
Oilseed Crops	43	Gravity Fed	25	$ 0.12
Wood chips	20	Trailer	25	$ 0.12
Stover 6x5 Round Bale	9	Flatbed	19.05	$ 0.16
Stover 9 x 4 x 4 Bale	9	Flatbed	16.9	$ 0.18
Switchgrass 4 x 4 x 8 Bale	9	Flatbed	12.34	$ 0.24
Switchgrass 5 x 4 Round Bale	8	Flatbed	9.05	$ 0.33
Compressed Silage	7	Forage Wagon	4	$ 0.75
Unprocessed Silage	3	Forage Wagon	1.6	$ 0.18

Observations and Conclusions

The Delta Region's basic transportation and logistics infrastructure is a significant strength. The region is strategically positioned logistically with major roads, river ports, intermodal facilities, and pipelines. The Memphis hub can reach 60% of the U.S. population overnight via rail and road.

In the region, movement of first-generation liquid biofuels (mostly biodiesel) from refineries to petroleum tank farms or blending stations is handled primarily by tanker truck. As the biofuels and bioproducts industries expand, there will be an increased demand on the trucking infrastructure, particularly if fuels are consumed within the region.

Nationwide, rail has been the primary mode of transport for first-generation biofuels from refineries. As regional production increases, the demand on regional short-line rail may increase as well.

Proximity to refined product pipelines sets the region apart, giving it a strategic advantage for blending and export of compatible second-generation liquid biofuels. Pipelines will be the preferred option for outbound movement of compatible second-generation biofuels.

Lignocellulosic biomass bulk density will have a significant effect on transportation costs to refineries, thus affecting location and size of biorefineries. Transport of agricultural crop residues to biorefineries could represent a new off-season opportunity to utilize farm-based rolling stock for revenue generation. An excellent model for assessment of feedstock supply chain costs has been developed within the region and is available online as a supplemental reference report to the study.[95]

River transport will likely not be economical for most low bulk density lignocellulosic biomass feedstocks, which will be processed in close proximity to production. However, barge transport of densified lignocellulosic biomass, such as pellets or briquettes, as well as high bulk density chemical and fuel products for export may represent a regional advantage.

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[95] Sumesh M. Arora, Sandra D. Eksioglu, Ambrish Acharaya, and Liam Leightley. "Analyzing the Design and Management of Biomass-Biorefinery Supply Chain." Available at www.agbioworks.org.

B. Training and Workforce Development

This summary is excerpted from the study sub-report "Workforce Development in Renewable Energy Technology" prepared by BioDimensions, Inc. The full sub-report is available online at www.agbioworks.org.

Profile of the Five-State Delta Region

The *Regional Strategy for Biobased Products in the Mississippi Delta* is focused on economic development within a five-state 98-county region of the Mid-South Mississippi Delta, which is home to more than 1.7 million people of working age. The area is overwhelmingly rural, consisting of extensive agricultural row crop areas in the alluvial plain surrounded by a perimeter of forested lands, with Memphis as the major urban hub. The region is positioned for significant re-development as a center of renewable energy production in the United States, from conversion of abundant biomass resources to energy, fuels, chemicals and materials.

The educational attainment of working-age people in the five-state Delta region is generally low, with 50% or more of the residents having attained less than or only a high school education. Low levels of education correlate with high unemployment, with Mississippi Delta rates chronically among the highest in the country. High unemployment leads to increased poverty rates, which are uniformly higher in the Mississippi Delta than the national average. Kentucky (15%) and Tennessee (16%) have the lowest regional poverty rates, followed by Missouri (18%), Arkansas (19%) and finally Mississippi (21%), where nearly one in five people live below the federal poverty level. The high poverty rates in this region of the country are not simply a reflection of the economic hardships faced by many people in the U.S. during the current recession, but rather are representative of chronic and systemic economic distress. Clearly the educational and economic development opportunity of a new biobased processing industry could initiate a social transformation of the region.

To address the generational poverty in the Mississippi Delta, a comprehensive economic development strategy based on the region's strategic advantage in diverse biomass capacity and local processing must be implemented. Educational institutions from high schools to technical centers to community colleges to universities must have an integrated approach in concert with agribusiness, private enterprise and public governments to address the problems of low levels of education, low-wage work, monoculture farming, and regional poverty.

Characteristics of the Renewable Energy Sector

The regional strategic opportunity for the Mississippi Delta region is in biomass processing. One definition of a rural biorefinery is:

> *An integrated factory to process crops into 'refined' fractions, located at the center of a farming community. The biorefinery system starts with the contract harvesting of whole crops which are then stored and fractionated into products and by-products for sale."*

Four key factors support the development of a biobased processing industry in this region:

1. Agricultural capabilities to grow diverse crops for food, fuel/energy and biobased products;
2. Potential to establish decentralized bioprocessing facilities in rural locations throughout the 98-county region, dictated by transportation constraints for low bulk density biomass;

3. Existing industrial infrastructure, such as idled cotton gin sites, for low-cost transitional processing of biomass;
4. Superior regional logistics to move feedstocks by truck and rail and products by rail, river, pipeline, and air.

Biorefineries will be highly replicable and sited in rural locations close to the biomass feedstocks, creating a new de-centralized bioprocessing industry in the region. The potential employment impact is based upon biomass availability and is described elsewhere in the Regional Report.

Staffing the biorefineries of the future requires a significant educational investment in the current and emerging workforce in the Mississippi Delta. At present, there are not enough skilled and trained workers, willing to live in rural locations, to support the needs of a new bioprocessing industry in the Mid-South Delta. Developing a skilled workforce to work in biorefineries and transitional manufacturing is the path to economic development and regional prosperity.

Table 24 shows a projected staffing plan and salary levels for a prototype first generation 10MM gpy liquid transportation fuel (ethanol used as a model) biorefinery in the Mississippi Delta. In addition to the approximate 25 direct jobs supported by the biorefinery, there would be an estimated 25 indirect jobs, most of them supporting transportation of feedstocks and products.

Table 24: Staffing and Salary Projections for 10 MM gpy Rural Biorefinery

Position	Number	Degree	Salary, $
Plant Manager	1	BA/BS Eng/Bus/Chem	125,000
Finance Manager	1	MBA/BA	100,000
Operations Manager	1	BS Engineer	100,000
Procurement & Logistics Mgr	1	Associate/BA/BS	60,000
QC/QA Manager	1	MS/BS Chemist	85,000
QC Technician	1	Associate/BS	41,600
Maintenance Manager	1	Associate	60,000
Maintenance Technicians	2	Diploma/Associate	41,600
Shift Operators	8	Diploma/Associate	33,280
Material Handlers	4	Diploma/Associate	33,280
Clerical Support	2	Diploma/Associate	33,280
Sales & Mkt	1	BA/BS	100,000
Total Staff:	24	Total Payroll:	$813,040

Projected starting salaries for the lowest-paid occupations (shift operators) are above the state median incomes for all states except Missouri. All other staffed positions at the biorefineries pay more than the state median income. As a point of comparison, in West Tennessee (Workforce Investment Areas 11, 12 and 13), the grain and oilseed milling sector currently accounts for nearly $59 million in wages paid,[96] with median worker incomes ranging from $29,360 to $38,252.

[96] Tennessee Department of Labor, The Source TN

Workforce Development Programs in the AgBio Study Region

The preparation and growth of a reliable and skilled workforce in renewable energy processing technologies is essential to fully exploit the regional bioprocessing opportunity. Realization of replicable decentralized bioprocessing facilities across the region requires workforce development, infrastructure development, and entrepreneurism, all pursued with a long-term perspective of the opportunity.

Workforce development in Renewable Energy Technologies (RET) involves classroom and textbook learning as well as hands-on experiential learning. Student competencies in RET programs cover a variety of skills, including advanced literacy, writing and critical thinking skills, life sciences skills and mathematics, an overview of the renewable energy sector in the United States, regional renewable energy strengths, and the role of local, state and federal policy toward renewable energy. Class-based knowledge is complemented by extensive experiential opportunities using oilseed crushers, processing unit operations, control systems, engines and other RET machinery. Safety training is also a priority.

Two elements have emerged as high priorities for RET education in the region: connecting students with externships that provide the opportunity to learn firsthand the necessary bioprocessing technology skills; and collaboration and cooperation amongst regional educational institutions. In addition, local industry professionals have described the need for an industry-recognized certification of basic entry-level skills to confirm qualification of an individual to work in a technically sophisticated bioprocessing production facility. This pending certification development would recognize employee on-the-job and computer-based training as an alternative to an Associate's degree. Industry professionals in the region are actively cooperating with academics to develop this certification to streamline the process of moving students from the classroom into the workplace.

Occupations in decentralized biorefineries will require fundamentally different skill sets from farming, pre-processing, and transporting feedstocks. *The bioprocessing industry represents a significant downstream diversification from agricultural production.* The challenge for renewable energy technology education is to develop a specific curriculum to provide a unique worker skill set in bioprocessing for an industry that is only beginning to emerge in the country and the study region. In spite of the Delta region's challenges of high unemployment and low educational attainment, visionary regional workforce development programs in renewable energy technologies have emerged.They are specifically designed to support and enable this emerging industry, as described below.

Arkansas WIRED and ADTEC

The Arkansas Delta WIRED (Workforce Innovations in Regional Economic Development), or ADWIRED, program is a regional consortium of science and technology organizations whose goal is to promote economic development in renewable energy through entrepreneurship, education and business creation. Arkansas WIRED seeks to increase biofuels research and development capacity, create an engine test facility (beginning Fall 2009 at Mid-South Community College in West Memphis, AR), and expand the advanced manufacturing support infrastructure. ADTEC (Arkansas Delta Training and Education Consortium) is a U.S. Department of Labor-funded community college consortium comprised of five institutions (Mid-South Community College, Arkansas Northeastern College, East Arkansas Community College, Arkansas State University-Newport, and Phillips Community College of the University of Arkansas System) dedicated to training a local workforce in renewable energy technologies and supporting regional economic development in the Arkansas Delta.

The ADWIRED-ADTEC model was developed using best practices from renewable energy technology programs across the U.S. and stands out as a regional and national leader for its combined strengths of visionary leadership, identification of regional strategic advantage in biomass, and investment in educating the bioprocessing workforce of the future. ADTEC stands out as not only a regional program of excellence, but a national best practice in renewable energy technology programs, and the Arkansas Delta emerging workforce will be well positioned for careers in the emerging regional bioeconomy.

The first class of students participating in the ADTEC program at Mid-South Community College will begin Fall 2009. ADTEC's goal is to graduate 550 students in three years with the skills and training necessary to gain employment in regional occupations in the bioeconomy, including positions in biorefineries and bioprocessing facilities.

CERETE (Center of Excellence in Renewable Energy Technology Education) is located within Phillips Community College, which has 3 campuses in southeast Arkansas. This program is developing a Certificate of Proficiency, Technical Certificate, and Associate of Applied Science in Renewable Energy Technologies focused on biodiesel and ethanol production.

Table 25: Course requirements for Levels of Certification in RET

Degree[97]	Certificate of Proficiency	Technical Certificate	Associate of Applied Science
Number of coursework hours	12	31	63–65
Core Coursework (Additive)	Biofuels Introduction to Renewable Energy Technology	English Algebra Computers Industrial Safety and Sanitation	Process Instrumentation Plant Sciences Chemistry Hydraulics Manufacturing Equipment Maintenance and Operation

ADSTEP is a high school program which allows students to begin pursuing certification in renewable energy technologies, preparing them for coursework at the post-secondary level and future employment.

The clear advantage of the ADTEC program is that the system of recruiting and teaching students, and employing graduates of the program, involves input from all levels of the developing bioprocessing supply chain and thus ADTEC has an industry-supported academic program and career pathways for its graduates in local industries.

West Tennessee Community Colleges

Nascent partnerships are forming between the ADTEC consortium and community colleges in Tennessee. Adoption of curriculum and career pathways in renewable energy technology is imminent, and post-secondary education leaders are forming strategic partnerships to use local and national best practices to develop programs for residents in West Tennessee.

University of Memphis Biofuels Energy and Sustainable Technology (BEST)

The BEST program at the University of Memphis is training bachelor's and master's degree level students for careers in renewable energy technology through the Department of Mechanical Engineering. BEST has created a 60-gallon biofuels training and test facility with the capacity to power the University of Memphis campus fleet. BEST and ADWIRED/ADTEC have established an active collaboration for program development and delivery.

[97] "Renewable Energy Technology Degree Check-off.pdf."

Southeast Missouri WIRED

The southeast or Bootheel area of Missouri in the study region faces educational challenges. These counties have a relatively low level of educational attainment, and although a third of the population has a high school degree, "the value of a High School Diploma (or equivalence) as a means to entry into high skills and high(er) wage jobs has declined steadily in recent years, and it is commonly accepted that some post-secondary training is now a critical factor in achieving living wage employment."[98] The Southeast Missouri WIRED (SEMO WIRED) program has been established to address these post-secondary training needs.

According to the Department of Labor's Education and Training Administration, the Missouri WIRED region is "transitioning from an economy based on agriculture and old-line manufacturing. New occupations require foundations in math and science. SEMO WIRED partners will develop innovative technologies and focus on higher productivity, foster entrepreneurship and business growth, further develop talent to meet existing needs, encourage new business start-ups, and leverage best practices in growth and economic development."[99] Targeted industries include biofuels, agribusiness and intermodal transportation. Regional cooperation and consultation between SEMO WIRED and ADWIRED has been established.

Kentucky and Mississippi

In Western Kentucky, Commonwealth Agri-Energy is a farmer cooperative which promotes value-added agriculture and diverse uses for Delta-grown crops.[100] This model seeks to extend the agricultural supply chain from field to factory, incorporating bioprocessing to products such as ethanol, to retain value for farmers and local producers. Staffing for this model requires farmers, transporters, bio-processors, chemical plant technicians and a variety of other support staff to grow, harvest and convert crops into products.

Both Kentucky and Mississippi have strong agricultural programs through their land-grant universities. The pioneering ADTEC consortium could provide a model for collaborative and comprehensive workforce development programs in bioprocessing in these areas of the study region due to their economic, educational and agricultural similarities and proximity.

Observations and Conclusions

The replicable bioprocessing industry of the future will afford new industrial employment opportunities across the entire Mid-South Delta region. The region faces a collective challenge to develop a new highly-skilled bioprocessing workforce to staff the envisioned rural biorefineries. Fortunately, the region has models of visionary best-in-class programs to develop the bioprocessing workforce of the future. Transforming the educational opportunities in bioprocessing for the region will be successful if states, community colleges, WIRED networks, four-year institutions and technology training centers work collaboratively to advance the innovation and diffusion of curriculum and best practices, with the goal that all eligible students and workers in the region, regardless of their state of origin, have access to the most current and highest quality training in renewable energy technology. This knowledge-sharing includes consortiums and cross-establishment credit transfers as well as internship and externship programs. Specific recommendations include:

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[98] *Technical Education in Missouri's 25th Senatorial District: Resources, Needs and Recommendations*
[99] http://www.doleta.gov/wired/regions/3g_southeast_missouri.cfm
[100] http://www.commonwealthagrienergy.com/

- Expand the ADTEC (Arkansas Delta Training and Education Consortium) model for workforce development to other institutions in the study region. The ADTEC program has assembled the best practices in teaching and learning in renewable energy technology through a careful survey of programs nationwide. The ADTEC curriculum developers have created a rigorous and thoughtful curriculum adapted to the region's strategic advantage in diverse biomass and potential bioprocessing capacity. Students recruited into this program will have both the classroom and experiential skills and training to gain employment in potential biorefineries in the region. Given the uniformity of demographic characteristics throughout the Mississippi Delta study region, replicating the ADTEC program would be a sound economic and educational investment for other states in the region. ADTEC stands out as a program of excellence in renewable energy technology training in the region and throughout the United States.
- Utilize funding for dislocated workers and youth employment to train individuals for careers in the developing Mid-South Mississippi Delta bioprocessing industry. Workforce Investment Boards and Agencies have funding for training and educating workers which can be utilized to enhance workforce development in renewable energy technologies.
- Develop a Work KEYS bioeconomy skill set and compatible industry certificates for entry-level jobs in renewable energy technology. Work KEYS is a nationally-recognized skills assessment program (*Appendix, Table 4 in the full report)* for employment-seeking adults. Work KEYS skills serve as employment currency and can be utilized as a first step toward employing workers in renewable energy technology in the five-state region. A Work KEYS job database with required skill levels for occupations in renewable technology industries can be assembled.

C. Industrial Infrastructure

This summary is excerpted from the study sub-report "Industrial Infrastructure & Economic Development" prepared by BioDimensions, Inc. and the sub-report "Logistics Assessment of the Delta Region" prepared by Strata-G LLC. The full sub-report is available online at www.agbioworks.org.

Introduction

Biorefineries, which process biomass feedstocks, will often be sited in rural locations, to minimize transportation costs for the incoming low-bulk density biomass. The fuel and chemical biorefineries of the future will most closely resemble chemical factories in terms of infrastructure, unit operations, and complexity. Co-siting of first generation biorefineries in the Delta region with existing industrial infrastructure—or repurposing of idled infrastructure—will be desirable to reduce capital, leverage existing competencies, and mitigate risk inherent in early-stage projects. Highly-skilled technical and operational personnel will be required to staff technically sophisticated fuel and chemical biorefineries.

Equipment and Facility Requirements

Feedstock pre-processing or densification facilities will primarily use physical processing equipment to grind, extract, dry, package, and/or densify biomass, usually in preparation for combustion as solid fuel or downstream conversion in biorefineries to other products. Biorefineries producing liquid fuels and chemicals can be described as "heavy industry." Although different conversion technologies need specific processing infrastructure requirements, some general characteristics for existing industrial infrastructure adaptable to biorefineries are summarized in Table 26.

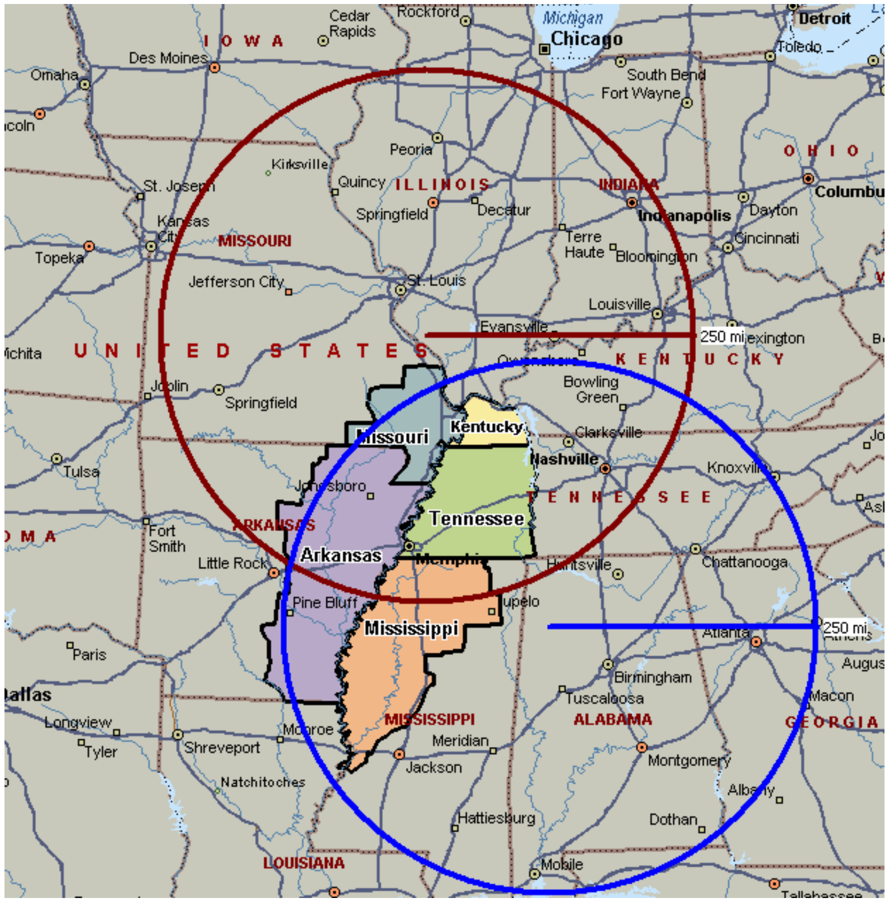
Table 26: Infrastructure Adaptable to Biorefineries

Equipment	Desirable Characteristics or Use
Processing	
Process vessels/fermenters	Stainless steel; agitated
Distillation columns	Stainless steel
Heat exchangers	Process heat transfer
Size reduction equipment	Hammermills/crushers for biomass
Material Handling	
Warehouses	Heavy floor loading
Warehouse equipment	Fork trucks, scales, packaging
Rail siding	
Truck scales	
Liquid bulk tanks	50K gallons+
Liquid truck/rail unloading station	Spill containment
Dryers	Biomass or solid products
Filters/Centrifuges	Solid-liquid separation
Utilities	
Process steam boiler	Solid fuel (coal/biomass); natural gas
Water cooling towers	Non-contact process cooling
Closed loop refrigeration	Non-contact process cooling
Process water filtration system	Process contact water
Waste water treatment system	Activated sludge
Carbon dioxide capture/compression	Co-product sale; process inerting
Support	
Laboratory facility	Fume hoods, analytical instruments
Maintenance facility	Welding, milling, cutting equipment

Utility Requirements

Liquid fuel and chemical biorefineries will require reliable electric service, process water, waste water disposition, and process heat and cooling. Process cooling can be provided by heat exchange using one-pass non-contact cooling water from surface water sources or wells, or by closed loop refrigeration systems using water or circulating refrigerants. Process heat can be provided by electrically heated systems (such as circulating oil), but is more typically (and economically) provided by high pressure steam generated from an on-site boiler and distributed through local supply piping. Traditionally, process industry steam boilers have used natural gas or coal as the energy source, but biorefineries may find it advantageous to install biomass-fired boilers for steam generation, to further utilize available biomass and/or provide for disposition of co-product streams. Furthermore, biorefineries in some rural locations may not have ready access to natural gas as an energy source. Alternatively, the Mid-South Mississippi Delta strategy area is positioned to readily access coal supplies from either southern Illinois or northwest Alabama, via 1-day round-trip truck transport, as shown in Figure 22. Coal is often advantaged relative to natural gas from a delivered cost basis, and its energy density and ease of storage may make it desirable for consideration as a process energy feedstock for rural biorefineries, either exclusively or co-fired with biomass. The relatively modest process energy supply requirements of a rural fuel or chemical biorefinery could make trucked coal a viable alternative, possibly advantaged from a reliability and cost perspective.

Figure 22: Trucked Coal Range for 1-Day Round-trip to Regional Biorefineries



Logistics Requirements

Most Biorefineries will source biomass feedstocks by truck from adjacent farm and forestlands. Good local secondary road infrastructure is essential for inbound biomass logistics. Transportation models generally indicate that a maximum 25-mile radius sourcing area is preferred to minimize freight costs. While maximum weight loads of about 25 tons are desirable, the bulk density of some biomass feedstocks may limit capacity to volume rather than weight. Biorefinery products, particularly liquid fuels and chemicals, will have much higher density than feedstocks and can generally be transported economically by truck, rail, and barge. Higher volume liquid transportation fuel products could be transported efficiently by barge, but a future mature industry producing compatible fuel products would likely take advantage of refined liquid fuel product pipelines which transect the strategy region, as the most economical mode of export.

Use of Cotton Gin Sites for Biomass Processing

Idled or operational cotton gin sites and infrastructure represent substantial existing processing assets in the Delta region that may be adaptable to pre-processing or refining of biomass feedstocks. Cotton gins are located in rural areas near cotton production sites, and they consist of biomass processing facilities with power intensive equipment, loading/unloading equipment, and storage/staging areas. U.S. cotton production has decreased since 2005, resulting in excess ginning capacity and numerous idled facilities.

Operational gins typically process less than three months out of the year during the cotton harvesting period, and in recent times, some gins operate for much shorter periods of time.

Research is currently being conducted by the USDA Agricultural Research Service (ARS) on utilizing traditional cotton gin equipment to process flax-cotton fiber blends.[101] The potential disadvantage of utilizing traditional cotton gin equipment to process other biomass is the risk of contaminating the gin equipment with foreign objects and fibers; however, this is perceived to be a low risk because gin equipment is cleaned each season before processing begins.[102]

ARS personnel also indicate it may be possible to modify traditional gin equipment or utilize additional specialized equipment modules in combination with traditional equipment for pre-processing other biomass feedstocks such as corn stover, pulp wood, and herbaceous energy crops. For example, existing dryer units and pneumatic transfer lines may be used in conjunction with modified equipment for size reduction of crop residues (e.g., corn stover) or dedicated energy crops (e.g., switchgrass), and existing hydraulic bale compressing equipment may be useful to achieve desirable densities of biomass bales.

Idled gin infrastructure and site footprint would be generally adaptable to solid fuel pellet or briquette production which can be accomplished in a single-floor building, with three-phase electrical service and adequate feedstock and product staging areas.

Another well-suited application would be commercial-scale juice extraction from sweet sorghum for ethanol production, using a stationary roller-mill at the gin site. The rural location of many gins, and the need for new value-added crops to replace cotton, would fit well with the development of sweet sorghum production as an energy crop. The sugar-containing juice is readily fermentable to ethanol, either at the gin, or other centralized location. The bagasse could be used to generate process energy for co-sited ethanol production or as a lignocellulosic feedstock for solid or liquid fuel production.

Expansion of bioprocessing at operational cotton gins would allow year-round operations, creating permanent jobs and allowing development of higher-skilled workers and higher-paying jobs.

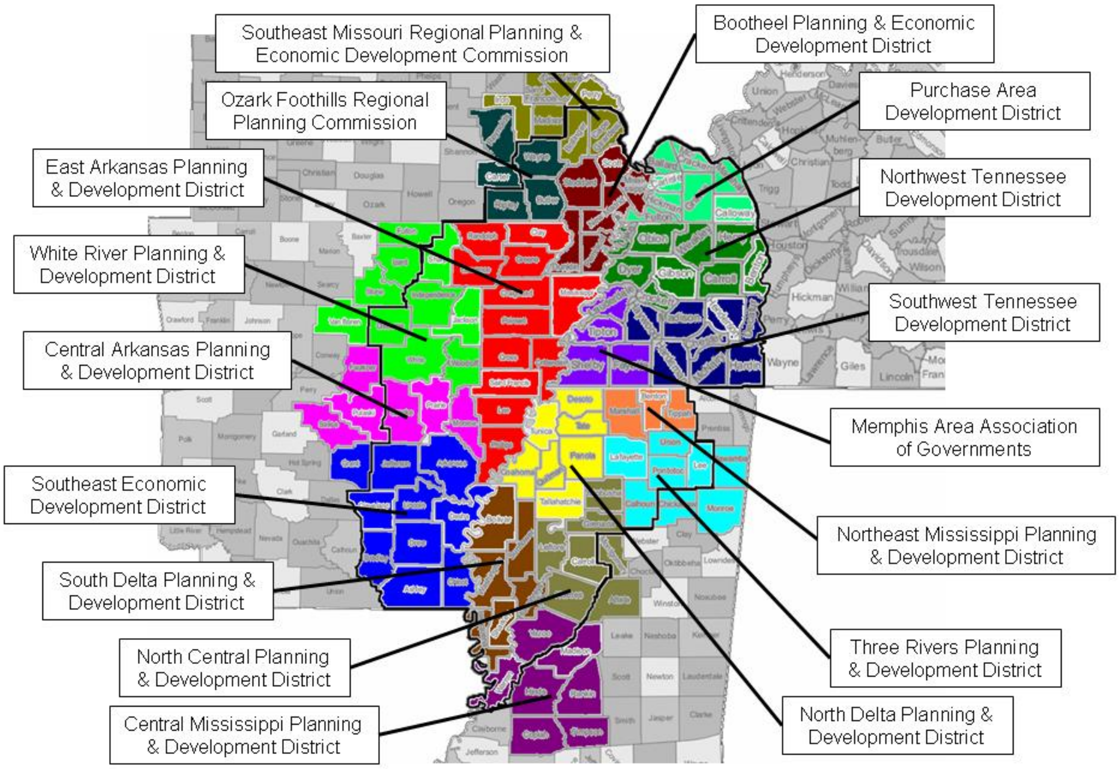
Economic Development Districts

The Strategy area counties overlap 17 Economic Development Districts, as shown in Figure 23. Most Districts maintain websites, which are an excellent resource for detailed information on industrial sites (city/county), photos, blueprints, and contacts for existing and green-field industrial locations within the study region.

[101] Foulk, J. A.; Dodd, R. B.; McAlister, D.; Chun, D.; Akin, D. E.; Morrison, H. (Available online September 2006) “Flax-cotton Fiber Blends: Miniature Spinning, Gin Processing, and Dust Potential.” *Industrial Crops and Products*, Volume 25, Issue 1, published January 2007, Pages 8-16.

[102] Thompson, Dale, National Cotton Council. Interview with Kevin Mitchell. October 20, 2008.

Figure 23: Economic Development Agencies in Study Region



Observations and Conclusions

Biorefineries will most closely resemble chemical factories in terms of infrastructure, unit operations and complexity. Highly-skilled technical and operational personnel will be required to staff technically sophisticated biorefineries.

Co-siting of first generation biorefineries in the region with existing industrial infrastructure will be desirable to reduce capital, leverage existing competencies, and mitigate risk inherent in early-stage projects.

Idled or operational cotton gin infrastructure represents a substantial existing processing asset in the Delta region that may be adaptable to new biomass operations, such as pre-processing, pelletizing/briquetting, or rural sweet sorghum ethanol production.

The 17 Economic Development Districts within the study region are an excellent source of detailed information and assistance for project siting and planning.

D. Environmental Issues

This summary is excerpted from the study sub-report "Environmental Considerations of Bioenergy in the Mississippi Alluvial Valley" prepared by Winrock International. The full sub-report is available online at www.agbioworks.org.

Introduction

The United States has set a goal of replacing 30% of petroleum-based transportation fuels with renewables within the next 20 years and the Mississippi Alluvial Valley (MAV), which incorporates much of the 98-county study region, has the opportunity to play a strong role in achieving that goal. Motivations for this goal include both environmental and national security. Bioenergy is widely believed to generate fewer greenhouse gas emissions and thus reduce contributions to global climate change, and there is increasing interest in finding alternatives to petroleum to increase national security and strengthen local economies. This report outlines the major environmental considerations associated with cultivating energy crops for use as liquid biofuels for transportation or as solid biomass for electricity generation in the Mississippi Alluvial Valley.

Greenhouse Gases (GHG)

Greenhouse gases are chemical compounds found in the Earth's atmosphere that absorb infrared radiation and trap heat in the atmosphere. There are both naturally occurring and manmade greenhouse gases. Naturally occurring water vapor, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are the most common greenhouse gases. There is increasing concern among scientists and global citizens that rising concentrations of greenhouse gases in the Earth's atmosphere are causing global climate change. Since much of these gases are generated through the combustion of fossil fuels, alternatives to fossil fuels for energy use are increasing, including the use of plant matter-based energy sources.

Energy crops are often said to be 'carbon neutral'. This shorthand term 'carbon' covers not only carbon dioxide but other greenhouse gases as well. The reason for the apparent neutrality is that growing plants absorb a similar amount of carbon dioxide to that generated during their combustion. This, however, does not account for all the emissions produced from the cultivation and conversion of that crop into biofuel or bioenergy end uses, which can be mitigated by replacing the liquid fuels used in agricultural production with biofuels, and the energy sources used in biofuels facilities with renewables.

The greenhouse gas emissions associated with a product are not measured but are calculated using an engineering approach called life cycle assessment (LCA). LCA studies are becoming the standard method of estimating environmental impacts of products and of comparison between products. Life cycle assessment practices are becoming increasingly refined but much uncertainty still exists. The fundamental concept of an LCA is that each process involved in creating a product is analyzed for its impact on the environment and these impacts are aggregated across the life of the product, often referred to as "cradle to grave", for example from seed to combustion in an engine in the case of soybeans grown for biodiesel.

GHG Emissions from Crop Production

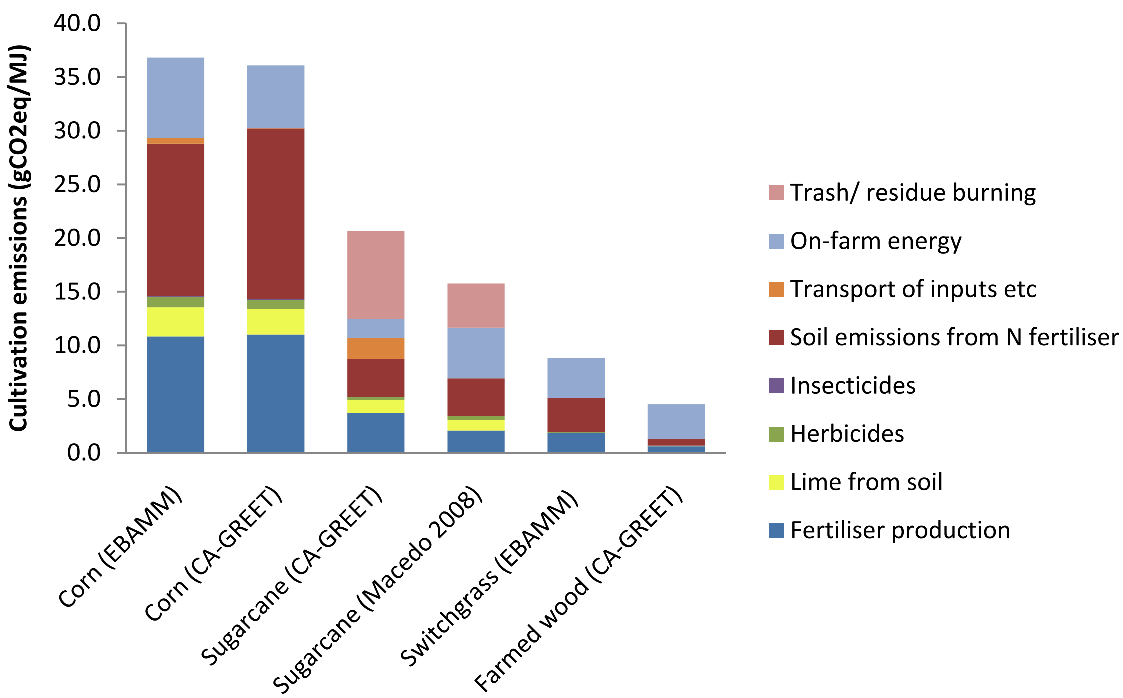
The first step in determining the greenhouse gas impacts of bioenergy is to assess the feedstocks. These considerations are the same regardless of the end use of the feedstock, whether it ultimately becomes a liquid transportation biofuel or biomass used for combustion to generate electricity. There are numerous components to consider with regard to crop production, but the five most impactful are:

- Fertilizer production
- N_2O emissions from crop production
- Carbon sequestration in soils
- Land use change
- Yield improvements

N_2O Emissions from Fertilizer and Crop Production

Fertilizers contribute to greenhouse gas emissions in two ways: from the energy and processing associated with their production and from nitrous oxide emissions generated from their application in the field. The type of nitrogen fertilizer used can make a substantial difference to the cultivation emissions. This is because energy required for the production of fertilizers differs and often results in substantially different emission factors. The GHG emissions associated with fertilizer production and subsequent nitrous oxide (N_2O) emissions from the field, which are directly proportional to the fertilizer applied, are substantial contributors to cultivation emissions (see Figure 24). Woody and herbaceous crops generally require less fertilizer on an annual basis than annual crops such as corn, which translates into a large benefit in current calculations.

Figure 24: Comparison of the Emissions Associated with Cultivation of Ethanol Feedstocks



Source: UC Berkeley (2006), CARB v2 (2009), Macedo *et al* (2008)

N_2O emissions from crop cultivation are one of the largest sources of GHG emissions. According to the 4th IPCC report, the Global Warming Potential of this GHG is 298 times greater, weight for weight, than CO_2. [103] Direct N_2O emissions have been shown to increase with the nitrogen

[103] IPCC, 2006

application rate. These represent up to 80% of the GHG emissions from biofuel production[104] and are one of the most uncertain areas when calculating GHG emissions for biofuels and other bioenergy crops. Winrock is currently conducting a study more closely investigating the linkages between fertilizer application practices, soil type, water conditions and N_2O emissions. One of the field sites for this study is located within the MAV region. Results of this study will contribute regionally specific data to further inform this area of greenhouse gas consideration.

Carbon Sequestration in Soils

Sequestration or release of carbon from soils can significantly affect the lifecycle GHG profile of bioenergy crops. Soil organic carbon represents an important carbon sink for bioenergy crops and strongly impacts soil quality. The soil carbon sequestration potential varies depending on soil type and surface texture, climate conditions and crop rotation.

Land use change from uncultivated to cultivated agricultural land results in soil carbon losses that can negate any positive effect of bioenergy as compared to fossil fuels. Crop residue removal, specifically corn stover removal, can also negatively impact soil carbon content. A recent study shows that even a 25% removal of corn stover reduces soil carbon. In contrast, soil carbon sequestration under perennial grasses like miscanthus and switchgrass represents a substantial opportunity to improve the GHG performance of biofuels.[105]

Crop residue contributes to soil organic matter and nutrient increases, water retention, and microbial and macro invertebrate activity. These effects typically lead to improved plant growth and increased soil productivity and crop yield, however some studies have illustrated these residues can contribute to increased N_2O emissions and reduced yields.[106] While the addition of residues can assist in building up soil carbon, N_2O emissions from crop residues are not always taken into account in biomass GHG calculation methodologies but are potentially important.[107] More research is needed to investigate the interactive effects of tillage, fertilizer application and crop rotation as they affect carbon sequestration, methane uptake and N_2O fluxes.

Land Use Change

GHG emissions associated with changing from one land use type to another, particularly converting from native forest or grasslands to agricultural land, can be considerable and often sufficient to negate the GHG benefits of bioenergy crops. There are two types of land use change: *direct* and *indirect*. *Direct* land use change occurs when native forest or grasslands are converted to agricultural land to produce a crop. This situation is relatively straight-forward.

Indirect land use change is more complicated. The overarching hypothesis of the indirect land use change debate is that diverting existing crops to biomass production induces a land-use change somewhere else in the world to 'fill the gap' in demand for the existing crop. For example, if efforts are made to shift from current production of soy, cotton or other crops within the MAV, the argument is that production of these crops will not simply go away but that they will be produced elsewhere on the planet and that it is likely that forestland or native grassland will be converted to agricultural land to accommodate the new crop production. The consequential GHG

[104] Smeets *et al*. 2009
[105] Anderson-Teixeira *et al* 2009
[106] Six *et al* 2002
[107] The C/N ratio of crop residues appears to be a key variable in determining the amount of N2O produced but here are no process-based models that integrate above- and below-ground dynamics with respect to C and N for biomass crops. Rather than rely on IPCC, one suggestion is for landscape scale estimations of N2O emissions from residues based on area-based quantities of nitrogen in crop residues by crop type (JRC, 2004).

emissions from this land use change are attributed to the biofuel and are so large they negate any fossil displacement benefit.

Policy-makers including the US Environmental Protection Agency (EPA) and California Air Resources Board (CARB) are currently proposing to include land use changes (including indirect) in LCA methodologies for biofuels. This approach is controversial and is the topic of much on-going debate.

Yield Improvement: Improving yield for a given fertilizer application rate provides substantial improvements for the GHG balance of any bioenergy crop. Understanding the impact of different agronomic factors on yield is essential to enable producers to optimize their production systems and improve the GHG balance. Yield increases are a key element of improving GHG balances of biofuels and other bioenergy crops but increased water requirements for increasing yield must also be recognized. Proposals for focusing biofuels on “marginal land” are based on the concept of eliminating competition with food crops or mitigating indirect land use changes with negative implications. The economic and environmental costs of increasing yield in these areas may be greater than the possible returns.

Biofuels and GHG Emissions

Over recent years as energy security and environmental concerns have risen up various political agendas, there has been a substantial interest in biofuels and their potential contribution to energy security, mitigation of GHGs in the transport sector and also in delivering rural economic development benefits. It has been suggested that these criteria should be used to determine if a biofuel is a viable alternative to a petroleum-based fuel: the biofuel should provide a net energy gain, have environmental benefits, be economically competitive, and be able to be produced on a large scale without reducing food supplies.[108]

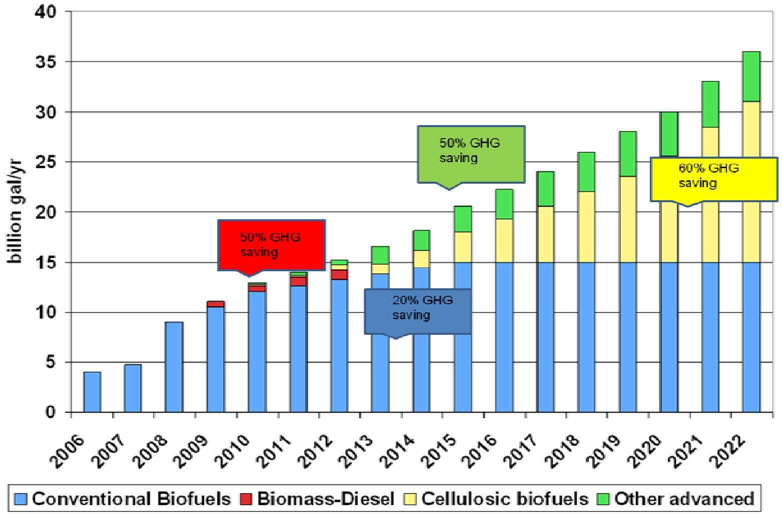
The U.S. Energy Independence and Security Act of 2007 (EISA) will increase the original Renewable Fuels Standard (RFS) target[109] of 4 billion gallons of renewable fuel production in 2006 to 36 billion gallons by 2022. The EISA categorizes fuels and caps the so-called ‘conventional’ renewable fuel (corn starch ethanol), so that by 2022, 21 billion gallons of the 36 billion gallons required must come from cellulosic biofuels or advanced biofuels derived from feedstocks other than cornstarch.

The categorization of fuels within EISA contains specific life-cycle GHG emissions for biofuels relative to life-cycle emissions from fossil fuels as Figure 25 illustrates. The EISA states that these lifecycle emissions must include direct and indirect emissions.

There is substantial discussion regarding the GHG emissions of biofuels and opportunities to meet climate change goals through promoting their use. Biofuels produce emissions throughout their production that are intended to be substantially less than their fossil equivalent and thereby represent a beneficial substitution. A majority of studies illustrate that biofuels can indeed deliver positive GHG balances compared to the fossil fuel reference. The assumptions under which these studies have been performed largely represent average conditions. Therefore, each feedstock will have a range of GHG savings or emissions depending on the model assumptions or real-life practices.

[108] Hill *et al*, 2006
[109] Established in the Energy Policy Act of 2005; currently under additional revision

Figure 25: Current EISA volume and GHG requirements

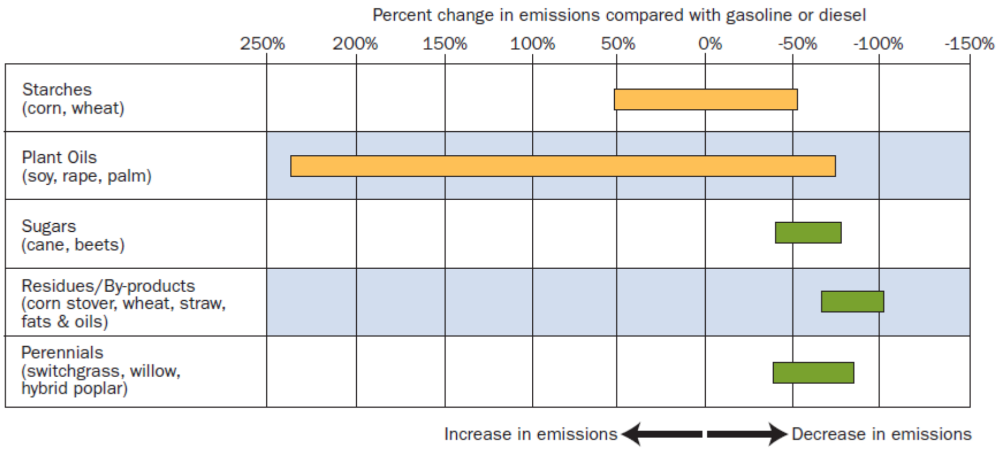


The specifics of the system under study are critical to the analysis. Generalizations about a biofuel's ability to deliver greenhouse gas reductions cannot be made based on the feedstock alone. For example, Figure 26 below shows the range of impacts and opportunities by feedstock type and one can see that there is considerable variability within feedstock categories. The widest variability is present within the plant oils category. Depending upon crop production, processing and co-product choices, the GHG impact of plant oil-based biofuels can range from a 75% decrease in emissions to a 225% increase in GHG emissions. This is particularly important to the MAV region where new oilseed crops for biofuel production are being considered. It will be vitally important to conduct regionally specific comparative LCA studies among the primary feedstocks and processing technologies under consideration to get a true sense of GHG reduction potential in the region.

One promising note is that camelina, one of the potential new oilseed crops suggested for consideration for the MAV region, is showing much promise as a biofuel feedstock because of a positive combination of many of the factors. A recent news report quotes David Shonnard, Robbins Chair Professor of Chemical Engineering at Michigan Tech as saying, "Camelina jet fuel exhibits one of the largest greenhouse gas emission reductions of any agricultural feedstock-derived biofuel I've ever seen. This is the result of the unique attributes of the crop—its low fertilizer requirements, high oil yield, and the availability of its co-products, such as meal and biomass, for other uses."[110]

[110] Michigan Tech, 2009

Figure 26: Impact on GHG Emissions by Biofuel Feedstock



NOTE: The data do not necessarily include impacts from land use changes (which are particularly important when land is converted from a natural system to agricultural land).

SOURCES: Data compiled from various fuel life cycle analyses. For starches, the minimum value is from Patzek (2007) and the maximum value is from Wang (2006), as modified by University of California–Berkeley researchers and reported in Turner et al. 2007. For plant oils, the minimum value is from Delucchi (unpublished) in Farrell and Sperling 2007a, and the maximum value is from Bauen et al. (2007). For sugars, data are from Bauen et al. (2007). For residues/by-products, data are from the International Energy Agency as reported in Worldwatch Institute 2007. For perennials, the minimum value is from Delucchi (2005) and the maximum value is from Wang (2006).

Source: Union of Concerned Scientists, 2007

The biofuels processing stage has a large influence on GHG emissions. Considerably worse performance is demonstrated if coal is used for process energy and better performance if natural gas or biomass is the energy source, but in all cases cellulosic ethanol performs considerably better in comparison. There are a host of detailed and comprehensive analyses of the fuel chain specific emissions from biofuels. These provide the foundations for establishing guidelines for reductions and fuel chain pathway GHG emission quantification. The U.S. federal government is attempting to more clearly and comprehensively define the process by which LCAs for biofuels are conducted.

Bioenergy and GHG Emissions

Energy crops can also be converted into electricity rather than transportation fuel by either combusting them directly, alone or in combination with coal, or by first gasifying the biomass and using the resulting synthesis gas to generate electricity. According to the Department of Energy's National Renewable Energy Laboratory, co-firing biomass in coal-fired power plants "is a near term, low-cost option for efficiently and cleanly converting biomass to electricity by adding biomass as a partial substitute fuel in high-efficiency coal boilers." This approach has been proven in all commonly used utility boiler types.[111]

Beyond simply being technologically feasible, co-firing reduces emissions of carbon dioxide and reduces emissions of sulfur compounds such as sulfur dioxide that will then reduce acid rain. Early woody biomass co-firing tests also showed a nitrogen oxide (NO_x) reduction potential as great as 30%.[112] Strategically, the use of lignocellulosic feedstocks for bioenergy, which is commercially proven, can assist in developing a feedstock supply chain for biofuels, which is not yet commercially developed. Reducing this initial risk can provide options for the future. The Chariton Valley Biomass Project in Iowa, currently stalled due to non-technical issues, is an on-going attempt to develop commercial scale switchgrass production and co-fire it with coal.

[111] NREL, 2000
[112] Ibid

Optimizing GHG Reductions

Current technology allows for multiple processing options from biomass. As discussed, energy crops can be used for liquid transportation fuels as well as to generate electricity, from which many vehicles could also be powered in the future. A key consideration with biomass-based systems is determining the most efficient use of the land necessary to cultivate the crop. A life cycle assessment conducted by Cambell concludes that cropland can deliver more transportation and GHG offsets from bioelectricity than ethanol. This conclusion is supported by Adler in his comparison of the life cycle of bioenergy cropping systems. Adler showed that on a unit-area basis of crop production, gasification of perennial grasses and hybrid poplar produced more than double the GHG reductions yielded by converting these crops to ethanol.[113]

This work is of significant importance to the MAV region where optimizing cropland in order to most efficiently balance food and energy needs is an important consideration. A regionally-specific investigation of the life cycle impacts of proposed biofuels and bioenergy scenarios will be critical to determining the best strategy for designing an optimal energy crop scenario for the region.

Air Pollutants

In addition to positive greenhouse gas benefits, bioenergy is believed to have considerable potential for reducing criteria air pollutant emissions. Criteria air pollutants are those common contaminants that are regulated under the Clean Air Act. These pollutants consist of particulate matter (PM), ground-level ozone (O_3), carbon monoxide (CO), sulfur oxides (SO_x), nitrogen oxides (NO_x), and lead. According to the U.S. Environmental Protection Agency (USEPA), particulate matter and ground-level ozone are the most widespread human health threats among these pollutants. The U.S. EPA has established National Ambient Air Quality Standards for these six pollutants. Geographic areas that do not meet these standards are designated as "non-attainment" areas. There is one non-attainment area within the 98-county study area of the MAV. The Memphis area, which includes Shelby County, Tennessee, and Crittenden County, Arkansas, is in non-attainment for ground-level ozone. Pulaski County, Arkansas, is expected to soon be designated as non-attainment for ground-level ozone as well. Ground-level ozone is created by the interaction between NO_x and volatile organic compounds (VOC) in the presence of sunlight and is particularly problematic in urban areas where these constituents are readily available from tailpipe emissions, industrial emissions and other sources. Biofuel emissions analyses of the U.S. Department of Energy's Alternative Fuels & Advanced Vehicles Data Center are discussed within the full report.

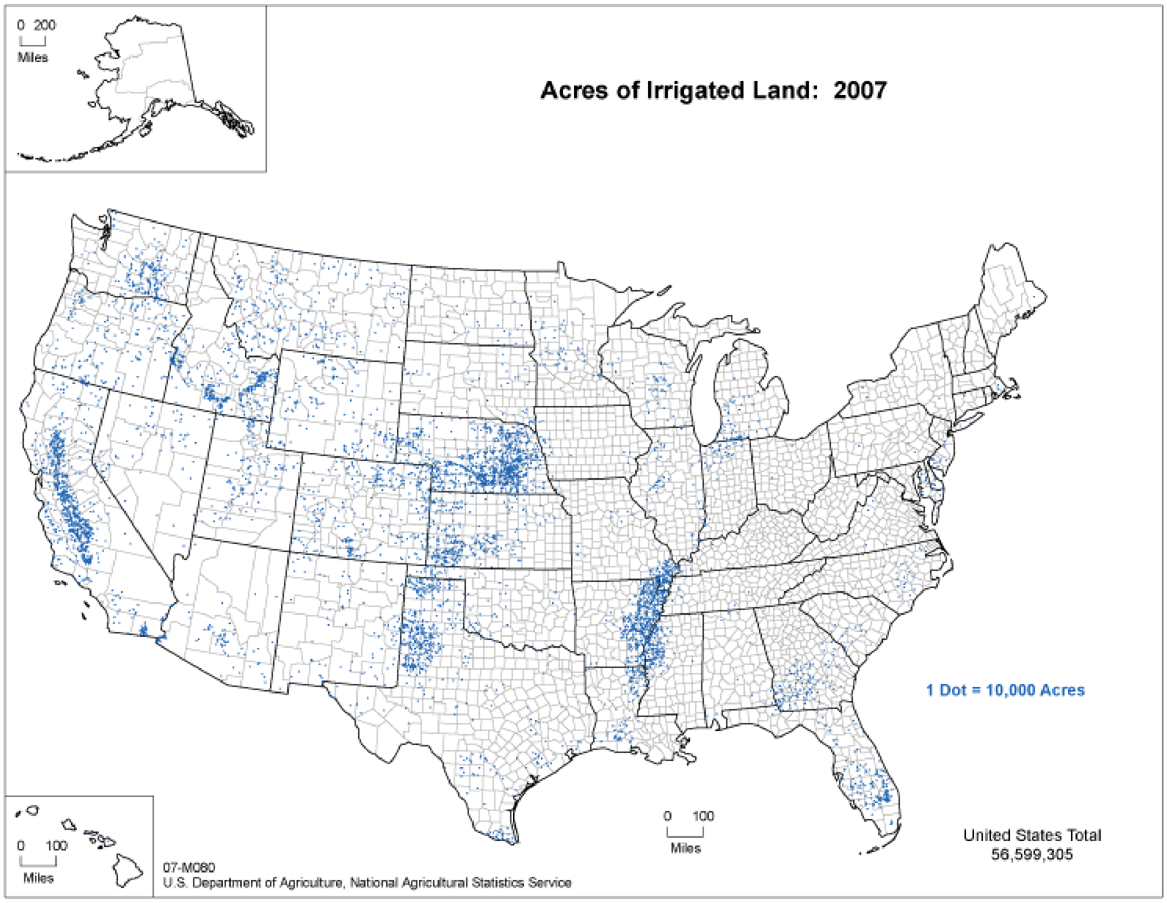
Co-firing biomass with coal for electricity production will also have a positive effect on air pollution. CO_2 and SO_2 emissions decline in proportion to the amount of coal offset by biomass. NO_x emissions are more difficult to quantify but have been shown to decline by up to 15% compared when coal is co-fired with biomass.[114]

Water

While the subject of GHG emissions is discussed widely with respect to bioenergy, considerations regarding water usage have lagged behind. But, this is now changing. Given the substantial volume of water consumed in the agricultural phase of production, water quality issues associated with agriculture, water use and release in processing, and the potential limitations of water availability in many regions of the world, these issues deserve further attention. This is an important consideration for the MAV region, which region relies heavily on irrigation (Figure 27).

[113] Adler *et al* 2007
[114] EESI, 2009

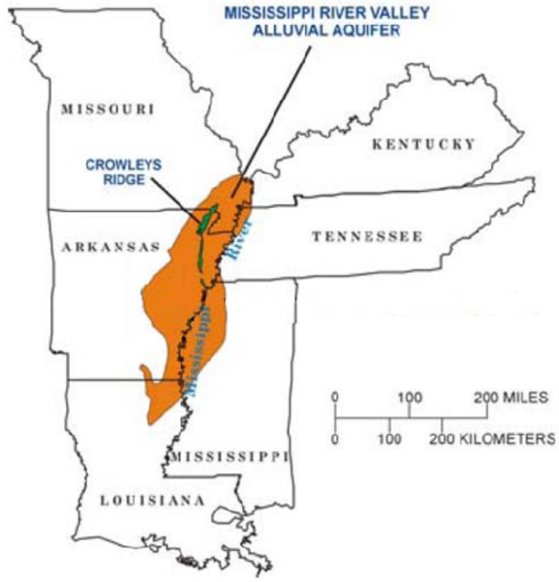
Figure 27: U.S. Acres of Irrigated Crop Land



Much of the irrigation water in the MAV is groundwater extraction from subsurface aquifers. One important agricultural source of groundwater is the Mississippi River Valley Alluvial Aquifer, shown in Figure 28 below. Aquifers in the region are currently under strain and are drawing attention from researchers and citizens. The United States Geological Survey (USGS) plays a vital role in research and education around groundwater issues in the region. Regarding the Mississippi River Valley Alluvial Aquifer's future, USGS researchers state,

> *"Ground water from the Mississippi River Valley alluvial aquifer can be a sustainable resource if managed properly. However, the rate at which ground water is being pumping cannot be sustained indefinitely, as indicated by large water-level declines and really extensive cones of depression, without some form of management. Management alternatives might include artificial recharge to the aquifer, limits on withdrawals from the aquifer, switching to withdrawals from other aquifers, conjunctive use of ground water and surface water, or a combination of approaches."*

Figure 28: Mississippi River Valley Alluvial Aquifer



Source: (Czarnecki *et al*, 2002)

Quantifying Water Use

There has been considerable effort in the global community to reach a consensus regarding the concept of the "carbon footprint" as a way of quantifying the amount of damage done to the atmosphere resulting from human activity. A similar idea has been taking shape to describe the amount of water consumed during a product's lifecycle to quantify the impact on the global water supply—i.e., the "water footprint" or "embedded water."[115]

From the perspective of most efficient use of water, a recent study conducted on the water footprint of bioenergy stated that the water footprint of bioenergy in general is large when compared to other forms of energy. The authors concluded that generating electricity from biomass is more efficient than producing biofuels because electricity generation makes use of the entire plant's yield rather than only the starch or oil fraction. They state that "For most crops, the WF [water footprint] of bioelectricity is about a factor of 2 smaller than the WF of bioethanol or biodiesel." The study also concluded that, in general, ethanol has a smaller water footprint than that of biodiesel, but that there is extensive variation in results depending upon the crop used, climate conditions in the geographic location of production and the agricultural practices used for crop cultivation.[116]

Water Use in Energy Crop Production

Clearly, the types of crops grown for biofuels and their location will influence outcomes for water use and quality. These issues have not yet been explored in sufficient detail to establish any robust conclusions on the impacts for water of increased demand for biofuels and changing agricultural patterns but must be undertaken in a regional context to have any real meaning. Improving water productivity (using less water per unit output) for biofuels has been proposed as a positive sustainability indicator, but will only really deliver a sustainable outcome if the context is understood. For some crops in areas with no water scarcity, reducing water use will not have any real impact.

[115] Chapagain and Hoekstra 2004, as cited by Fingerman et al. 2008
[116] Gerbens-Leenes et al, 2009

The current discussion that surrounds biofuels and potential negative impacts on land use change have led to recommendations for crop yield and biofuel yield increases to enable greater productivity per unit of land.[117] The linear relationship between yield and transpiration relates to yield of total above-ground plant biomass and therefore the increases in yield, if delivered in response to the policy recommendations, will require increased water resources.[118] Any recommendations for significant yield increases should recognize and mitigate negative impacts on water resources where such risks exist.

Water Use in Biofuel Processing

The amount of water consumed during biofuel production depends on the production process itself and the degree of water reused and recycled. The proportion of water used during biofuel processing is much smaller than that of the feedstock cultivation stage and generally represents around 1–2% of use compared to the 98%–99% during cultivation. For feedstocks that do not require cultivation (such as residues), this proportion is reversed and weighted to the processing stage.

Water requirements for advanced processing technologies will vary. Research illustrates that with current technology, producing one gallon of cellulosic ethanol through a biochemical conversion process, such as dilute acid pretreatment followed by enzymatic hydrolysis, consumes 9.8 gallons of water, which can be reduced to 5.9 gallons with improved yield, but an optimized thermochemical conversion process for ethanol production requires only 1.9 gallons. This is compared to approximately 3 gallons for a typical dry mill corn ethanol plant. The same report finds that fast pyrolysis of forest wood residue consumes 2.3 gallons of water in producing one gallon of biofuel, and that with investments in better technology, there may be an opportunity to reduce this further. Improved process integration and further technological innovations are improving water recycling and reuse with the lowest reported water requirement at less than one gallon for each gallon of ethanol produced.[119]

Biodiesel refining requires less water per unit of energy produced than ethanol. Overall, consumptive use is about one gallon of fresh water per gallon of biodiesel and overall water use may be up to three gallons per gallon of biodiesel produced. Consumptive water use in petroleum refining also differs according to process technology and location, varying from less than three gal/gal gasoline for some Canadian tar sands and Saudi Arabian crude oil to as high as seven gal/gal for domestic crude in certain U.S. locations.[120]

Water Quality

Energy crop production and processing can also present water quality problems. For many crops, applying fertilizers, such as nitrogen and phosphorus, and herbicides, fungicides, insecticides, and other pesticides can result in detrimental water quality impacts including increased nitrate and sediment loading in waterways. These increases can contaminate drinking water supplies, reduce oxygen content in the water, produce sulfides and ammonia, and negatively affect the local ecosystem. Changing cropping patterns to accommodate new biofuel crops and promoting the use of 'degraded,' 'marginal' or unmanaged grasslands to cultivate crops requiring fertilization could likely lead to much higher application rates of nitrogen which could, in turn, increase the severity of the nutrient pollution in waterways.

Soil

Much of the discussion around cultivating energy crops is common to any discussion of intensive agricultural production. Sustainable agricultural practices like conservation tillage (or "no-till") and more

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[117] Searchinger et al. 2008; Fargione et al. 2008; RFA 2008

[118] However, increased plant densities to deliver increased yield also decrease evaporation losses from the soil. Thus total evapotranspiration would not increase proportionately with increased plant density and some of the reduced evaporation losses would be partitioned over to transpiration.

[119] Wu *et al*, 2009

[120] Ibid

efficient use of nutrients are important considerations with increasing energy crop production as they are with food production. These practices address two important parameters of agricultural production: erosion and nutrient management. Conservation tillage has the environmental benefit of reduced erosion from crop lands and thus reduced sediment loading of waterways and water bodies. This reduction in sediment loading also results in better nutrient management, specifically reductions in phosphorus loadings from soil-bound phosphorus.

Energy crop production has the potential to generate additional soil-related environmental benefits with the introduction of perennial crops onto cropland that is currently in annual production. Perennial trees and grasses offer the opportunity to significantly reduce fertilizer use and its associated nutrient pollution issues and improve soil carbon stocks. These benefits are above and beyond the reductions in fossil fuel use and represent an opportunity to decrease erosion, better manage nutrients, reduce greenhouse gas contributions from crop production and build soil carbon.[121]

Observations and Conclusions

The 98-county study region and the Mississippi Alluvial Valley have the opportunity to play an important role in developing a strong domestic renewable energy sector. There is productive cropland and an experienced agricultural sector that can be dedicated to cultivating energy crops and a strong transportation and logistics infrastructure available. Developing bioenergy processing and production capacity represents a promising opportunity to take a leadership role in U.S. clean energy efforts.

- The region's strong agricultural infrastructure positions it well for success with new crops for liquid fuel production and other end use options.
- Co-firing biomass in coal-fired power plants is a commercially proven, low-cost option for efficiently and cleanly converting biomass to electricity. Strategically, co-firing of lignocellulosic feedstocks can assist in developing a feedstock supply chain for biofuels, which is not yet commercially developed. Within the study region, proximity to commercial coal-fired electric generation plants presents opportunities for co-firing biomass for electricity production.
- The region's strong logistics and transportation network also helps to position the MAV well for leadership in this sector.
- When considering introducing new energy crops and biofuel processing capacity into the region, leaders must consider the relative impacts of the multiple options on greenhouse gas emissions, air pollution, water use and water quality. The key to this effort will be doing thorough site specific life cycle assessment studies on the top options under consideration.

[121] Perlack *et al* 2005

E. SWOT Analysis

SWOT analysis is a strategic planning method used to evaluate the **S**trengths, **W**eaknesses, **O**pportunities, and **T**hreats involved in a project or in a business venture. During the performance of research and planning activities for the Mid-South Mississippi Delta project a considerable number of interviews and research activities were undertaken by the project team—generating a significant amount of information on the readiness and suitability of the region for biomass-based economic development. The SWOT format provides a logical framework for reporting some "topline" conclusions from this work.

STRENGTHS

Biomass Production	Substantial volume of biomass, much of it from existing underutilized resources, is available within the region from forest and agricultural land resources. This provides the ability to build an economy around a local, sustainable resource. High yield agronomic environment, benefiting from good soils, high levels of water availability, and a comparatively long growing season. Diverse range of crops grown and suited to the region's production environment, with major current crops including corn, cotton, hay, rice, sorghum, soybeans and wheat. Population of farmers with demonstrated capability and willingness to alter their crop portfolio in response to changing market conditions and opportunities. Production environment suited to growth of each main type of biomass crop—lignocellulosic, grains/starch, sugar crops and fiber. Limited pressure on agricultural land from urban and suburban sprawl (a serious issue in other parts of the nation). Regional demonstration projects taking place in alternative crops.
Infrastructure	Multiple high capacity pipelines for petroleum and natural gas distribution run through the region. Proximity to refined product pipelines sets the region apart, giving it a strategic advantage for blending and export of compatible second-generation liquid biofuels. Pipelines will be the preferred option for outbound movement of compatible second-generation biofuels. Memphis is a major logistics hub and the region is well served with rail, highway and river commercial transportation assets. The Memphis hub, which moves 19 million tons of cargo annually, can reach 60% of the U.S. population overnight via rail and road. The majority of the land available in the region for commercial construction is relatively flat, facilitating construction of facilities and lowering development costs. Region also has a climate allowing year-round construction work. Regional inventory of brownfield sites with good transportation access available for redevelopment. Existing base of refining and chemicals production facilities in the region with potential for adoption and use of biobased inputs. Multiple private research farms and university-related agricultural research and experiment stations provide a robust infrastructure for R&D and field trials in support of biomass production. Idle or underutilized assets in the cotton processing industry may be suited to alternative biomass applications with a higher-and-better use.
Economic Development	Comprises parts of five states, thereby increasing political capital available for projects (five governors, 10 federal senators, etc.) Region is served by 17 local economic development districts, providing on-the-ground local knowledge and services at a sub-regional scale. Presence of visionary, best-in-class training and workforce development programs serving the region. The ADWIRED-ADTEC model was developed using best practices from renewable energy technology programs across the U.S. and stands out as a regional and national leader.

WEAKNESSES

Biomass Production	There are doubts relating to the usability of crop residues from key crops in the region. Rice straw has a high silica content which is harmful to harvesting equipment, while corn stover in the region is typically ploughed under and used to return nutrients to the soil. Relative lack of regional agricultural-processing and food-processing operations lead to the bulk of food and feed commodities leaving the region for value-added processing. This also results in processing residues being unavailable within the region for those commodities processes externally. Technologies for forest residue biomass collection and consolidation are untested in the region. Forest biomass is held by a great many forest land owners, many of which are not actively engaged in the management or sale of their forest biomass. Conversion of cropland from cotton to alternative biomass crops will result in further decline in the economics of the cotton processing industry within the region.
Infrastructure	While the Mississippi River provides excellent north/south shipping capabilities, the majority of biomass will likely be used in local production applications, rendering the river only a marginal transportation asset for this sector. Barge transport of densified lignocellulosic biomass, such as pellets or briquettes, as well as high bulk density chemical and fuel products for export may represent a regional advantage. Limited bridge crossing points on the Mississippi complicate the siting of biomass processing operations in terms of access and transportation of low-bulk density biomass. Ethanol, the near-term bulk biofuel opportunity for the region, is not able to be transported using existing petrochemical pipeline infrastructure.
Economic Development	Multiple state and local economic development jurisdictions complicate implementation of a unified economic development strategy. Variations in state policies pertaining to renewable fuel standards, renewable portfolio standards, biomass project incentives and supports, etc. create an uneven economic development playing field across the five state region. Relative lack of organized farmer cooperatives makes joint-farmer investments in shared biorefineries and other captive infrastructure more challenging to organize and perhaps less likely to occur.
Other	Comparatively low levels of regional education attainment present a workforce development challenge for an industry largely incorporating technical jobs classifications.

OPPORTUNITIES

Biomass Production	Demonstrated willingness of the region's farmers to adopt new crops and change their cropping profiles bodes well for participation in bioeconomy opportunities. Modern genetic and transgenic technologies, in combination with traditional breeding techniques, show significant promise for generating substantial increases in crop yields. Modern genetic and transgenic technologies are driving progress in the expression of positive output traits—creating high performance and higher value crops for industrial biomass applications Plant transformation techniques increasing the potential for the use of plants as biochemical "factories" for the production of high-value phytochemicals, biopharmaceuticals and nutraceuticals. Development and introduction of biomass crops with lower water consumption requirements (such as sorghum and perennial grasses) will lower pressures on regional aquifers driven by agricultural irrigation.
Infrastructure	Existing base of chemical companies, with associated knowledge and skills in the industry, provides a base of experience upon which to build a bio-based chemicals industry. Second-generation biofuels, such as biobutanol, may have greater opportunities for utilization of the high capacity refined product pipeline infrastructure in the region. Idle and underutilized cotton gin sites within the region may be available for repurposing to other bioeconomy uses (such as biomass concentration, pelletizing operations or sweet sorghum, juice instruction). Base of coal-fired electric power stations presents an opportunity for early-stage adoption of biomass for co-firing, thereby creating a captive regional market for biomass in the near-term. Strategically, co-firing of lignocellulosic feedstocks can assist in developing a feedstock supply chain for biofuels, which is not yet commercially developed. Major funding from the private and public sectors is driving intensive R&D and piloting projects for advanced biomass conversion technologies. Multiple pilot scale facilities for lignocellulosic biomass conversion are showing great promise for advancements leading to commercial cellulosic ethanol viability and the production of other value-added and specialty chemical products. Adoption of smart grid and other technologies facilitating the sale of electricity into the grid infrastructure will encourage the development of small-scale generating capacity. Variability in the scale of biomass conversion and biofuel production facilities means a broad range of operations, from multiple small and local biorefineries to large-scale refineries employing advanced technologies for high-value product fractionation. Current liquid fuels infrastructure for the fueling of on-highway vehicles can more readily accommodate biobased liquid fuels than alternative proposed options such as hydrogen or rechargeable electric vehicles. Growing interest and acceptance by consumers of diesel powered vehicles, and their introduction to the US market by major manufacturers such as Mercedes, Audi and Volkswagen, Jeep and BMW, is favorable for the development of biodiesel, since up to 100% biodiesel is compatible with typical diesel engines. Honda, Nissan and Hyundai have announced intensions to bring diesel versions of their vehicles into the US market.
Economic Development	Decentralized rural biorefinery growth will lead to significant employment opportunities in the region's rural communities and small towns—communities that currently suffer from comparatively high unemployment rates. Increased acceptance of global warming and climate change being related to human causation factors is powering an intensive global effort to develop and implement renewable and sustainable resources to drive economies. Potential increases in federal EPA renewable fuel standards (from 10% to 15%) will be a significant external driver of investment in ethanol capacity. Global economic recovery—predicted by some economists to begin in 2010—will increase demand for oil and petrochemicals resulting in likely increases in prices. Higher fossil fuel resource prices increase economic feasibility of biobased fuels and associated resources. Long-term finite nature of fossil-fuel resources makes renewable asset development an absolute need—main question is timing, as opposed to feasibility. Growth of carbon trading markets favor development of carbon neutral or carbon capture projects—projects in which biomass has the potential to be a significant contributor. Potential to expand the initiatives of the ADWIRED-ADTEC program across the region as a scalable solution to workforce development for a biobased economy.
Other	Consumer acceptance and preference for renewable products is well-established by survey data. As renewable products increase in volume and price competitiveness with non-renewable commodities, there adoption by the market is all but assured (performance and quality attributes being equal).

THREATS

Biomass Production	Long multi-year timelines for breeding, development, and establishment of dedicated energy crops such as switchgrass or miscanthus makes their adoption risky for producers without established contracts from reliable purchasers. Low cost imports of ethanol and other biobased inputs from Brazil and other Latin American nations may place competitive constraints on domestic biofuel projects. Ongoing food-versus-fuel debate still an unresolved issue. Production of biomass on cropland displaces land that could be used for food production (even if that land is currently used for a fiber crop, such as cotton, it still has potential for food crop production). The production of biomass via algal pathways has the potential to be a disruptive technology—altering the comparative competitiveness of plant-based biomass in a negative fashion.
Infrastructure	Economic feasibility of lignocellulosic conversion processes for fuels and chemical products still unproven. Current on-the-road inventory of gasoline powered vehicles may not be suited to the use of high ethanol content gasoline. Major vehicle manufacturers may not recognize warranties on vehicles in which more than 10–15% ethanol content gasoline has been used. Existing petrochemicals supply industry base has a vested interest in opposing mandates and other policy oriented mechanisms that would force upon them higher alternative fuel or renewable input content. Oil companies have a particularly strong federal lobby.
Economic Development	More aggressive state government policies favoring biomass and associated project development are being pursued by states outside of the southeast region. Lack of regional state requirements in terms of renewable portfolio standards limits the impetus for electric utilities to use biomass for coal co-firing applications. State government emphasis on non-biomass renewable energy options (such as wind or solar) may limit resources available to biomass projects. Current constraints on capital markets, coupled with recent poor financial performance of first-generation biofuel production facilities, generate an unfavorable investment climate for biofuel and biomass projects.
Other	Unpredictable fossil fuel prices and feedstock prices add significantly to the risk of biofuel and other related projects (as vividly demonstrated by the challenges faced by soy-based biodiesel plant operators) Ongoing concerns and disinformation pertaining to the energy-positive versus energy-negative debate on biofuels, especially first generation ethanol and biodiesel, threatens support for biobased initiatives.

VI. Economic Impact of a Regional Bioprocessing Industry

An industrial bioprocessing pathway using biomass feedstocks offers an exciting new economic development opportunity for the Mid-South Mississippi Delta region, but it represents a quite different model and value-chain from the current fossil-resource based economy and from the mature biomass food and feed industry.

Table 27: Comparison of the Biomass Industrial Platform versus Traditional Platforms

Biomass Industrial	Biomass Food & Feed	Petroleum / Fossil Fuel
Renewable	Renewable	Non-Renewable / Finite Resource
Potentially low carbon	Potentially low carbon	High carbon emissions
Domestic production	Domestic production	Highly dependent on imports
Opportunities for new supply chains, partnership, technology and innovation	Mature, heavily consolidated industry	Mature, heavily consolidated industry
Lignocellulosic biomass must be processed locally	Can be shipped globally for processing	Can be shipped globally for processing

While a biobased model for industrial development brings fresh challenges, the concept for biomass-based economic development for the Mid-South Mississippi Delta region is attractive for multiple economic and economic development reasons. From a general economic development perspective the opportunity is for:

- Generation of new jobs and income from development and production of new biomass-based feedstocks and biobased products.
- The regional distribution of jobs across both rural and urban development environments.
- New income opportunities through participation in emerging carbon trading and offset markets.
- The substitution of locally produced renewable resources for non-renewable import materials. This results in positive financial import substitution and limits the leakage of financial resources outside of the region.
- Environmental benefits to be achieved through reduced carbon emissions and petrochemical based pollutants.
- Reduced waste disposal challenges because of the biodegradability of biobased products.

Additional advantages occur for the region in the near-term and mid- to longer-term time horizons:

Near-Term Advantages:

- Reutilization/redeployment of existing industrial infrastructure into producing green, biobased products.
- Introduction of new rotational crops such as canola and sunflower that will offer farmers increased options, revenue opportunities, and increase yields in existing regional crops.
- Opportunities to create new supply chains and pilot demonstration projects in the region with new partners.

- Added value for underutilized biomass resources such as crop and forest residues, and processing byproducts.

Mid/Long-Term Advantages:

- The development of decentralized biorefineries across rural areas processing oilseeds, sugar crops and lignocellulosic biomass.
- Opportunities for the growth of high-value biomass on marginal lands.

Specific Impact Estimates for Anticipated Mid-South Mississippi Delta Regional Biomass Economy Development

Based on the analysis of feedstocks, markets and regional assets the following represent the types of replicable projects that are most likely to be developed within the *next decade* and potential employment impacts that could result from such developments:

- **Oilseed Crushing**. It is estimated that the introduction of new oilseed crops for farming on 400,000 acres of Mid-South Mississippi Delta crop land would generate sufficient oilseed volumes (based on canola and sun flower seeds as the oilseed crops) to support five 200 tons per day crushing plants (using CO_2 mechanical crushing systems) with between 20–30 direct jobs per plant (100–150 jobs total across five facilities).
- **Biomass Combustion Feedstock Densification.** There is a near-term opportunity for developing plants that would produce densified biomass to provide between 2 and 5 million tons of dry biomass pellet/briquette feedstocks for co-firing in coal-fired power plants or for other direct combustion applications. This would require the development of between 13 (for 2 million) and 33 (for 5 million) pellet plants with an output of 150,000 tons of pellets per plant. At an estimated 20 jobs per pellet plant this would generate between 260 and 660 direct jobs in the region.
- **Lignocellulosic Liquid Fuels Production**. Under the assumption that the production of ethanol and other liquid fuels from lignocellulosic materials will become commercially viable, the region's sustainable annual supply of 59 million dry tons of lignocellulosic biomass would, at a conversion rate of 80 gallons of ethanol per dry ton, have the capacity to manufacturer 4.7 billion gallons of ethanol. Using the model of many rural 40-million gallon output biorefineries located across the region for economic access to biomass, production of 4.7 billion gallons would sustain 117 biorefineries. A 40 million gallon output biorefinery would require 40 personnel (4,680 jobs total across 117 facilities).
- **Niche Opportunities.** A range of alternative, niche opportunities should be continually encouraged in the region that will encourage entrepreneurialism, offer new opportunities to farmers, and supply unique raw materials and products to biobased industries. Although these businesses should be encouraged, the diversity and uniqueness of each opportunity did not lend itself to quantifying potential job growth. It should be noted however that each of these businesses will be small businesses and offer the resulting benefits to the community and employees.

Table 28 lists projections of direct and indirect employment impacts using an employment multiplier of 3.0 (two indirect jobs created for every one direct job). As is discussed below, multiple impact studies related to biofuels have been conducted around the nation and they are concluding that a higher employment multiplier should be used (because of the high degree of local inputs and significant labor requirements related to biomass production and transportation).

Table 28: Job Generation from Biomass-Based Economic Development (3.0 Employment Multiplier)

Per Facility:

Facility Type	Direct Jobs Per Facility	Indirect Jobs Per Facility (3.0 multiplier)	Total Jobs Per Facility
200-ton per day oilseed crushing plant	25 jobs per plant	50 jobs per plant	75
150,000-ton output biomass densification plants (producing pellets/briquettes)	20 jobs per plant	40 jobs per plant	60
40-million gallon per year lignocellulosic ethanol plant	40 jobs per plant	80 jobs per plant	120

For the Region:

Facilities	Direct Jobs	Indirect Jobs (3.0 multiplier)	Total Jobs
5 x 200-ton per day oilseed crushing plants	125	250	375
20 x 150,000-ton biomass densification plants	400	800	1,200
117 x 40-million gallon lignocellulosic ethanol plants	4,680	9,360	14,040
TOTALS	**5,205**	**10,410**	**15,615**

These impact estimates are likely conservative. Some in-depth impact analyses related to specific individual projects provide additional insight to some of the upper impact bounds that might be achievable. A good example of this is the study by Leistritz *et al*[122] who examined the economic impacts of a 50 million gallon per year biorefinery using lignocellulosic wheat straw as the feedstock. Plant construction cost was estimated to be $176.5 million and during plant operation $53 million of the plant's $74.6 million in annual operating expenses were assumed to be paid to in-state entities (with the largest expenditure item being for feedstocks, at $36 million). The feedstock purchases represent income for local farmers, custom-baling operators, and those involved in transporting feedstock. The study estimates that the plant would directly employ 77 workers with an estimated payroll of $2.7 million. Using input-output analysis the study concluded that the $53 million of direct expenditures would result in secondary impacts totaling $130 million for a total contribution to the North Dakota state economy of $183 million annually. What is most interesting in the ND analysis is that the authors conclude that the total economic activity generated in state by the plant would support more than 2400 jobs in multiple sectors across the state economy—therefore implying an employment multiplier effect of 1:31 (77 direct biorefinery jobs supporting a total of 2400 jobs). Such large scale indirect impacts are also recorded in another biorefinery impact assessment performed by Hodur *et al*[123] examining a 50 million gallon per year corn ethanol plant employing 40 workers. The Hodur study concluded that the refinery operations would support a further 500 jobs in other sectors of the state economy (a 12.5 employment multiplier).

It should be noted that employment multipliers of 31 and 12.5 respectively are very high versus typically cited general employment multipliers which tend to be in the 2.0 to 3.0 range.[124] In a meta analysis of

[122] Leistritz FL, Senechal SM, Stowers MD, McDonald WF, Saffron CM and Hodur NM. *"Preliminary feasibility analysis for an integrated biomaterials and ethanol biorefinery using wheat straw feedstock."* AAE Rpt No 590. North Dakota State University, Department of Business and Applied Economics, Fargo, ND. 2006

[123] Hodur NM, Leistritz FL and Hertsgaard T. "Contribution of the North Dakota Agricultural Products Utilization Commission Programs to the North Dakota Economy". AAE 06006. North Dakota State University, Department of Business and Applied Economics, Fargo, ND. 2006.

[124] For example see Kansas study at http://www.ipsr.ku.edu/publicat/multipliers/multipliers.htm

multiple biofuel related impact studies, however, Bio Economic Research Associates,[125], concluded that 400,000 direct jobs in biorefineries on a national level will generate an additional 1.9 million jobs—equivalent to a 4.75 employment multiplier. Based on these studies the Mid-South Mississippi Delta bioproducts study team believes that there is justification to use a 5.0 multiplier in deriving an estimate of the jobs that will be created and related to biorefinery and bioproduct manufacturing operations. The net results of using a 5.0 multiplier (four indirect jobs for every one direct job) are shown on Table 29. It should be noted, however, that the total jobs allocable to biorefinery operations would not necessarily be all new jobs, since much of the biomass feedstocks production component would comprise existing employment in farm and forestry labor.

Table 29: Job Generation from Biomass-Based Economic Development (5.0 Employment Multiplier)

Per Facility:

Facility Type	Direct Jobs Per Facility	Indirect Jobs Per Facility (5.0 multiplier)	Total Jobs Per Facility
200-ton per day oilseed crushing plant	25 jobs per plant	100 jobs per plant	125
150,000 ton biomass densification plants (pellets/briquettes)	20 jobs per plant	80 jobs per plant	100
40-million gallon per year lignocellulosic ethanol plant	40 jobs per plant	160 jobs per plant	200

For the Region:

Facilities	Direct Jobs	Indirect Jobs (5.0 multiplier)	Total Jobs
5 x 200-ton per day oilseed crushing plants	125	500	625
20 x 150,000 ton biomass densification plants	400	1,600	2,000
117 x 40-million gallon lignocellulosic ethanol plants	4,680	18,720	23,400
TOTALS	**5,205**	**20,820**	**26,025**

Longer-term, the introduction of processes to produce high-value specialty chemicals, chemical intermediates and second generation liquid biofuels will likely enhance the level of job creation through the development of multiple small-scale specialized chemical facilities. It is reasonable to envision a 2x growth in total biomass based economic development in the region over the long-term, generated both through specialized chemical and fuel products and through increasing production volumes achieved through crop yield and process yield improvements. Thus, ten to fifteen years into the future it is reasonable to anticipate a total impact in the 98-county region approaching 50,000 total (direct plus indirect) jobs through a maturing biomass and biobased products economy.

[125] Bio-era (Bio Economic Research Associates). "U.S. Economic Impact of Advanced Biofuels Production: Perspectives to 2030". February, 2009. Study performed for Bio.

VII. Policy Impact on a Regional Bioprocessing Industry

Federal and state government policies are of significant importance to the development of a renewable resource-driven economy. With respect to biomass the influence of government is particularly impactful given the history of federal subsidies to agricultural production, national and state ownership of significant forest lands, and the long-established support and regulation of agriculture and forestry through federal agencies such as the U.S. Department of Agriculture, Department of the Interior, U.S. Forest Service, Food & Drug Administration, Environmental Protection Agency, etc. At the state level there is significant variability in terms of policies, incentives and other programs supporting biomass and renewable development—but the majority of U.S. states are engaged in policy-related actions that influence the growth and development of the biomass economy.

A. State Policy and the Biobased Products Sector

Given the environmental, strategic and economic issues attached to fossil-fuels and the opportunity to develop new economic activity via development and implementation of alternative and renewable energy resources, energy has been a major focus of state policies and support activities around the nation. In 2009 the Southeast Agriculture & Forestry Energy Resources Alliance (SAFER) in conjunction with the University of Florida released the "Southern Bioenergy Roadmap"—a study which included a review of policies pertaining to renewable bioenergy at a state level and included each of the five states in the Mid-South Mississippi Delta study region. The SAFER report divides bioenergy policies into three macro categories: regulatory mechanisms, incentive-based policies, and support-based policies (defined as follows):

- Regulatory mechanisms are government policy instruments which regulate, mandate, or restrict in order to promote bioenergy development. The primary regulatory mechanisms used in the South are blending requirements (also called renewable fuel standards), renewable energy standards (also called renewable portfolio standards), net-metering, interconnection standards, and alternative fuel vehicle (AFV) acquisition regulations.
- Incentive-based policies aid bioenergy suppliers, producers or consumers through financial instruments such as subsidies, production incentives, or grants. The types of incentive-based policies most frequently identified within the South are tax incentives, subsidies, grants, low-interest loans and loan guarantees.
- Support-based programs play a vital role in creating initiatives for the development of bioenergy. Support-based programs include biofuel infrastructure development, bioenergy production assistance, technical assistance and public outreach, and advancement of bioenergy technologies.

Using the Database of State Initiatives for Renewables and Efficiency (DSIRE), general literature review and Web resources, and a series of personal interviews conducted by the University of Florida research team the SAFER study summarizes policies across the five Mid-South Mississippi Delta region as shown in Table 30.

Table 30: Summary of Bioenergy Policies by State, 2008

	Arkansas	Kentucky	Mississippi	Missouri	Tennessee
State Energy Plan		Yes			Developing
Regulatory Mechanisms					
Renewable Fuel Standard	Yes			Yes	
Renewable Portfolio Standard				Yes	
Both Net-metering/ Interconnection Standards	Yes	Yes		Yes	
Alternative Fuel Vehicle Acquisition Regulations	Yes	Yes		Yes	Yes
Incentive Based Policies					
Tax Incentives	Yes	Yes		Yes	
Subsidies and Grants	Yes		Yes	Yes	Yes
Loan-Based policies				Yes	Yes
Support-Based Policies					
Production & Infrastructure Development	Yes	Yes	Yes	Yes	Yes
Extension & Education Outreach		Yes	Yes	Yes	Yes
Technology Advancement Policies	Yes	Yes		Yes	Yes

Regulatory Mechanisms

Renewable Fuel Standards (RFS) establish requirements for a set percentage of renewable fuels to be used in the supply of transportation fuels within a state. Such standards are obviously an important step towards building a market for biofuels within a state since fuel blenders and distributors must assure the fuels distributed within the state meet biofuel content standards. Among the five states in the project region only two, Arkansas and Missouri have renewable fuels standards set. Missouri's is the most far reaching, requiring all gasoline sold in the state to have 10% ethanol content. Arkansas' requirement is for all diesel vehicles operated within the state fleet to use at least 2% biodiesel. It should be noted that the federal RFS requires ethanol blending essentially at the 10% level by oil refiners across the nation, and while blend levels are not uniform across the country most blends in most states would be close to this level. Were an individual state to set an RFS of 15% or higher it would be an incentive for further biofuel investments.

A Renewable Portfolio Standard (RPS) is a regulation that requires the increased production of energy from renewable energy sources, such as wind, solar, biomass, and geothermal. The RPS mechanism generally places an obligation on electricity supply companies to produce a specified fraction of their electricity from renewable energy sources. Only Missouri has a RPS currently, passed by a voter ballot initiative and requiring that investor-owned utilities in Missouri obtain 15 percent of their electricity from renewable sources by 2021. An RPS can drive interest from power generators to include biomass as a co-firing component of their coal-fired power plant electricity generation.

Net-Metering and Interconnection Standards impact electricity consumers who also maintain their own supplemental electricity generating systems. Net-Metering allows such customers to run their meters backwards when generating excess power (thereby generating net utility bill savings), while Interconnection Standards set established technical requirements for safety and power quality for feeding customer generated power into the electricity grid. In the study region Arkansas, Kentucky and Missouri have adopted both net-metering and interconnection standards. These policies may be an important step in enhancing the economics of small-scale distributed biomass power generation operations.

Alternative Fuel Vehicle (AFV) Acquisition Regulations dictate a state requirement for state agencies to purchase alternative fuel vehicles for use in their agency fleets. Four out of the five states in the Mid-South Mississippi Delta Region have AFV requirements in place, with Mississippi being the one exception.

Incentive Based Policies

Tax Incentives are frequently used by states to incent actions by businesses and individuals. Within the study region Arkansas, Kentucky and Missouri have implemented tax policies to encourage biofuels development. Arkansas has a biodiesel tax refund program and a biodiesel income tax credit, Kentucky offers a biodiesel income tax credit, and Missouri offers a wood energy tax credit for individuals or businesses processing Missouri forestry industry residues into fuels (a $5 per ton tax credit).

Subsidies and Grants are typically used to help support capital investment by businesses or individuals in renewable energy projects, or other-related economic development activities. Arkansas, Mississippi, Missouri and Tennessee each have subsidy and grant programs supporting bioenergy investments.

Loan-Based Policies use low- or no-interest loans to help support capital investment by businesses or individuals in renewable energy projects, or other-related economic development activities. Missouri and Tennessee both offer loan programs to support bioenergy projects.

Support-Based Policies

This category includes a range of programs and initiatives designed to support creation of a favorable environment for biofuels development and implementation. In general these policies act in one of three ways: providing funds or tax rebate programs that support investment in biofuels production facilities; providing funds to support the provision of technical assistance and education services related to biofuels (often delivered through extension services of land grant universities), and technology advancement policies designed to support R&D and the commercialization of innovations in biofuel feedstocks, processing and conversion technologies. Each of the five states offer support-based policies within their portfolio.

The states each clearly vary in their portfolio of policies and incentives in regards to renewable energy technology and bioenergy in particular. All of the states in the Mid-South Mississippi Delta are engaged in initiatives that do incent renewable fuels development. Battelle's Technology Partnership Practice has produced summary tables for renewable fuel incentive activities for each state in the U.S. and the findings from this analysis for the five Mid-South Mississippi Delta states are presented in Tables 31 through 35:

Table 31: Arkansas Incentives by Renewable Energy Technologies

Incentive Program	Green/Renewable Energy Technologies					Hydrogen & Fuel Cell Technologies		Enabling & System Technologies		Conservation, Management, Efficiency, Infrastructure
	Solar	Wind	Hydro/ Ocean	Biomass	Geothermal	Fuel Cells	Hydrogen	Energy Storage	Grid Systems	
ENERGY PRODUCTION										
Small Business Revolving Loan Fund										●
Alternative Fuels Development Fund				●						
Biodiesel Tax Refund				●						
Biodiesel Income Tax Credit				●						●
TECHNOLOGY DEVELOPMENT										
Electric Vehicle Equipment and Fuel Cell Income Tax Credit						●				

Source: Battelle categorization of DSIRE and AFDC information.

Table 32: Kentucky Incentives by Renewable Energy Technologies

Incentive Program	Green/Renewable Energy Technologies					Hydrogen & Fuel Cell Technologies		Enabling & System Technologies		Conservation, Management, Efficiency, Infrastructure
	Solar	Wind	Hydro/ Ocean	Biomass	Geothermal	Fuel Cells	Hydrogen	Energy Storage	Grid Systems	
ENERGY PRODUCTION										
Solar Water Heater Loan Program	●									
TVA – Green Power Switch Generation Partners Program	●	●								
Biodiesel Income Tax Credit				●						

Source: Battelle categorization of DSIRE and AFDC information.

Table 33: Mississippi Incentives by Renewable Energy Technologies

Incentive Program	Green/Renewable Energy Technologies					Hydrogen & Fuel Cell Technologies		Enabling & System Technologies		Conservation, Management, Efficiency, Infrastructure
	Solar	Wind	Hydro/ Ocean	Biomass	Geothermal	Fuel Cells	Hydrogen	Energy Storage	Grid Systems	
ENERGY PRODUCTION										
Energy Efficiency Lease Program										●
Tennessee Valley Authority—Green Power Switch Generation Partners Program	●	●								
Energy Investment Loan Program	●		●	●	●					●
Biofuels Production Incentive				●						
TECHNOLOGY DEVELOPMENT										
Energy Investment Loan Program	●		●	●	●					●

Source: Battelle categorization of DSIRE and AFDC information.

Table 34: Missouri Incentives by Renewable Energy Technologies

Incentive Program	Green/Renewable Energy Technologies					Hydrogen & Fuel Cell Technologies		Enabling & System Technologies		Conservation, Management, Efficiency, Infrastructure
	Solar	Wind	Hydro/ Ocean	Biomass	Geothermal	Fuel Cells	Hydrogen	Energy Storage	Grid Systems	
ENERGY PRODUCTION										
Wood Energy Production Credit				●						
Energy Loan Program	●	●		●						
Missouri Ethanol Production Incentive				●						●
Missouri Qualified Biodiesel Production Incentive				●						

Source: Battelle categorization of DSIRE and AFDC information.

Table 35: Tennessee Incentives by Renewable Energy Technologies

Incentive Program	Green/Renewable Energy Technologies					Hydrogen & Fuel Cell Technologies		Enabling & System Technologies		Conservation, Management, Efficiency, Infrastructure
	Solar	Wind	Hydro/ Ocean	Biomass	Geothermal	Fuel Cells	Hydrogen	Energy Storage	Grid Systems	
ENERGY PRODUCTION										
TVA – Green Power Switch Generation Partners Program	●	●								
Wind Energy Systems Exemption		●								
Tennessee Clean Energy Technology Grant	●	●				●				
Local Government Energy Loan Program										●
Small Business Energy Loan Program	●	●	●	●	●					●
Alternative Fuel Refueling Infrastructure Grants				●						●

Source: Battelle categorization of DSIRE and AFDC information.

While tax incentives and support programs can be important mechanisms in encouraging renewables investments, regulatory mechanisms are likely to have the highest impact in the near-term since they, ideally, mandate adoption of renewable fuels and/or electricity generation from renewable resources. It is in the area of regulatory mechanisms that most attention is required within the study region because:

- Kentucky, Mississippi and Tennessee do not have renewable fuel standards.
- Arkansas, Kentucky, Mississippi and Tennessee do not have renewable portfolio standards.

In terms of renewable fuel standards, only Missouri has a percent mandate for ethanol in gasoline (requiring a 10% blend). Were each of the five states to set a 15% requirement, the amount of ethanol required would be significant and a definite stimulus for biofuels development projects in the region. Table 36 shows the estimated gasoline consumption for each of the five states and indicates that were all five of the states to mandate 15% ethanol content in gasoline the immediate result would be demand for 259 million gallons of ethanol annually (enough demand to sustain 26 distributed rural 10 million gallon per year biorefineries).

Table 36: Mid-South Mississippi Delta Region Estimates for 10% Ethanol Content in Gasoline

Study Area Counties	Population of Study Area Counties	Estimated Gasoline Consumption (barrels/day)	Estimated Gasoline Consumption (gallons/day)	Estimated Gasoline Consumption (gallons/year)	Ethanol Required At 10% (gallons/year)
Arkansas (30)	842,301	25,932	1,089,139	397,535,735	59,630,360
Kentucky (8)	163,425	5,031	211,317	77,130,705	11,569,606
Missouri (11)	304,236	9,367	393,393	143,588,445	21,538,267
Mississippi (28)	851,331	26,210	1,100,816	401,797,840	60,269,676
Tennessee (21)	1,497,373	46,100	1,936,182	706,706,430	106,005,965
Total (98)	**3,658,666**	**112,639**	**4,730,847**	**1,726,759,155**	**259,013,873**

Source: Energy Information Administration

The Impetus for Regional Policy Conformance

As the results of the policy analysis show, there is considerable disparity amongst the states in regards to their policies and incentives for biobased economic development. This represents a problem for the five state Mid-South Mississippi Delta region since there is an uneven geographic playing field for biobased development. Under current policy and incentive conditions the 11 study-area counties in Missouri offer a significant advantage for biobased industry development with a robust suite of programs favoring investment in bioenergy businesses. The 28 counties within the region located in Mississippi, however, are at a comparative disadvantage with no favorable regulatory mechanisms and fairly limited incentive and support programs.

It would clearly be to the advantage of the region as a whole to have similar policies and incentives available across each of the five states. As a minimum, those states which do not have renewable fuel standards and renewable portfolio standards should be encouraged to pursue them—ideally setting a 15% ethanol blend requirement. In particular, standards that would encourage the use of ethanol (to help spur investment in lignocellulosic production technologies) and the use of biomass for co-firing in coal-fired power generation applications would be particularly impactful in the near- to mid-term.

B. Federal Policy and the Biobased Products Sector

National legislation and the policy actions of individual federal regulatory agencies have significant impacts on the development of biofuels, biobased products and the “renewables” industry in general. Federal policies, programs and incentives in regards to the environment, climate change, foreign oil substitution, public lands management, agricultural subsidies, renewable fuel standards, etc. shape the economics and investment climate for renewables development and significantly impact potential time horizons for development of the sector.

Changes in the U.S. Presidency and in the make-up of the U.S. Congress, together with the previous Bush administration’s unpredictable stance on energy and climate have generated a somewhat confused investment climate for biofuels and associated renewable products. Indeed, as recently as May of 2009, the American Soybean Association testified before the U.S. House of Representatives Small Business Subcommittee on Regulations, Healthcare and Trade noting that uncertainty over federal policy, such as the extension of the biodiesel tax credit, implementation of the Renewable Fuel Standard (RFS-2), and implementation of the U.S. Department of Agriculture’s (USDA) Bioenergy Program is undermining investor confidence in the biofuels industry.[126]

Among federal policies and programs, several stand out as key to shaping the biobased products environment and the prospects for renewable resource development in general. Some of the key programs are highlighted below.

Energy Independence and Security Act of 2007 (EISA)

The explicit purpose of the EISA, signed into law in December of 2007 by President Bush, was “to move the United States toward greater energy independence and security, to increase the production of clean renewable fuels, to protect consumers, to increase the efficiency of products, buildings, and vehicles, to promote research on and deploy greenhouse gas capture and storage options, and to improve the energy performance of the Federal Government, and for other purposes.”[127]

[126] American Soybean Association press release online at http://www.soygrowers.com/newsroom/releases/2009_releases/r052109.htm. Accessed on 07/27/2009.
[127] Library of Congress, THOMAS federal legislative information system.

With respect to renewable liquid fuels production, the EISA includes both regulatory mechanisms including a renewable fuel standard (RFS) with mandatory production quotas for biofuels and incentive-based policies to promote the production and use of biofuels (ethanol and biodiesel). The following summarize the key items in the act with respect to renewable fuels:

- Renewable Fuel Standard, increased production of biofuels—the total amount of biofuels added to gasoline is required to increase to 36 billion gallons per year by 2022, from 4.7 billion gallons in 2007. In addition, the legislation requires that 21 billion gallons of the 36 billion gallon total must be derived from non-cornstarch products (e.g., sugar or cellulose).[128] A timetable is established with required renewable contents—conventional renewable fuel; advanced biofuels (cellulosic, biomass-based biodiesel) for U.S. transportation fuel to phase in year by year. [129]
- EISA authorizes $500 million for FY 2008 through 2015 for a grant program that:
    - Makes awards to the proposals for advanced biofuels with the greatest reduction in lifecycle greenhouse gas emissions compared to the comparable motor vehicle fuel lifecycle emissions during calendar year 2005; and
    - Shall not make awards to projects that do not achieve at least an 80 percent reduction in such lifecycle greenhouse gas emissions.
- EISA authorizes $25 million for FY 2008 through 2010 for grants for R&D, demonstration, and commercial application of biofuel production technologies in states with low rates of ethanol production.
- The legislation increases CAFE (Corporate Average Fuel Economy) standards—requires auto manufacturers to increase gas mileage to 35 mpg (14.8 km/l) by 2020; affects all passenger automobiles, including light trucks.

At the present time the U.S. Environmental Protection Agency is in the process of proposing an expanded Renewable Fuel Standard (commonly referred to as RFS2). The proposed RFS2 standards are particularly notable for introducing a requirement that renewable fuel manufacturers must prove their feedstocks meet a specific definition for renewable biomass—a definition that is meeting considerable resistance from agricultural and forest land owners and commodity groups. The ultimate disposition of the federal definition of "renewable biomass" will have a significant effect on development of the biorenewables business sector.

Food, Conservation, and Energy Act of 2008 (U.S. Farm Bill)

The 2008 Farm Bill represents a $288 billion, 5-year agricultural policy and a "continuation" of the 2002 Farm Bill. The legislation extends federal agricultural subsidies and targets other areas including energy, nutrition, conservation, and rural economic development. The act includes an array of items aimed at advancing domestic bioenergy, these energy components (Title IX in the legislation) are summarized here with a selected emphasis on items highly related to this study.[130]

- The Bill continues and increases funding for federal procurement of bio-based products, construction and development of advanced biofuel refineries, biomass R&D, and biodiesel education.

[128] Gutterson, Neal and James Zhang, "Important issues and current status of bioenergy crop policy for advanced biofuels," *Biofuels, Bioproducts, & Biorefining* magazine (2009).
[129] U.S. Department of Energy, Energy Efficiency and Renewable Energy Division, Federal Biomass Policy site, http://www1.eere.energy.gov/biomass/federal_biomass.html.
[130] USDA, Economic Research Service, 2008 Farm Bill resources, Title IX: Energy (http://www.ers.usda.gov/FarmBill/2008/Titles/TitleIXEnergy.htm)

- Competitive grants are awarded to assist in the development and construction of demonstration-scale biorefineries designed to convert biomass into advanced biofuels. "Advanced biofuels" are essentially any not produced from corn starch. Grants will cover up to 30% of the project costs.

- New programs under the Farm Bill encourage renewable energy use by biorefineries, systems and energy efficiency improvements, rural energy self-sufficiency, development of next-generation feedstocks, and use of forest and woody biomass for energy production.
    - Legislation authorizes payments to existing operators of biorefineries to replace fossil fuels with systems using renewable biomass.
    - The Farm Bill establishes the new Biomass Crop Assistance Program (BCAP) to support establishment and production of eligible crops for conversion to bioenergy. Further, the program assists land owners with collection, harvest, storage, and transportation of these crops to conversion facilities. Specific assistance includes:
    - – Annual payments to support production
    - – Payments up to 75% of cost of establishing an eligible crop
    - – Matching payments up to $45/dry ton for delivery to conversion facility

American Recovery and Reinvestment Act of 2009

The $787 billion economic stimulus package signed into law by President Obama in February 2009 is intended to boost the U.S. economy in the midst of the recession that began in late 2007. The act includes federal tax relief, expansion of unemployment benefits, and new domestic spending on education, health care, and infrastructure, including specific funding for energy. Energy-related investments alone total $61 billion.

The American Council on Renewable Energy (ACORE) summarizes the renewable energy provisions in the act.[131] The items affecting biomass include:

- Direct spending – the legislation provides $16.8 billion in direct spending for renewable energy and efficiency programs over ten years. Funds allocated to modernize the nation's electricity grid and invest in "smart grid" technologies total $11 billion. Also allocated is $2.5 billion for R&D demonstration projects for renewable energy.
- Tax incentives – the bill extends the Production Tax Credit (PTC) for three years for electricity derived from renewable sources including biomass. In addition, the bill provides the option of instead taking an Investment Tax Credit (ITC), which now applies to all renewable energy technologies. Other tax incentives include: increased credit for alternative fuel pumps and Advanced Energy Manufacturing Credits (for manufacturing components used to generate renewable energy).
- Bond and Loan Programs – ARRA allocates $1.6 billion for new Clean Renewable Energy Bonds (CREBs) to finance facility development, including those for both closed- and open-loop biomass. The bill provides $6 billion for a Renewable Energy Loan Guarantee Program, with temporary program for renewable energy power generation and transmission projects that begin construction by September 30, 2011.

[131] ACORE, *Overview: Renewable Energy Provisions, American Recovery and Reinvestment Act of 2009*, http://www.acore.org/files/images/email/acore_stimulus_overview.pdf.

American Clean Energy and Security Act of 2009 (Currently under consideration)

As of July 2009, the American Clean Energy and Security Act (ACES, a.k.a. the Waxman-Markey Bill) has been approved by the U.S. House of Representatives, but not by the Senate.[132] The bill would establish a cap-and-trade system to limit greenhouse gases in order to address climate change. The legislation requires a 17% reduction in 2005 emissions by 2020. The bill further includes a Renewable Electricity Standard requiring that 20% of an electricity provider's portfolio come from renewable sources by 2020. With respect to biomass, the ACES have adopted the Farm Bill's (expanded) definition of renewable forest biomass for the Renewable Electricity Standard and for carbon offsets.[133]

Engaging in Discussions Shaping the Federal Agenda

Clearly, moving forward, federal policies are going to continue to shape the economic viability of the renewables sector. Because the Mid-South Mississippi Delta region includes counties in five states, there is opportunity for the region to leverage an influential base of U.S. senators and congresspersons in shaping legislation and federal policies to favor biobased resource development. As implementation of the *Regional Strategy for Biobased Products in the Mississippi Delta* moves forward it will be important for the region to prepare a shared position statement on federal policies and incentives that can be used in advising the region's congressional delegation. It should be noted that the entire southern U.S. region shares the characteristic of having biomass as its principal renewable resource—as such the efforts of the 98-county region to influence policy should be coordinated with the political representation of other southern states in presenting a coordinated push on favorable biomass-based economic development policies, incentives and standards.

[132] Broder, John, "House Passes Bill to Address Threat of Climate Change," *NY Times*, June 26, 2009.
[133] Gibson, Lisa, "BPA Suggests Moderate Changes to Waxman-Markey Legislation," *Biomass Magazine*, July 10, 2009.

VIII. Recommended Strategies

Anticipated Development Path for the Mid-South Mississippi Delta Region

It is no easy task to identify the key products and development timelines for biofuels and biobased products. However the project team has reached the general conclusions illustrated on Figure 29 and Table 31, taking into account:

- The characteristics of the regional agricultural production environment
- Current and emerging technologies in biomass processing
- The emergence of alternative markets for biomass
- A key goal of not disrupting existing food and feed production value-chains.

The anticipated development paths are presented across four primary feedstock platforms: plant oils; sugar/starch; cellulosics, and niche products. The primary product developments for each of these platforms are placed on Figure 29 according to the research team's best estimate of timing—divided into "near-term" (current to three-years), "mid-term" (three to six years) and "longer-term" (more than six years from the present). Additional perspective on these opportunities is provided on Table 32.

Figure 29: Anticipated Development Paths by Key Feedstock Platform

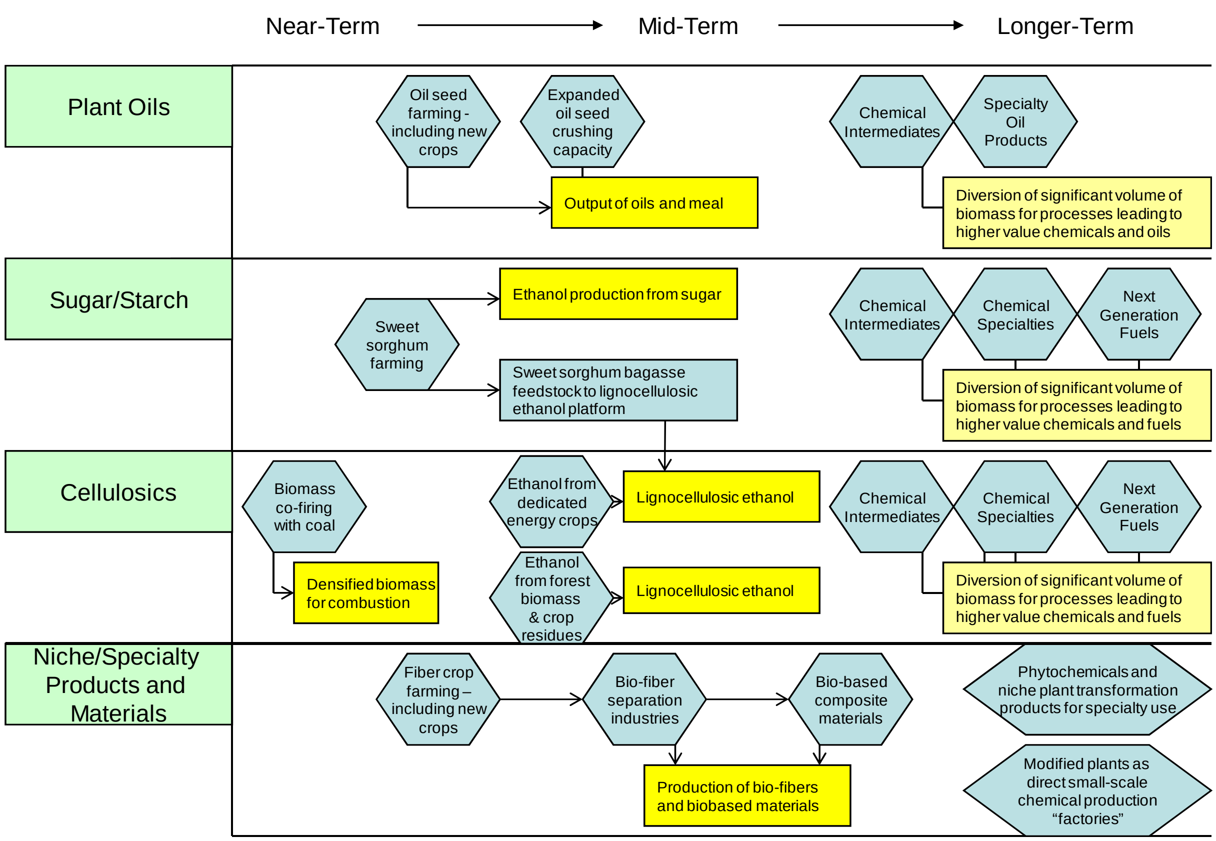

Table 37: Anticipated Development Paths by Key Feedstock Platform

Platform	Current	Near Term	Mid Term	Long Term
Plant Oils/Oilseeds Examples: soybeans, canola, camelina, sunflowers	Soybeans improved with biotechnology produced primarily for processing outside of region. One major processing facility and several small mechanical crushers in the region. Identity preserved production of specialty soybeans for export. Little to no success with soybean-based biodiesel. Protein isolates and value-added products on a limited scale for food and health. Cottonseed processing at four locations.	New to region oilseed crops (canola and sunflower) produced for export outside the region. Improved identity preservation systems expanded for oilseed crops. Development of high value markets in oleochemical platform.	Specialty oilseed processing at locations across the 98 county study region. Introduction of novel new crops (camelina and high erucic acid rapeseed)	Potential opportunity for regional breeding improvements for new oilseed crops. Output traits including novel fatty acid profiles introduced in the region. Introduction of niche market, specialty oilseeds (eg., castor) Algae development and commercialization
Sugar/Starch Examples: corn, milo, sweet sorghum, sugar cane, sugar beet.	Corn improved with biotechnology produced primarily for processing outside the region Limited success for corn-based ethanol. Milo (grain sorghum) produced for livestock feed.	Development of first generation (ethanol) fuels from sweet sorghum. Identity preservation systems for corn.	Development of chemical intermediates from sweet sorghum and potentially adds enough value to draw supply of corn and/or grain sorghum. Breeding improvements for sweet sorghum. Development of bridge technologies with sweet sorghum bagasse as a lignocellulosic biomass feedstock. Yield improvements and corn fractionation technology for corn.	Breeding and development of sugar cane and/or other sugar crops that will be suitable for region. Output traits including plant-made enzymes commercialized. High value biobased products may draw acreage away from other crops and/or create a local demand for commodity corn.
Ligno- cellulosic biomass	Current pulp, paper, and lumber industry. Utilization of rice hulls, wheat straw and other products in a range of bedding products and feed intermediates.	Combustion for heat and electricity. Regional crop trials of dedicated energy crops. Begin production of selected annual bioenergy crops for identified markets.	First generation (ethanol) cellulosic biofuels. Crop improvements in dedicated bioenergy crops.	Second generation biofuels such as biobutanol. Specialty green chemicals.
Niche Crops	Production of kenaf, work at University of Mississippi and ABI, transitional tobacco development.	Comprehensive assessment of potential new crops with regional institutions. Increased market development for crops such as kenaf that are already being produced.	Increase processing opportunities and market development mechanisms for niche crops. International market development for niche product customers for crops that can be grown in the region and which utilize identity preservation systems.	Plants used as factories for novel drugs and industrial proteins.

Overall Observations and Conclusions

Lignocellulosic Biomass – Abundant resources within the Mid-South Mississippi Delta will make lignocellulosic biomass processing the key technology—and industry—for the region's biobased economy. In addition to sustainably available woody biomass and crop residues, production of dedicated energy crops on 10% of current cropland would more than double the region's annual lignocellulosic biomass availability, to 59.0 million tons per year. This is sufficient to produce an estimated 4.7 billion gallons of liquid transportation fuel annually, well in excess of the 3.4 billion gallon total regional consumption of finished petroleum products.

Rural Development – Due to its low bulk density and corresponding high cost to transport, lignocellulosic biomass will "anchor" future processing to the Delta region, in close proximity to its production. This offers significant potential for development of a decentralized replicable bioprocessing industry in the region, with significant job growth. In contrast, renewable wind or solar equipment and components can be (and already are) produced outside the primary regions of energy generation and those areas only require modest support staff to maintain equipment operability once in place. For the Delta region, jobs must come to the biomass.

Technology – Little conversion technology for lignocellulosic biomass is being innovated in the study region; however, international technology providers are pursuing business strategies to implement, or make technologies available, to biomass-rich regions of the country such as the Mid-South Delta. The region must position itself as an "implementation partner" to attract and enable inward technology investment.

Technology – Despite significant progress in recent years to advance the technologies necessary to produce second generation biofuels, the leading technologies for lignocellulosic conversion are just reaching the commercial demonstration stage. These early demonstration projects carry significant commercial risk, as they generally seek to validate and optimize novel technologies and processes. The International Energy Agency concludes that large-scale demonstration projects will provide the needed comparative data to determine the "best technology pathway" between the thermochemical and biochemical lignocellulose conversion routes.

Technology – The region's academic and private-sector research farms have the capability to evaluate new crop performance and determine optimum production practices. However few of these organizations own the necessary germplasm and/or are willing/able to invest in years of breeding to advance crop genetics. It is likely that most advanced germplasm and support will be provided by companies outside the region.

New Energy Crops – *Sweet sorghum* has been identified by the project team as the preferred near-term dedicated energy crop for the Delta region, compared to switchgrass and miscanthus. Sweet sorghum is preferred due to the relative ease of incorporation of an annual crop into existing rotations; demonstrated yield and agronomic requirements; known technology to convert sugars to ethanol (or other higher-value fermentation products); and value-added disposition options for the bagasse.

New Oilseed Crops – *Sunflowers and winter canola* have been identified by the study team as the most promising near- to mid-term new oilseed crops for the region, due to agronomic compatibility and potential regional oil markets. Establishment of regional crushing facilities will be necessary to achieve the full commercial development of these crops and lead to the introduction of other oilseed crops in the future.

Biorefineries – Liquid transportation fuel biorefineries processing lignocellulosic feedstocks will most closely resemble chemical factories in terms of infrastructure, unit operations, and complexity. Highly-skilled technical and operational personnel will be required to staff these technically sophisticated biorefineries. Wage rates will reflect these skill requirements.

Workforce Development – ADTEC (Arkansas Delta Training and Education Consortium) has assembled the best practices in teaching and learning in renewable energy technology through a careful survey of programs nationwide. The ADTEC curriculum developers have created a rigorous and thoughtful curriculum in recognition of the region's strategic advantage in diverse biomass feedstocks and the bioprocessing industrial opportunity. ADTEC stands out as a program of excellence in renewable energy technology training in the region and throughout the United States.

Logistics – The Delta Region's comprehensive transportation and logistics infrastructure is a significant strength for development of a regional bioprocessing industry. Roads, river ports, rail, and intermodal facilities are generally adequate to support the envisioned decentralized economic development. Proximity to refined product pipelines sets the region apart, giving it a strategic advantage for blending and export of compatible second-generation liquid biofuels.

Logistics – Historically, cost-effective river transport has reduced the availability of grain for regional processing by providing a cost-effective conduit for export of these grains to large centralized processing facilities. Lignocellulosic processing will reverse that trend, as river transport will not likely be an economical mode for inbound or outbound movement of these low bulk density feedstocks, which will need to be processed in close proximity to production. However, barge export of densified lignocellulosic biomass products - such as pellets or briquettes—as well as high bulk density chemical and fuel products, may represent a regional advantage.

Industrial Infrastructure – Co-siting of first generation regional biorefineries with existing industrial infrastructure will be desirable to reduce capital, leverage existing competencies, and mitigate risk inherent in early-stage projects. Among other regional assets, cotton gin sites that are centrally located, with buildings, scales, and utilities, may be ideal locations for new biomass operations such as pre-processing, pelletizing/briquetting, or rural sweet sorghum ethanol production. Also, transport of crops and crop residues to biorefineries could represent a new off-season opportunity to utilize farm-based rolling stock assets for revenue generation.

Near-term Opportunities – The project team has identified four near- to mid-term bioprocessing opportunities as the most promising for the region: co-firing biomass in regional coal-fired power plants and process industry coal boilers; introduction of specialty oilseed crops and local crushing facilities; development and demonstration of sweet sorghum-based ethanol production; and introduction of lignocellulosic-based ethanol and/or liquid fuel demonstration facilities.

Job Creation – Within the next decade, assuming commercial viability of lignocellulose conversion to liquid fuels, it is reasonable to foresee a biofuels and biobased products sector in the 98-counties generating upwards of 25,000 jobs (5,100 direct jobs in biorefineries and processing plants, and over 20,000 indirect jobs in the supply chain including biomass production, transportation and multiple other supporting sectors). These jobs will be distributed across decentralized small to mid-scale rural biorefineries and bioprocessing operations.

Environmental Considerations – In assessing new energy crops and biofuel processing opportunities, leaders must consider the relative impacts of the multiple options on greenhouse gas emissions, air pollution, water use and water quality. The key to this effort will be conducting thorough site specific life cycle assessment studies on the top options under consideration.

Policy – Federal policy is now heavily incentivizing the development of the bioprocessing industry; however, the region has not significantly benefited from this support to date. State level policies, programs and incentives in regards to biomass based economic development are far from consistent across the five states, which can create an uneven playing field and result in competition, rather than cooperation.

Cooperation and Collaboration – The Mid-South Mississippi Delta bioprocessing factories of the future will be located across the region, in close proximity to lignocellulosic feedstocks. Aggressive realization of this industry provides an unprecedented opportunity for cooperation among regional entities which support and enable economic development. On a national level, leading efforts to demonstrate early commercial bioprocessing projects have generally been characterized by collaboration among academic, public, and private sector entities. The emerging bioeconomy represents a unique opportunity for cooperation—rather than competition—to accelerate economic development for the entire region. An excellent model for collaborative organization has been developed within the region and is available online as a supplemental reference report to the study.[134]

Strategic Recommendations

1. Pursue Selective Near-term Opportunities: Well-conceived projects to demonstrate near-term success and develop new supply chain models by linking farmers, processors, logistics providers, and factories to make biobased products should be strongly encouraged and supported by regional agencies. Larger and replicable opportunities will result from these new supply chains and early demonstration projects. The project team has identified four near- to mid-term bioprocessing opportunities as the most promising for the region: co-firing biomass in regional coal-fired power plants and process industry coal boilers; introduction of specialty oilseed crops and local crushing facilities; development and demonstration of sweet sorghum-based ethanol production; and introduction of lignocellulosic-based ethanol and/or liquid fuel demonstration facilities.

2. Expand Bioprocessing Workforce Development: The DOL-supported Arkansas ADWIRED/ADTEC and Missouri WIRED programs represent a national best practice for renewable energy workforce development and should be expanded to other institutions in the study region to ensure that skilled local workers will be available to staff the technically demanding bioprocessing industry of the future.

3. Establish a Regional Agricultural R&D Network: The region contains a number of strong public and private research farms with leading academic and commercial agricultural R&D programs, often with overlapping objectives. A "region-focused" network of these organizations should be established to, among other things: leverage capabilities; improve program efficiency; develop consistent protocols and processes; and enhance information exchange. A vital role of this network will be coordination of regional testing and addressing institutional barriers to new crop introduction.

4. Establish a Regional Bioprocessing Technology Consortium: Much of the bioprocessing industry will be developed in rural locations in proximity to biomass feedstocks, but with limited access to the advanced technical competencies necessary to support local biorefineries. A consortium of region-based public and private entities should be established to provide ready access to process technology support services and enable the region's emerging bioprocessing industry.

5. Establish a Regional Business Development Office: The regional bioprocessing industry of the future will be decentralized, replicable, and will share common supply chain and business characteristics. To facilitate the most aggressive realization of this industry, a centralized Business Development Office is recommended, to support the efforts of the implementation partners across the five-state, 98-county region. This central coordinating office would serve as an information clearinghouse, entry point for imported technologies, focal point for funding collaboration, and resource for coordination and integration of support services.

6. Expand Farmer Networks: In order to mitigate risk, manage expectations, and facilitate communication and knowledge sharing on the production of new crops and opportunities, regional

[134] Sumesh M. Arora. "A Collaborative Model for Renewable Energy Technology Adoption," Doctoral research, 2009.

agencies are encouraged to support the formation of farmer networks and expand programs with existing farmer organizations and Land-grant University cooperative extension services. Ideally, the networks would include publicly-funded training, demonstrations and crop production, and a focus on creating and strengthening linkages between farmers and downstream bioprocessing companies. The 25Farmer Network pilot program in West Tennessee, supported by funds from the Tennessee Department of Agriculture, Memphis Bioworks Foundation and BioDimensions, Inc. may serve as a useful model for the region. Efforts should be made to increase participation of disenfranchised and minority farmers in these programs.

7. Harmonize State Policies and Incentives: The five states represented in the strategy share common biomass resources within the Delta region and will therefore share a similar opportunity to develop the bioprocessing industry within their boundaries. Leaders and key agencies within the states should adopt supportive and consistent policies to encourage value-added biobased products, which are technology and feedstock neutral. Implementation partners in the five states should collaborate to make specific recommendations for policy makers in the region.

8. Develop a Regional Policy Statement: Federal policies are going to continue to shape the economic viability of the renewables sector. Because the Mid-South Mississippi Delta region includes counties in five states, there is opportunity for the region to leverage an influential base of U.S. senators and congresspersons in shaping legislation and federal policies to favor biobased resource development. A shared position statement on federal policies and incentives should be prepared for the region’s congressional delegation.

Appendix A: List of Sub-reports and Authors

The following reports were used as input into the "Regional Strategy for Biobased Products in the Mississippi Delta." In most cases detailed summaries are provided in the full document. Each of the full reports can be downloaded at www.agbioworks.org.

Assessment of Agricultural and Forestry Biomass Resources in the Mid Portion of the Mississippi River Alluvial Valley – Jim Wimberly, BioEnergy Systems, LLC

Commercial Production Opportunities and Issues for Alternative Crops – Mike Karst, Entira

Potential for Sweet Sorghum in the Mississippi Delta Region – Hillary Spain, BioDimensions, Inc.

West Tennessee Oilseed Diversification Project – Don Lossing and Kenneth Moss, Frazier, Barnes & Associates

Biomass Conversion Technologies and Products – Randall Powell, Ph.D., BioDimensions, Inc. and Michael Ott, BIOWA

Bioenergy Products and Processes of Particular Interest in the Mid-south Region – Jim Wimberly, BioEnergy Systems LLC

Logistics Assessment of the Delta Region – Leah Berry, Kevin Mitchell and Jack Britt, Ph.D., Strata-G LLC

Workforce Development in Renewable Energy Technology – Leah Wells, BioDimensions, Inc.

Industrial Infrastructure & Economic Development – Steven Smith and Randall Powell, Ph.D., BioDimensions, Inc.

Environmental Considerations of Bioenergy in the Mississippi Alluvial Valley – Karen McSpadden and Jessica Chalmers, Winrock International

A Collaborative Model for Renewable Energy Technology Adoption – Sumesh Arora, Strategic Biomass Solutions, Mississippi Technology Alliance

Analyzing the Design and Management of Biomass-Biorefinery Supply Chain – Sandra Duni Eksioglu, Ph.D., Mississippi State University; Ambrish Acharaya and Liam Leightley, Ph.D., Institute for Advanced Learning and Research; Sumesh Arora, Director of Strategic Biomass Solutions, Mississippi Technology Alliance

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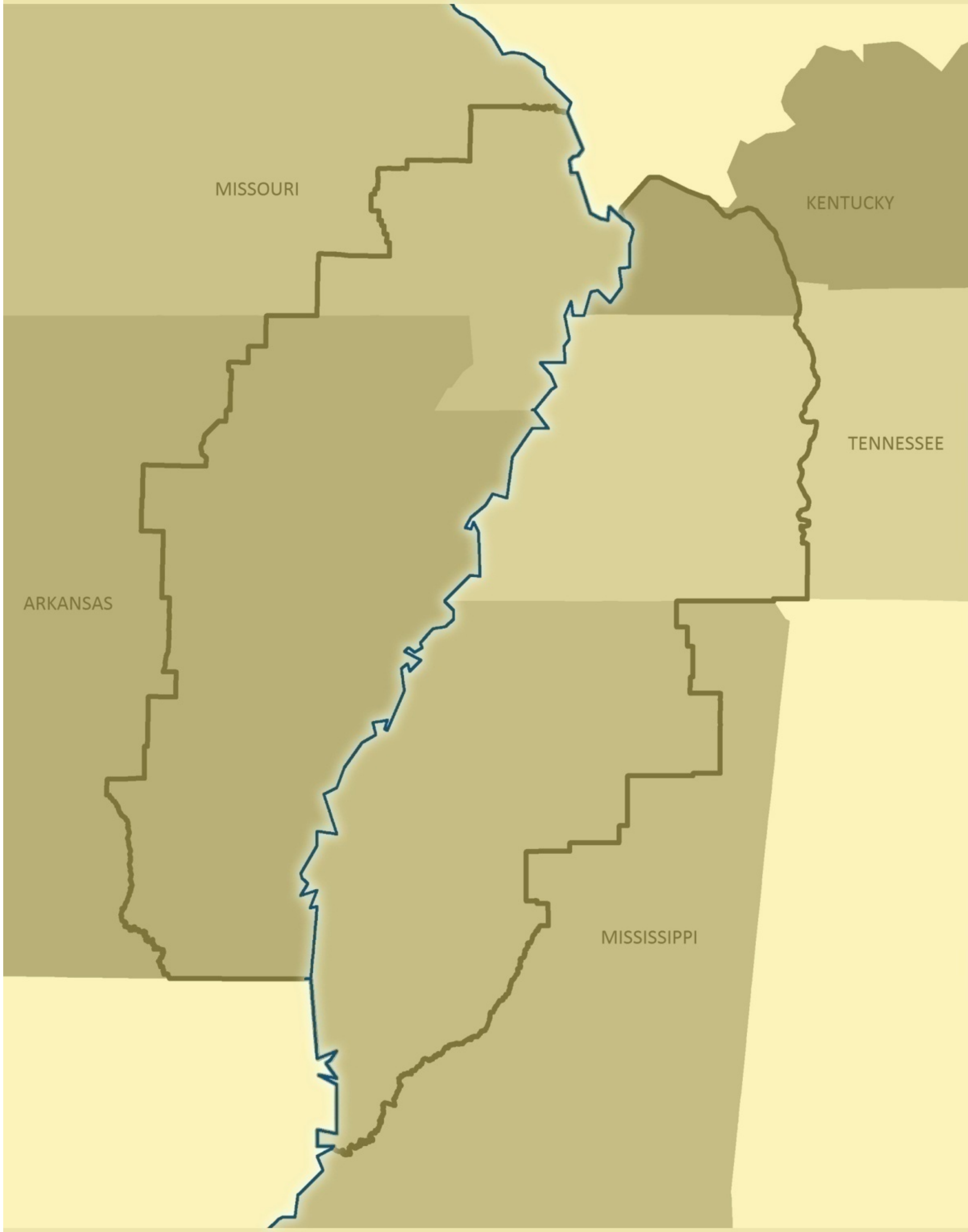

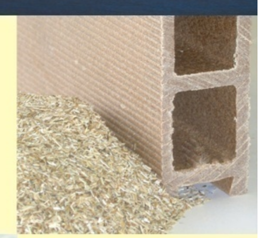

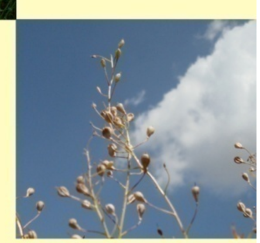

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