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


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Regional Strategy for Biobased Products in the Mississippi Delta
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.

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 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.

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

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.

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.
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.
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.

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

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**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**

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

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.
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

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

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

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

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

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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.

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 cofiring, animal feed, and eventually a feedstock for lignocellulosic fuels processes.

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 CO₂ 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).

Table ES-5: Sustainable Lignocellulosic Biomass Availability

<table>
<thead>
<tr>
<th>Biomass Source</th>
<th>Total Production, million tons/year</th>
<th>Estimated sustainable usable quantities, million tons/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural field residues</td>
<td>31.5</td>
<td>7.2</td>
</tr>
<tr>
<td>Agricultural processing residues</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Forest residue biomass</td>
<td>9.8</td>
<td>6.4</td>
</tr>
<tr>
<td>Forest stem wood biomass</td>
<td>12.7</td>
<td>12.7</td>
</tr>
<tr>
<td>Dedicated energy crops</td>
<td>31.5</td>
<td>31.5</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>86.8</strong></td>
<td><strong>59.0</strong></td>
</tr>
</tbody>
</table>

**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” 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.

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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 (DEC) production opportunities may be sustainably and realistically pursued:

- Production of DEC s, 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 DEC s, 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 DEC s, 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 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.

\[ 59 \text{ million dry tons of lignocellulosic biomass} \times 80 \text{ gallons of ethanol per dry ton} = 4.7 \text{ billion gallons of ethanol.} \]

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

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

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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.

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.

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.

- **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 CO₂ 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.

- **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

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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)

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

For the Region:

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

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

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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.
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 Chalmer, 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
Appendix B: Contacts

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Regional Strategy for Biobased Products in the Mississippi Delta
<table>
<thead>
<tr>
<th>Company/University/Association</th>
<th>Name</th>
<th>Title/Position</th>
<th>Address</th>
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<tbody>
<tr>
<td><strong>Mississippi Delta Developers Association</strong></td>
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<tr>
<td>C/O Delta Council Development Department</td>
<td>Frank Howell, Director</td>
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<td>P.O. Box 257</td>
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<tr>
<td>Stoneville, MS 38776</td>
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<tr>
<td>662-686-3655</td>
<td><a href="mailto:fhowell@deltacouncil.org">fhowell@deltacouncil.org</a></td>
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<td><strong>Mississippi Technology Alliance</strong></td>
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<td>Strategic Biomass Initiative</td>
<td>Sumesh Arora, Director</td>
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<td>134 Market Ridge Dr.</td>
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<td>Ridgeland, MS 39157</td>
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<td>601-960-3659</td>
<td><a href="mailto:sarora@technologyalliance.ms">sarora@technologyalliance.ms</a></td>
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<td><strong>Monsanto Company</strong></td>
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<td>C/O Delta &amp; Pine land Renaissance Center</td>
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<td>1712 Aaron Brenner Drive, Suite 301</td>
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<td>Memphis, TN 38120</td>
<td><a href="mailto:barry.l.knight@monsanto.com">barry.l.knight@monsanto.com</a></td>
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<td>901-375-5661</td>
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<td><strong>Sunny Morris, Ph.D.</strong></td>
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<td>Member - AgBio Regional Steering Team</td>
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<td>Executive Director, Arkansas Delta WIRED</td>
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<td>2000 W. Broadway</td>
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<td>West Memphis, AR 72301</td>
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<td><strong>Murray State University</strong></td>
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<tr>
<td>College of Business &amp; Public Affairs</td>
<td>Tim Todd, Dean</td>
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<td>109 Business Building</td>
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<td>Murray, KY 42071</td>
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<td>270-809-4181</td>
<td><a href="http://www.murraystate.edu/cbpa">www.murraystate.edu/cbpa</a></td>
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<tr>
<td>Regional Business &amp; Innovation Center</td>
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<tr>
<td>Regional Stewardship</td>
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<tr>
<td><strong>Office of Bioenergy Programs</strong></td>
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<tr>
<td>David Madison, Executive Director</td>
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<td>619 Ward Ave</td>
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<td><strong>PPG Industries Inc.</strong></td>
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<td><strong>The Price Companies</strong></td>
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<td><strong>ProAg Services</strong></td>
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<tr>
<td>John Shoffner, Owner &amp; Business Manager</td>
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<td><strong>Purchase Area Development District</strong></td>
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<td>Jennifer Walker, Executive Director</td>
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<td><a href="http://www.purchaseadd.org">www.purchaseadd.org</a></td>
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<td>P.O Box 588</td>
<td><a href="mailto:jennifer.beckwalker@purchaseadd.org">jennifer.beckwalker@purchaseadd.org</a></td>
<td><a href="http://www.purchaseadd.org">www.purchaseadd.org</a></td>
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<td><strong>Shoffner Research Farms</strong></td>
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<td>John Shoffner, Owner &amp; Business Manager</td>
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<td><strong>Southeast Missouri Economic Development Alliance</strong></td>
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Regional Strategy for Biobased Products in the Mississippi Delta

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