Sun Grant Initiative

South Central Region

FEEDSTOCKS WORKSHOP REPORT

October 1-3

20

07

Southern Hills Marriott Hotel
Tulsa, Oklahoma

TABLE OF CONTENTS

Sun Grant Initiative
South Central Feedstock Workshop

Table of Contents 1
Executive Summary. 3
Sun Grant Overview 4-5
Daily Meeting Agendas 6-8
Workgroup Structure 9
Primary and Secondary Workgroup Questions 10
South Central Sun Grant Agricultural Production Information. . 11-15

Workgroup Results 16-57
Sustainable Lignocellulosic Crops 16-21
Sustainable Starch & Oil Seed Crops 22-26
Sustainable Crops Residues 27-31
Sustainable Woody Energy Crops & Forest Residues 32-36
Agricultural Industries By-Products 37-44
Engineering & Resource Economics 45-49
Policy Development and Analysis 50-53
Environmental Interactions 54-55
Communications 56-57

Conclusion by Clarence Watson. 55-59
Workshop Attendee Directory 60-61
References 62-63

The workshop used to support the collection of information contained in this publication was supported in part by USDA-CSREES Special Grant award 2006-34474-17038 and by the Oklahoma Agricultural Experiment Station. .

This report is printed using funds from USDA Special Grant 2005-34474-16038 and issued by Oklahoma State University as authorized by the Vice President, Dean and Director of the Division of Agricultural Sciences and Natural Resources and has been prepared and distributed at a cost of $1,762.50 for 150 copies. 0409.

EXECUTIVE SUMMARY

Since 2002, the Sun Grant Initiative has been focusing on the need to research new alternatives to America's energy demands, while providing economic opportunities for rural areas. With this theme in mind, the South Central Sun Grant Initiative office, based out of Oklahoma State University, hosted the 2007 Feedstocks Workshop, focusing on the South Central region. From October 1-3, 2007, groups of subject matter experts from land grant institutions and industry experts alike met for three days at the Southern Hills Marriott Hotel in Tulsa, OK to discuss topics related to producing feedstocks for biofuel purposes.

Topics were broken down into nine different areas, with attendees participating in the area that correlated to their area of expertise. Some attendees participated in more than one group. Workshop groups included: Technical Groups (Sustainable Lignocellulosic Crops, Sustainable Starch and Oil Seed Crops, Sustainable Crops Residues, Sustainable Woody Energy Crops and Forest Residues, and Agricultural Industries By-Products) and Overarching Groups (Resource Economics and Engineering, Policy Development and Analysis, Environmental Interactions, and Communications). Each group was presented with the same questions, which they discussed and put into a report. This publication includes all of the reports presented.

The discourse presented by this very intelligent and able group of individuals is of great value to the feedstocks industry as a whole. Results varied slightly by group, as they were customized for specific feedstocks. However, the bottom line ultimately ended the same - in stating there is a sustainable and economic need for the continued research within the field of feedstocks. In sharing this report, it is hoped by the South Central Regional Sun Grant Initiative staff that institutions, industry partners, and the government are all able to utilize this information for the betterment of the field.

C. E. Watson

Dr. Clarence Watson
Director

Raymond L Huhnke

Dr. Raymond Huhnke
Associate Director

South Central Regional Sun Grant Center
Oklahoma State University

SUN GRANT OVERVIEW

Who is the Sun Grant Initiative?

The Sun Grant Initiative concept arose from discussions between leadership at South Dakota State University and U.S. Senator Tom Daschle. These discussions began in late 2000 and proceeded through 2001. The founding principles are to develop biobased products, many of them with industrial applications, and concurrently stimulate renewed economic activity particularly in rural areas.

Agricultural production has been, and will continue to be, the source of food, feed, and fiber. In coming years, agricultural commodities will provide primary building blocks for energy, materials and chemicals. These "biobased" products will include liquid fuels, lubricants, plastics, building materials, neutraceuticals, pharmaceuticals, industrial enzymes, monomers, polymers, and many other items. Advances in biological sciences, combined with continuing developments in process engineering, will make this possible.

As the science and technology developments move forward, new industries will emerge and prosper. Additionally, existing companies will develop new businesses. Significant employment opportunities will also develop. Currently, many raw materials for industrial production are derived from petroleum. The biobased economy will not supplant the petroleum industry, but will complement and augment it.

The Sun Grant Initiative is an activity that will enlist the resources of the nation's Land Grant Universities in helping push the biobased economy to reality. Through activities involving South Dakota State and Senator Daschle's staff, the Sun Grant Initiative was proposed to occur in five regions, with coordination in each of the regions through one of the Land Grant universities. The South Central Region was defined as Colorado, New Mexico, Kansas, Missouri, Arkansas, Louisiana, Texas, and Oklahoma. Oklahoma State University was asked to serve as the coordinating institution for the consortium. The other lead institutions are South Dakota State University, Cornell University, University of Tennessee, and Oregon State University

Through a special Federal appropriation, funding was provided for planning purposes in federal FY02. These funds are being used to convene regional planning sessions. Leadership of the Land Grant Universities in the South Central Region met for an initial orientation and planning session in April of 2002. Stakeholder meetings were held by the South Central Region in June of 2002 which involved individuals from within the consortium and external parties. Using input from these meetings, a planning document draft was developed and finalized in September 2002.

What is the Sun Grant Initiative Mission?

Biobased products hold great promise for renewable energy and biobased, non-food industries. The Sun Grant Initiative is a national program established to create new solutions for America's energy needs and to revitalize rural communities by working with land-grant universities and their federal and state laboratory partners on research, education, and extension programs.

Where are the Sun Grant Initiative Regional Centers?

There are five regional administrative centers throughout the country:

•Western Regional Center at Oregon State University in Corvallis, OR

• South Central Regional Center at Oklahoma State University in Stillwater, OK

• North Central Regional Center at South Dakota State University in Brookings, SD

• Southeastern Regional Center at University of Tennessee in Knoxville, TN

• Northeastern Regional Center at Cornell University in Ithaca, NY

South Central Sun Grant Land Grant Partners

Oklahoma State University is the administrative center for the South Central Region. Land grant institutions within the South Central Region are:

COLORADO STATE UNIVERSITY, KANSAS STATE UNIVERSITY , LANGSTON UNIVERSITY, LINCOLN UNIVERSITY, LOUISIANA STATE UNIVERSITY, NEW MEXICO STATE UNIVERSITY, OKLAHOMA STATE UNIVERSITY , PRAIRIE VIEW A & M UNIVERSITY, SOUTHERN UNIVERSITY, TEXAS A & M UNIVERSITY, UNIVERSITY OF ARKANSAS, UNIVERSITY OF ARKANSAS AT PINE BLUFF, UNIVERSITY OF MISSOURI

What Makes the South Central Region Unique?

The South Central Center and associated regional Land Grant Universities' work involves developing biobased products, creating energy self-sufficiency, preserving the environment, and investing in rural economies. Stakeholders recognize the South Central region's many strengths in becoming a leader in the biobased economy of the future. Assets identified include:

- Abundance of land, infrastructure and human capital,
- Excellent biomass production capacity, some of which is underutilized,
- Opportunity for production of many types of biomass,
- Feedstock sources from co-/by-products from animal production and processing,
- Outstanding industrial sector to commercialize products and
- Rural communities desire to diversify the economy while preserving the agricultural base.

In addition to the aforementioned community assets, the South Central Region's member universities also possess a tradition of collaboration within the region, across the U.S. and around the world partnering with other educational institutions, government agencies, and agriculture, business, and industry. This multi-disciplinary approach to and expertise in biofuels research is paramount to the Region's success.

Contacts:

Leadership at the South Central Sun Grant is provided by the following individuals:

Dr. Clarence Watson, Ph.D.
Director, South Central Regional Center
Dr. Raymond L. Huhnke, Ph.D., P.E.
Associate Director, South Central Regional Center
Cara Laverty, MBA
Program Specialist, Sun Grant Initiative

For More Information...

South Central Region Sun Grant Initiative
Oklahoma State University
214-A Agricultural Hall
Stillwater, Oklahoma 74078-6021
Phone:405-744-3255
Fax: 405-744-6059

Email: sungrant@okstate.edu
Web Site: www.sungrant.okstate.edu

FEEDSTOCKS MEETING AGENDA

First Day

Monday - October 1, 2007

1:00 p.m.	Registration Outside Cypress Room, Second Floor
1:30 p.m.	Orientation Meeting of Steering Committee Sycamore Room, Second Floor
2:00 p.m.	Welcome Council Oak Ballroom, First Floor, Rooms A & B Dr. Clarence E. Watson, Associate Director of Ag Experiment Station
2:05 p.m.	Building Regional Biomass Partnerships John Ferrell, U.S. Department of Energy Terry Nipp, Sun Grant Initiative
2:30 p.m.	U.S. Department of Energy "Billion Ton Goal" Anthony Turhollow, Oak Ridge National Library
2:50 p.m.	Feedstock Supply Systems Guest Speaker: Richard Hess, Idaho National Laboratory
3:20 p.m.	Goals and Structure of the Workshop Mark Downing, Oak Ridge National Laboratory Ray Huhnke, Oklahoma State University
3:40 p.m.	Group A Workgroup Orientation Introductions and Discuss Objectives Group A-1: Redbud Room, Second Floor Group A-2: Sycamore Room, Second Floor Group A-3: Dogwood Room, Second Floor Group A-4: Magnolia Room, Second Floor Group A-5: Pecan Room, Second Floor
5:45 p.m.	Informal Reception Hospitality Room 306
6:30 p.m.	Dinner Council Oak Ballroom C, First Floor Guest Speaker: David Fleischaker, Oklahoma Secretary of Energy

FEEDSTOCKS MEETING AGENDA

Second Day

Tuesday - October 2, 2007

6:30 a.m.	Breakfast Buffet - Hotel Restaurant
8:00 a.m.	Conversion Technology for Cellulose & Feedstock Challenges Bob Wallace, Strategy Analysis Area Lead for the National Renewable Energy Laboratory Council Oak Ballroom, First Floor, Rooms A & B
8:45 a.m.	Group A Workgroup Sessions (Continued in Same Rooms)
10:00 a.m.	Break and Refreshments
10:30 a.m.	Group A Workgroup Sessions (Continued in Same Rooms)
12:00 p.m.	Lunch - Council Oak Ballroom C, First Floor
1:00 p.m.	Group B Workgroup Orientation Introductions and Discuss Objectives Group B-1: Redbud Room, Second Floor Group B-2: Dogwood Room, Second Floor Group B-3: Sycamore Room, Second Floor Group B-4: Magnolia Room, Second Floor
2:30 p.m.	Feedstock Database Management and Utilizing GIS Spatial Data Layers Mark Downing, Oak Ridge National Laboratory
3:00 p.m.	Break and Refreshments
3:30 p.m.	Group B Workgroup Sessions (Continued in Same Rooms)
5:00 p.m.	Workgroup Sessions End for the Day
5:15 p.m.	Informal Reception Hospitality Room 306
6:00 p.m.	Depart for Evening Banquet Meet in Hotel Lobby
6:30 p.m.	Evening Banquet Oklahoma Aquarium

FEEDSTOCKS MEETING AGENDA
Third Day

Wednesday - October 3, 2007

6:30 a.m.	Breakfast Buffet Hotel Restaurant
8:00 a.m.	Breakout into Workgroups to Finalize Summary Report Group A-1: Redbud Room, Second Floor Group A-2: Sycamore Room, Second Floor Group A-3: Dogwood Room, Second Floor Group A-4: Council Oak Ballroom, First Floor, Rooms A & B Group A-5: Council Oak Ballroom, First Floor, Rooms A & B Group B-1: Pecan Room, Second Floor Group B-2: Magnolia Room, Second Floor Group B-3: Council Oak Ballroom, First Floor, Rooms A & B Group B-4: Council Oak Ballroom, First Floor, Rooms A & B
9:00 a.m.	Group Reports to All Participants Council Oak Ballroom, First Floor, Rooms A & B
10:00 a.m.	Break and Refreshments
10:30 a.m.	Group Reports (Continued in Same Rooms)
12:00 p.m.	Group Wrap-Up, "Where Do We Go from Here?" John Ferrell, U.S. Department of Energy Terry Nipp, Sun Grant Initiative Clarence Watson, Oklahoma State University
12:30 p.m.	Workshop Ends Lunch Begins
1:30 p.m.	Steering Committee Wrap-Up Session Council Oak Ballroom, First Floor, Rooms A & B
2:30 p.m.	Meeting Adjourns

WORKGROUP STRUCTURE

Technical Groups

A-1	**Sustainable Lignocellulosic Crops**
A-2	**Sustainable Starch and Oil Seed Crops**
A-3	**Sustainable Crop Residues**
A-4	**Sustainable Woody Energy Crops & Forest Residues**
A-5	**Agriculture Industries By-Products**

Overarching Groups

B-1	**Resource Economics and Engineering**
B-2	**Policy Development and Analysis**
B-3	**Environmental Interactions**
B-4	**Communications**

WORKGROUP QUESTIONS

Primary Questions...

- What are the currently available feedstocks and quantities of each?
- What existing feedstocks can be enhanced and at what increase in productivity?
- What are the best candidate feedstock species and varieties?
- What "new" feedstocks can be produced, and in what quantities?
- What inventories and information are available for existing feedstocks?
- What are the most significant voids that must be addressed before making a reasonable assessment of feedstock inventories?

Secondary Questions...

- What sources of information are available to help determine which lands are capable of producing specific feedstocks?
- What are the constraints to feedstock delivery to the plant?
- What are the technology drivers for feestock development?
- What are the process co-products (plus associated value) and/or cost?
- What are the potential benefits of feedstock production?
- What are the consequences of feedstock production?
- What are the consequences of biofuels production?
- What are the social issues associated with biofuels?

SOUTH CENTRAL SUN GRANT AGRICULTURAL PRODUCTION INFORMATION

Current (2006) Production of Selected Croplands & Non-Croplands in the South Central United States *

NOTE: Crop Statistics Taken from National Agricultural Statistics Service (NASS)

ARKANSAS

ARKANSAS CROP STATISTICS						
Crop	**Descriptor**	**2006 Acres Harvested**	**2006 Average Yield per Acre**	**Actual Production (Tons)**	**Estimated Biomass* in Tons (DM)**	**Estimate**
Corn Silage (All)	Wet	4,000	12 tons/ac	48,000	16,800	35% DM
Hay (All)	Dry	1,465,000	1.7 tons/ac	2,519,800	2,015,840	80% DM
Sorghum Silage	Wet	2,000	10 tons/ac	20,000	7,000	35% DM
Wheat (All)	Grain	305,000	61 bu/ac	18,605,000 bu	533,750	1.75 tons/ac
Rice (All)	Grain	1,400,000	6,850 lbs/ac	95,900,000 cwt	4,200,000	3 tons/ac
					6,773,390	

ARKANSAS NON-CROPLAND STATISTICS				
Crop	**Descriptor**	**Estimated Acres**	**Estimated Average Yield (DM)**	**Estimate**
CRP	Active	238,970	358,455	1.5 tons/ac
Pastureland & Rangeland	No Woodland	1,977,177	2,965,766	1.5 tons/ac
			3,324,221	

COLORADO

COLORADO CROP STATISTICS						
Crop	**Descriptor**	**2006 Acres Harvested**	**2006 Average Yield per Acre**	**Actual Production (Tons)**	**Estimated Biomass* in Tons (DM)**	**Estimate**
Corn Silage (Irr)	Wet	75,000	23 tons/ac	1,725,000	603,750	35% DM
Corn Silage (Dryland)	Wet	15,000	8 tons/ac	120,000	42,000	35% DM
Sorghum Silage	Wet	17,000	18 tons/ac	306,000	107,100	35% DM
Alfalfa (Irr)	Dry	680,000	4.2 tons/ac	2,856,000	2,284,800	80% DM
Alfalfa (Dryland)	Dry	100,000	1.3 tons/ac	125,000	100,000	80% DM
Other Hay (Irr)	Dry	510,000	2.2 tons/ac	1,096,500	877,200	80% DM
Other Hay (Dryland)	Dry	240,000	1.4 tons/ac	324,000	259,200	80% DM
Proso Millet (Dryland)	Grain	255,000	18.5 bu/ac	4,717,500	510,000	2 tons/ac
Oats (Irr)	Grain	7,000	91.5 bu/ac	640,500	21,000	3 tonss/ac
Oats (Dryland)	Grain	3,000	20 bu/ac	60,000	5,250	1.75 tons/ac
Wheat (All)	Grain	1,919,000	21.6 bu/ac	41,450,400	3,358,250	1.75 tons/ac
					8,168,550	

COLORADO NON-CROPLAND STATISTICS				
Crop	Descriptor	Estimated Acres	Estimated Average Yield (DM)*	Estimate
CRP	Active	2,465,745	3,698,618	1.5 tons/ac
Pastureland & Rangeland*	No Woodland	17,341,749	26,012,624	1.5 tons/ac
			29,711,241	

KANSAS

KANSAS CROP STATISTICS						
Crop	Descriptor	2006 Acres Harvested	2006 Average Yield per Acre	Actual Production (Tons)	Estimated Biomass* in Tons (DM)	Estimate
Corn Silage (All)	Wet	300,000	12 tons/ac	3,600,000	1,260,000	35% DM
Hay (All)	Dry	3,050,000	2.2 tons/ac	6,557,500	5,246,000	80% DM
Sorghum Silage	Wet	60,000	10 tons/ac	600,000	210,000	35% DM
Wheat (All)	Grain	9,100,000	32 bu/ac	291,200,000 bu	15,925,000	1.75 tons/ac
Barley (All)	Grain	18,000	27 bu/ac	486,000 bu	31,500	1.75 tons/ac
Oats (All)	Grain	40,000	45 bu/ac	70,000 bu	70,000	1.75 tons/ac
					22,742,500	

KANSAS NON-CROPLAND STATISTICS				
Crop	Descriptor	Estimated Acres	Estimated Average Yield (DM)	Estimate
CRP	Active	3,260,404	4,890,606	1.5 tons/ac
Pastureland & Rangeland	No Woodland	15,504,008	23,256,012	1.5 tons/ac
			28,146,618	

LOUISIANA

LOUISIANA CROP STATISTICS						
Crop	Descriptor	2006 Acres Harvested	2006 Average Yield per Acre	Actual Production (Tons)	Estimated Biomass* in Tons (DM)	Estimate
Corn Silage (All)	Wet	5,000	14 tons/ac	70,000	24,500	35% DM
Hay (All)	Dry	390,000	2.5 tons/ac	975,000	780,000	80% DM
Sorghum Silage	Wet	1,000	10 tons/ac	10,000	3,500	35% DM
Wheat (All)	Grain	105,000	53 bu/ac	5,565,000 bu	183,750	1.75 tons/ac
Sugar Cane	Sugar/Seed	435,000	27.3 tons/ac	11,875,500 tons	3,562,650	30% DM
Rice (All)	Grain	345,000	5,820 lbs/ac	20,079,000 cwt	1,035,000	3 tons/ac
					5,589,400	

LOUISIANA NON-CROPLAND STATISTICS				
Crop	Descriptor	Estimated Acres	Estimated Average Yield (DM)	Estimate
CRP	Active	311,014	466,521	1.5 tons/ac
Pastureland & Rangeland	No Woodland	1,194,963	1,792,445	1.5 tons/ac
			2,258,966	

MISSOURI

MISSOURI CROP STATISTICS						
Crop	Descriptor	2006 Acres Harvested	2006 Average Yield per Acre	Actual Production (Tons)	Estimated Biomass* in Tons (DM)	Estimate
Corn Silage (All)	Wet	60,000	13 tons/ac	780,000	273,000	35% DM
Hay (All)	Dry	4,140,000	1.7 tons/ac	6,955,200	5,564,160	80% DM
Sorghum Silage	Wet	2,000	5 tons/ac	10,000	3,500	35% DM
Wheat (All)	Grain	910,000	54 bu/ac	4,914,000 bu	1,592,500	1.75 tons/ac
Oats (All)	Grain	28,000	65 bu/ac	1,820,000 bu	49,000	1.75 tons/ac
Rice (All)	Grain	214,000	6,400 lb/ac	13,696,000 cwt		
					7,482,160	

MISSOURI NON-CROPLAND STATISTICS				
Crop	Descriptor	Estimated Acres	Estimated Average Yield (DM)	Estimate
CRP	Active	1,597,506	2,396,259	1.5 tons/ac
Pastureland & Rangeland*	No Woodland	4,854,438	7,281,657	1.5 tons/ac
			9,677,916	

NEW MEXICO

NEW MEXICO CROP STATISTICS						
Crop	Descriptor	2006 Acres Harvested	2006 Average Yield per Acre	Actual Production (Tons)	Estimated Biomass* in Tons (DM)	Estimate
Corn Silage (All)	Wet	84,000	25 tons	2,100,000	735,000	35% DM
Hay (All)	Dry	350,000	4 tons	1,449,000	1,159,200	80% DM
Sorghum Silage	Wet	17,000	19 tons	323,000	113,050	35% DM
Wheat (All)	Grain	270,000	36 bushels	9,720,000	472,500	1.75 tons/ac
					2,479,750	

NEW MEXICO NON-CROPLAND STATISTICS				
Crop	Descriptor	Estimated Acres	Estimated Average Yield (DM)	Estimate
CRP	Active	590,000	885,000	1.5 tons/ac
Rangeland	Productive Areas of State†	24,441,468	36,662,202	1.5 tons/ac
Note: † indicates Non-Arid Regions			**37,547,202**	

OKLAHOMA

OKLAHOMA CROP STATISTICS						
Crop	Descriptor	2006 Acres Harvested	2006 Average Yield per Acre	Actual Production (Tons)	Estimated Biomass* in Tons (DM)	Estimate
Corn Silage (All)	Wet	35,000	17 tons/ac	595,000	208,250	35% DM
Hay (All)	Dry	3,180,000	1.1 tons/ac	3,593,400	2,874,720	80% DM
Sorghum Silage	Wet	16,000	5 tons/ac	80,000	28,000	35% DM
Wheat (All)	Grain	3,400,000	24 bu/ac	81,600,000 bu	5,950,000	1.75 tons/ac
Oats (All)	Grain	8,000	30 bu/ac	240,000 bu	14,000	1.75 tons/ac
Rye (All)	Grain	65,000	16 tons/ac	1,040,000 bu	113,750	1.75 tons/ac
					9,188,720	

OKLAHOMA NON-CROPLAND STATISTICS					
Crop	Descriptor	Estimated Acres	Estimated Cost to Bid from Current Use	Estimated Average Yield (DM)	Estimate
Native Grasslands		15,465,388	$15-$30	23,206,622	1.5 tons/ac
CRP	Active	1,073,035	$35-$60	1,700,504	1.5 tons/ac
Improved Pasture		5,020,135	$20-$60	22,788,954	4.5 tons/ac
				47,696,080	

TEXAS

TEXAS CROP STATISTICS						
Crop	**Descriptor**	**2006 Acres Harvested**	**2006 Average Yield per Acre**	**Actual Production (Tons)**	**Estimated Biomass* in Tons (DM)**	**Estimate**
Corn Silage (All)	Wet	160,000	15 tons	2,400,000	840,000	35% DM
Hay (All)	Dry	5,200,000	1.7 tons	8,736,000	6,988,000	80% DM
Sorghum Silage	Wet	100,000	15.5 tons	1,550,000	542,500	35% DM
Wheat (All)	Grain	1,400,000	24 bu/ac	33,600,000	2,450,000	1.75 tons/ac
Oats (All)	Grain	100,000	37 bu/ac	3,700,000	175,000	1.75 tons/ac
Sugar Cane	Sugar/Seed	41,000	41.2 tons/ac	1,689,200	506,760	30% DM
Rice (All)	Grain	150,000	7,170 lb/ac	10,755,000	450,000	3.0 tons/ac
					11,953,060	

TEXAS NON-CROPLAND STATISTICS				
Crop	**Descriptor**	**Estimated Acres**	**Estimated Average Yield (DM)**	**Estimate**
CRP	Active	4,077,807	6,116,711	1.5 tons/ac
Rangeland	No Woodland	83,402,865	125,104,298	1.5 tons/ac
			131,221,008	

* Estimated biomass represents potential if all acres of a particular crop or grassland were used for biomass only. It should be noted that not all acres will be harvestable for biomass or suitable for biomass production.

- General DM Values were 35% for corn and sorghum silages, 80% for dry hay, and 30% for sugar cane.
- Small grain crop biomass assumes a conservative 1.75 tons DM/ac yield, unless otherwise specified.
- Rice biomass yield potential is estimated at 3 ton DM/ac.
- CRP biomass yield potential is estimated at 1.5 ton DM/ac.
- Some overlap of crop use may exist.

SUSTAINABLE LIGNOCELLULOSIC CROPS WORKGROUP RESULTS

Regional Overview

Oklahoma and other states in the region have large acreages of unplowed grasslands. Abandoned grasslands are being invaded by woody plants and weeds.

In terms of Switchgrass:

- Haskell produces 4-7 DM tons/acre
- Stillwater produces 7-15 DM tons/acre
- ~15 in. precipitation
- 70 lb. N/acre (second year) inputs

There are very few lodging problems associated with native grass hays. Oklahoma has:

- Five million acres of improved pastures.
- One million acres in the Panhandle that are Conservation Reserve Program lands.
- Over 8.5 million acres in cropland.
- More than 15 million acres are in native prairie.

Existing Feedstocks that can be Enhanced

Warm and cool season, thick and thin-stemmed perennials and annuals exist, as the region is very diverse. Different crops will be appropriate for each region. Pastures entail simple management with low inputs, making it cost effective. West Texas and New Mexico should utilize perennial, warm-season grass due to low inputs - particularly water. Low inputs in marginal environments are needed to keep costs as low as possible. Arkansas dry land soybeans historically have a low value, but may be useful for biofuels. More than just monocultures are needed, as diversity is necessary (e.g. legumes).

"New" Feedstock Resources and Desirable and Nondesirable Traits

Enhancements to existing feedstocks, as well as desirable and nondesirable traits of each, include:

- Utilize excess hay production in wet years. Tall fescue and Bermuda grass hays that are not utilized and go to waste are not profitable to the producer, but could be for biofuel use.
- Roadside resources, as grasses are maintained and the infrastructure is already in place.
- Harvesting of scrub trees to improve grasslands, so in one year a farmer could have both grass and timber profitability/utilization.
- Problem weeds, such as amaranth, kochia, and Johnson grass could be used for biofuel.
- Bermuda grasses, particularly in wastewater or manure situations. Switchgrass does not respond that well to nitrogen in wastes, so look at crops that work well in poor water situations. Bermuda grass may take too much nitrogen for a good balance of inputs versus outputs in the energy system.
- Switchgrass takes fewer trips over the field and tends to dry down faster than Johnson grass or sorghums, but it is hard to establish. Yield is the best estimate until the composition is realized.
- Legume intercropping brings in nitrogen and a value-added wildlife aspect. Also provides crop diversity, which is usually more flexible in bad years-much more so than in a strict monoculture. Cool season legumes provide out of season growth and forage. In terms of ease of legume establishment, use legumes with high water requirements in the wetter portion of the region, medics in dryer areas; legume and grass have to match-up/complement each other (not compete for shade or other resource); the system is dependent upon timing of harvest in terms of products in the mixture and type/amounts of energy obtained.
- Cool season perennials in mixtures seem to be a good fit, as opposed to monoculture. Cool season crops may be suitable for wetter areas of the region, such as Arkansas or east Texas, or in rarer niches.
- High yielding "wet" crops, such as rice, can provide residue after grain production.
- Cereal rye, wheat, triticale, and barley in winter rotation or double croppings are a source of feedstock. However, they require high fertilizer input. Use these in wastewater or manure

systems where nutrients are in excess. From an economic standpoint, annuals allow for flexibility of profitability in certain years. Most likely, they are not a great source of feedstock, due to long growing season, high fertility, high water use (store moisture requirement), and harvesting grain first (then biomass).

- The Conservation Reserve Program (CRP) has many acres, but probably is not the most productive land and would require continued high inputs. Current CRP land is arid, and has a less than one ton per acre potential. Tall grass prairie that has been abandoned instead of CRP may have greater potential but still may only yield less than three tons under optimum conditions. This would be beneficial in carbon balance systems (e.g. carbon credits), wildlife, riparian buffers, and environmental benefits - not just biofuel. It is possible to not harvest for carbon, but keep it in the soil.
- Sweet sorghums are dependent upon sugar cane-type mills for processing, and are probably best for coastal regions.
- Corn - it is in question whether or not it is bad to have both the grain starch and cell wall component (i.e. silage) in the same feedstock. In terms of processing facilities, some say they just want the cellulose and not the grain while others will take both. It is unknown at this point which preference will dominate the industry.
- OK - 2,000 tons/day biomass through timber production (Weyerhauser). It is recommended that their model be used for harvesting large quantities of biomass, as they do this each day.

Crop Types Presented by Workgroup

NOTE: (See Table 1)

- Warm and cool-season, thin stemmed perennials: Switchgrass, Big and Little Bluestem, Indian grass, Bermuda grass, Love grass, Tall fescue, and Wheat grass.
- Warm-season, thick-stemmed perennials: Energy cane (~10 DM ton/acre), Miscanthus (~7-10 DM ton/acre, needs some N, but not much; can become invasive and is expensive to establish).
- Warm-season annuals - Forage sorghum, Sweet sorghum, Sorghum Sudan, Photoperiod-sensitive Sorghum, Cowpea, Soybean, and Lablab.
- Cool-season legumes for mixture systems: Clovers, vetches, medics.
- Others: weeds, such as Amaranthus sp., kochia, Johnson grass.
- Low versus high rainfall: humid areas will have a higher yield potential with less annual fluctuations and may be less input sensitive. Dry regions will likely need at least limited supplemental irrigation, water, and N. Use efficient crops to reduce the effects of annual and seasonal fluctuations and to give more flexibility in dry years. It is in question as to whether farmers can get by without irrigation, nutrients, or inputs on grasslands. Farther west, yields go down and inputs will be forced down. Also to be researched is the cut-off line for the expected yield-beyond for which a reliable source of biomass can be expected. Will farmers want to take the year-to-year risk?
- Warm-humid: high input and high biomass crops (grasses), forest products, cane crops, sorghums, rice, winter cover crops, wetlands (how to harvest?), year-round potential more so than other subregions.
- Warm-dry: perennial, warm-season grasses (possibly mixtures) or multi-use rangeland, canes in river valleys, Bermuda grass, and sorghums.
- Cool-humid: Switchgrass, tall fescue, annual sorghums, woody crops (short rotation), and Miscanthus.
- Cool-dry: native and improved or introduced cool season perennials (e.g. wheat grasses), rangeland, and sorghums.

Available Inventory and Information for Existing Feedstocks

- For acres of switchgrass in the South Central region, see Figure 1.
- CRP acreages by state and county are available for existing feedstocks, and how they were reseeded ; not much biomass information.
- Isolated thesis or dissertation information and research data not published.
- "Biomass Energy in Arkansas," written by Wimberly in 2002 (*Wimberly*).
- "Louisiana Biomass and Bioenergy Overview," written by Jackson and Mayfield in 2007 (*Jackson*).
- "Biomass Feedstock Availability in the United

States: 1999 State-Level Analysis," written by Walsh et al (*Walsh*).

- "Carbon Negative Biofuels from Low-input, High-Diversity Grassland Biomass," written by Tilman, et al (*Tilman*).
- "Bioenergy Project Development and Biomass Supply," from the International Energy Agency (*International Energy Agency*).
- "Primary Production of the Central Grassland Region of the United States," (*Sala*); note: middle part of the country has 'best guesses' based on rainfall.
- The United States Department of Agriculture's NASS (*National Agricultural Statistics Service*) and state agricultural statistics: for agricultural commodities (hay), consider surrogates for these numbers to supplant for the crop listed; use it as a base (e.g. use pasture acreages as surrogates for other grasses or use sugar cane acres and production as a surrogate for energy cane potential).
- NRCS (*Natural Resources Conservation Service*) provides soil data; used to estimate potential yields and productivity indices.
- Native grasslands productivity reports (*Tilman*). Switchgrass variety trial information and research reports are available.
- The USDA-NASS (*United States Census of Agriculture*) & USFS (*United States Forest Service*) reports have rangeland estimates periodic assessments down to the county level.
- NASA (*National Aeronautics and Space Administration*) has satellite images, remote sensing, and Geographic Information Systems (GIS) or Global Positioning System (GPS) imagery.

Significant Voids to be Addressed before Assessing Feedstock Inventories

- Private land estimates are lacking and hard to obtain.
- Annual variability, especially in dry areas, is a void. There cannot be much variability in the feedstock production supply to the facilities.
- Knowledge of the "optimum" growing condition for each crop (soil, climate, models). A web-based database system may be used to predict these conditions. To do this, enter a crop and get a map generated that will show the best areas for the particular crop. Take existing data (research) and translate into usable information.
- Use many different data layers and come up with a baseline. Take into consideration the complexity of the issue, like factors other than just the plant-environment relationship (e.g. human factor, using crops in areas where they shouldn't be used, importing water, and rural sociology or hunting habitats).
- The global carbon cycle needs to be inventoried and the carbon balance assessed, not just yields.

Constraints to Feedstock Delivery to the Plant

- The physical distance of the plant from where the feedstock is actually grown severely limits productivity and feasibility.
- Infrastructure: the number of trucks going into the plant needs to be reduced, and thus reduce bulk of biomass and pretreatment in the field.
- There is an issue of year-round supply. Seasonal harvesting leads to storage issues, such as hay fire hazards and DM losses. If harvesting is delayed, the producer will start losing biomass, as optimum harvesting cannot be achieved. There are harvesting problems with delays, including lodging, snow cover, and architectural stability (mixtures may help alleviate stability problems associated with monocultures). One crop will not work; the producer must have crops ready to go year-round to supply plants. Machines are needed that can pick-up lodged plants. Fire insurance programs are needed for growers who lose their crop prior to harvesting. Prairie hay can be harvested at multiple times during the year. Switchgrass has an eight month harvest window without losing too much quality. However, the issue lies in what the producer will do the rest of the year. Fast growing trees don't have the harvest window problems, are always ready to go, and could be used to fill in gaps between herbaceous crops.
- Trucking constraints exist regarding round versus square bales. Square works better now. Stacking chopped Switchgrass has worked well *(Bransby)*. Height, or load, requirements are needed for highways.
- There is currently a lack of transportation methods (number of trucks, trains, etc.) to supply the 24/7 delivery of feedstocks. Oftentimes, if economics are good enough, people will work

Table 1: Sub-Regional Climate Zones Categorized by Workgroup and Associated Best-Fit Crops (*Compiled by Workgroup*)

	WARM	COOL
HUMID	**MO, AR, LA, E. TX, E. OK** Switchgrass Energy Cane Biomass Rice Sorghums Bermuda Grass Woody Invasives (1x Opportunity)	**MO, AR** Switchgrass Tall Fescue Miscanthus Sorghums
DRY	**W. TX, NM, W. OK, S. CO** Warm-Season Perennial Grasses (Mixtures) Native Warm-Season Grassland Sorghums Bermuda Grass Woody Invasives (1x Opportunity)	**CO, N. KS, MO, NM** Cool-Season Perennial Grasses (Native and Introduced) Rangeland Sorghums

Figure 1: Acres of Switchgrass in the South Central Region (*www.bioenergy.ornl.gov*)

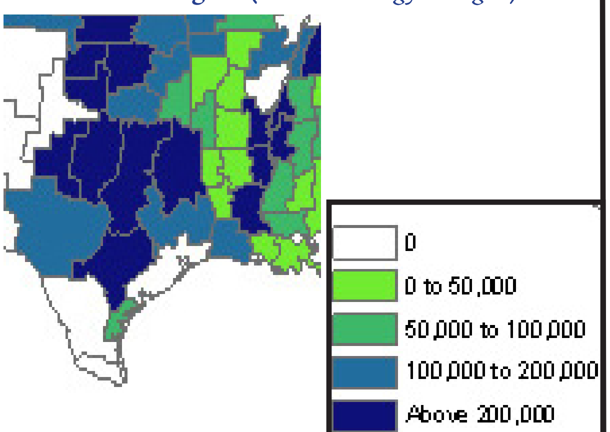


Figure 2: Percent Area Having Grass/Herbacious Cover in the South Central Region - 1992 (*www.nrcs.usda.gov*)

out the logistics.

- There is more information needed regarding timing of drying - whether it is dried at the refinery or prior to delivery.
- Land must be bidded out of its current use, and it is not known how much they are willing to pay (i.e. at $25 per ton, not much acreage will get devoted to biomass production.
- It is not known if the industry is trying to grow something the average farmer will not have the equipment to manage or harvest.

Technology Drivers for Feedstock Development

- In research performed by Casler, et. al, it states that switchgrass breeding programs and the seed industry have combined to create a seed marketing and distribution system (*Casler*). This encourages movement of switchgrass seeds across large areas. Since the economy prefers high-volume cultivars, the seeds will "result from germplasm that is broadly adapted across multiple ecological zones." There are also very few cultivars from east of the Mississippi River, causing a huge reliance on a small number of eastern cultivars and a broad distribution of cultivars from the Great Plains.
- Reducing inputs: water-use efficiency, and nitrogen use (nitrogen is a high cost to the producer and significantly limits the bottom line profit).

- Establishing: perennial warm season grasses, especially natives, are commonly a problem. No-till establishment on less stable soils is a major question.
- Lowering lignin for fermentation systems: have lignin remain beneficial to the plant, but "un-lock" when it comes to fermentation.
- Mineral researching: find out which minerals really limit energy production and how much reduction is needed; minimize soil contamination of feedstock.
- Lowering nitrogen materials: nitrogen is bad for fermentation, and too many emissions.
- Optimizing biological nitrogen fixation to minimize the impact on beneficial nutrients.
- Increasing cellulose content to lower sugar may lead to less stand-loss and higher energy production.
- Researching of species diversity and carbon budget analyses is needed.
- Information is needed regarding fire prevention and containment of feedstocks.

Process Co-Products

Other chemicals to break-down or break-out other products include:

- Policosanol: long-chain alcohols from sugar cane wax may have health benefits and high value.
- Xylitol: Five carbon sugar alcohol, sweetener substitute.
- Bio-pharmaceuticals.

Benefits of Feedstock Production

- Ecological benefits: wildlife habitat, stream bank stability, soil stability (reduced erosion) aesthetics, carbon sequestration, carbon credits and water credits (quality and quantity), species diversity, flower diversity for various pollenators.
- Economy of rural areas: low-input crops could possibly improve the economy of rural areas.
- Annuals: rotational benefits, disease and insect resistance, warm and cool season diversity would create year-round production systems.
- Minerals that are removed and not used could be returned back to the farm land.

Consequences of Feedstock and Biofuels Production

- Marginal land: land that should be broken-out for high levels of crop production; sod-busting causes carbon and moisture loss.
- A false sense of improved economy and jobs may exist, as once facilities are built, not that many jobs will be associated with the processing plant. Also, will dollars stay locally in rural areas? Will this enhance or decrease property values?

Social Issues Associated with Biofuels

- Discontent with the facilties when near people in terms of odors, aesthetics, and traffic.
- Land ownership pattern shift: What about the family farm? Are we going too large and will this help eliminate the family farm due to corporation and industrialization?

Works Cited:

Bioenergy Feedstock Information Network (BFIN). Hosted by the U.S. Department of Energy, Oak Ridge National Laboratory, Idaho National Laboratory, National Renewable Energy Laboratory. www.bioenergy.ornl.gov (See Page 20).

Bransby, David. U.S. Agriculture: A Major Player in the U.S. Energy Scene. Presented at Energy in Agriculture: Managing the Risk workshop. www.farmfoundation.org/projects/documents/BransbyFORWEB.pdf. Kansas City, MO. June 27-28, 2006. (See Page 19).

Casler, M.D.; K.P. Vogel, C.M. Taliaferro, N.M. Ehlke, J.D. Berdah, E.C. Brummer, R.L. Kallenbach, C.P. West, and R.B. Mitchell. Latitudinal and Longitudinal Adaptation of Switchgrass Populations. Crop Science, Volume 47. November-December 2007. Crop Science Society of America, Madison, WI. (See Page 20).

International Energy Agency. "Bioenergy Project Development and Biomass Supply." Paris, France. 2007. http://iea.org/textbase/nppdf/free/2007/biomass.pdf. (See Page 19).

Jackson, Samuel W. and Chyrel Mayfield. Louisiana

Biomass and Bioenergy Overview. Southeastern Sun Grant Initiative. Pages 1-2. May 2007 revision. (See Page 18).

National Aeronautics and Space Administration (NASA). www.nasa.gov. (See Page 19).

National Agricultural Statistics Service (NASS). www.nass.usda.gov. (See Page 19).

Natural Resources Conservation Service (NRCS). www.nrcs.usda.gov. (See Pages 19, 20).

Sala, O.E. and W. J. Parton, L. A. Joyce, W. K. Lauenroth. "Primary Production of the Central Grassland Region of the United States." Ecology: Vol. 69, No. 1, pp. 40-45. 1988. (See Page 19).

Tilman, Jason; Jason Hill and Clarence Lehman. Carbon-Negative Biofuels from Low-Input High-Diversity Grassland Biomass. Science Magazine, Volume 314. December 8, 2006. (See Page 19).

United States Census of Agriculture (USDA-NASS). www.agcensus.usda.gov. (See Page 19).

United States Forestry Service (USFS). www.usfs.gov. (See Page 19).

Walsh, M.E., D.G. De La Torre Ugarte, H. Shapouri, and S.P. Slinsky. "Bioenergy Crop Production in the United States: Potential Quantities, Land use Changes, and Economic Impacts on the Agricultural Sector. " Environmental Resource Economics. Chapter 24, pages 313-333. 2003. (See Page 19).

Wimberly, Jim. Biomass Energy in Arkansas. Foundation for Organic Resources Management. Arkansas Biodiesel Conference. Fayetteville, AR. December 2002. (See Page 18).

Sustainable Lignocellulosic Crops Workgroup Members

Mark A. Marsalis, Co-Leader	New Mexico State University	Las Cruces, NM
Joe Brummer, Co-Leader	Colorado State University	Fort Collins, CO
Jon Biermacher	Samuel Roberts Noble Foundation	Ardmore, OK
Edmund Buckner	University of Arkansas	Pine Bluff, AR
Francis Epplin	Oklahoma State University	Stillwater, OK
Felix Fritschi	University of Missouri	Columbia, MO
Alison Goss Eng	U.S. Department of Energy	Washington, DC
Gregory Gessel	John Deere Technical Center	Moline, IL
Carol Jones	Oklahoma State University	Stillwater, OK
Dave Jordan	MacDon Industries	Kansas City, MO
Ron Madl	Kansas State University	Manhattan, KS
James Muir	Texas A&M University	College Station, TX
Terry Nipp	Sun Grant Initiative	Washington, DC
Mike Palmer	Oklahoma State University	Stillwater, OK
David Porter	Oklahoma State University	Stillwater, OK
Bill Rooney	Texas Agricultural Experiment Station	College Station, TX
Vincent Russo	Lane Research Center	Lane, OK
Lee Tarpley	Texas Agricultural Experiment Station	College Station, TX
Anthony Turhollow	Oak Ridge National Laboratory	Oak Ridge, TN
Chuck West	University of Arkansas	Fayetteville, AR
Yanqui Wu	Oklahoma State University	Stillwater, OK

SUSTAINABLE STARCH & OIL SEED CROPS WORKGROUP RESULTS

MID-SOUTH REGION TRAITS

A Brief Introduction

The discussion of the feedstock types and quantities, both present and future, is best understood if placed within the context of the Mid-South Region. Weather conditions greatly influence the types of crops grown and their productivity. The Mid-South Region may be more variable for weather than any other region in the continental United States. Average yearly precipitation amounts in non-mountainous parts of the region vary from about 10-70 inches (*Daly*). The length of the frost-free period varies from 120 to 365 days. In general, the climate becomes wetter and warmer and the growing season lengthens from northwest to southeast. The region's weather presents opportunities and challenges that make this region unique to the United States.

Opportunities

The length of the growing season in the Mid-South Region permits an intensification of cropping systems, including double-cropping, except in the northwest portion of the region. Multiple energy crops could be grown and harvested within a year on the same land. Furthermore, an extended growing season in Texas and Louisiana permits the culture of sugarcane, perhaps an under utilized energy crop in the United States. The longer seasons and high sun angle associated with the southern latitudes result in high sunlight availability to drive photosynthesis and productivity. Finally, this long growing season means that feedstocks might be available from the field for a greater portion of the year than in other United States regions.

For multiple reasons, including weather, there are many acres of under utilized land in the Mid-South region. Although constraints exist, energy crop expansion might be possible. There are numerous livestock raised in the region. These animals present a competition for some feedstocks, but more importantly, they also present an economical use for several energy production by-products.

Challenges

The challenges to energy crop production in the Mid-South Region are multiple, and these challenges may account for a large portion of the under utilized land. Although yearly precipitation is large in at least part of the region, distribution within the year is not optimum for many crops (see Figure 3). In places where rainfall is the greatest, the wetter months occur in winter and drought stress during the month of August is common (see Figure 4). Water quality is an increasingly large challenge, particularly in places that rely on irrigation. Warm temperatures and high humidity in the region stimulate insect, diseases, and weed pests. Finally, the large animal industry makes the entire region starch deficient, except for food crops like wheat and rice. Corn and other feed grains are usually imported into the region.

FEEDSTOCK AVAILABILITY

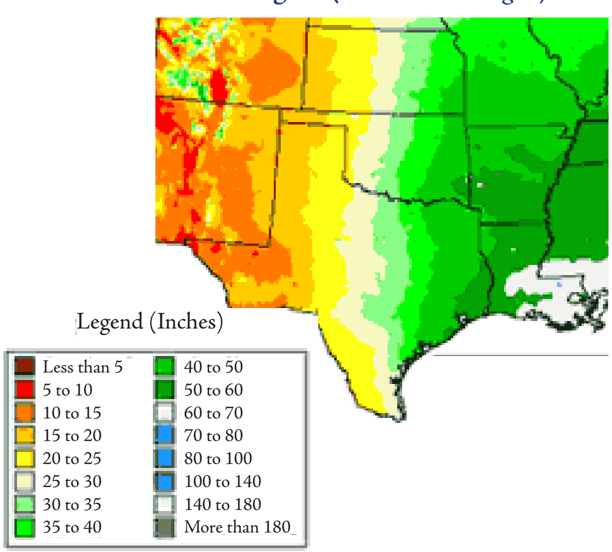
Currently Available Feedstocks

Starch, oil seed, and sugar crop amounts are presented in Table 1. Because annual figures vary, data are presented as three year averages from 2004-2006 (*National Agricultural Statistics Service*). Estimates for the 2007 season are also provided. As stated earlier, crop production in the Mid-South Region is diverse, and production of more than 18 crops are tracked by NASS. Wheat, corn, and grain sorghum are grown in all eight states. Soybean is grown in six states, but not in the most western states of New Mexico and Colorado. Unlike other regions, both sugar beets (Colorado) and sugarcane (Texas and Louisiana) are grown in this region. Several other cereal and oil seed crops are grown in at least three of the eight states.

Table 2: Acres & Production for Cereal, Oil Seed, & Sugar Crops in the Mid-South Region (*www.nass.usda.gov*)

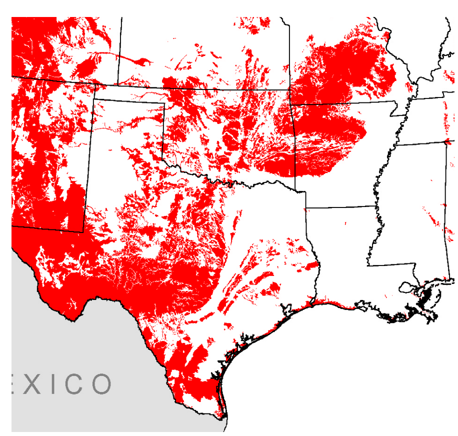
	AVERAGE (2004, 2005, 2006)		2007	
CROP	HARVESTED	PRODUCTION	HARVESTED	PRODUCTION
CEREAL CROPS	Acres	Bushels	Acres	Bushels
Corn	9,404,000	1,242,376,000	11,440,000	1,663,160,000
Wheat	19,159,000	655,583,000	20,369,000	704,140,000
Grain Sorghum	6,822,000	443,726,000	5,975,000	457,900,000
Oats	210,000	9,537,000	168,000	6,995,000
Barley	74,000	7,665,000	71,000	7,874,000
Rye	75,000	1,353,000	60,000	1,080,000
Millet	287,000	6,258,000	N/A	N/A
Rice (45 lb/bu)	2,395,000	350,639,000	2,022,000	312,441,000
Total Cereals	*38,426,000*	*2,737,137,000*	*40,105,000*	*3,153,590,000*
OIL SEEDS (Oil)	Acres	Pounds	Acres	Pounds
Soybean (60 lb/bu)	12,328,000	27,521,280,000	10,670,000	23,196,600,000
Peanut	259,000	911,853,000	211,000	715,200,000
Sunflower	403,000	545,940,000	312,000	465,400,000
Total Oil Seeds	*12,990,000*	*28,979,073,000*	*11,193,000*	*24,377,200,000*
SUGARS & TUBERS	Acres	Tons	Acres	Tons
Sugarcane	459,000	11,889,000	474,000	12,940,000
Sugarbeets	38,000	853,000	32,000	738,000
Potato	102,000	1,871,000	N/A	N/A
Total Sugars and Tubers	*599,000*	*14,613,000*	-	-

Figure 3: Annual Average Precipitation in the South Central Region (*www.nrcs.usda.gov*)



Period: 1961 - 1990

Figure 4: Drought Vulnerable Soil Landscapes (Root Zone AWC Less Than or Equal to 6") in the South Central Region (*USDA-NRCS*)



The Mid-South Region, similar to the United States as a whole, is increasing starch crop production and decreasing oil seed crop production in 2007. Demand for starches in the ethanol industry is partially responsible for this challenge. Wheat, corn, and soybeans will be competing for these acres in 2008. Oil seed production will likely rebound, at least partially. The wild card in assessing energy crop production in the mid-south region is the large amount of other crops produced in the region. There are nearly 20 million acres of hay production and an equal amount of grazing land. As prices for starch and oil seed crops rise, some of this land could be converted to energy crops. However, as cellulosic ethanol technology improves, conversion of forage and grazing lands to grain energy crops might not happen.

The Sustainable Starch and Oil Seed Crops discussion group estimated the mid-south region has approximately a 20 billion gallon ethanol limit, based on the acreage of starch crops planted and their current yields. The region may have reached that limit with current starch crop planting levels. However, if ethanol prices remain high, some land currently devoted to food crops might be planted to ethanol crops. If that happens, this 20 billion gallon limit might rise. The mid-south region has more food crop (e.g. wheat and rice) acres than any other USA region.

FEEDSTOCK ENHANCEMENTS

Requirements

Increasing existing feedstock production will require enhancement in two areas: increasing grain yield per acre and increasing fuel production per bushel of grain. Advances in technologies developed within and outside the region is essential to both of these enhancements. Further, a partnership between public and private entities is required.

Increasing Grain Yield Per Acre

Increased grain yield per acre is a major focus of most current breeding and agronomy programs. Our ability to increase yield is related to the number of breeders involved in the effort and amount of money invested in yield enhancement. Private companies are an important contributor to this effort. Average corn yields have increased in the recent past, but increases in wheat yields have been limited. Few commercial breeders are involved in grain sorghum breeding. Protecting yield from abiotic stresses like drought and heat, as well as biotic stresses from diseases and insects, should be important activities.

Increasing crop yields is dependent upon weather, especially precipitation during the growing season. Unfortunately, the constraints on water supplies, both rain-fed and irrigated, in the Mid-South Region may have already been reached. In rain-fed environments, conservation tillage and other practices that reduce runoff result in maximum yields based largely upon growing season rainfall. Under irrigated conditions, yields are often a function of annual rainfall and the availability of irrigation water. This last variable is becoming more of a constraint in part of the region that overlies the Ogallala Aquifer.

Increasing Fuel Production Per Bushel of Grain

Increased fuel production from a bushel of grain could be accomplished through modification of grain composition. Increasing ethanol production from starch crops might be possible if starch concentrations were increased. However, most cereal grains are already more than 70 percent starch. Reducing protein concentrations might be possible, but seed viability needs to be monitored and maintained. Genetic material may exist in breeding programs, but has not been released because low protein wheat, corn, and grain sorghum is often rejected by livestock feeders and flour millers. Barley used in beer production has been bred to result in increased beer production by reducing protein concentration. Therefore, a model exists for this approach.

Some of the technologies involved in producing ethanol from cellulose could be used to increase ethanol for grain crops. Grain contains some fiber, and that fiber could be used to generate ethanol. Ethanol production per bushel of grain could be increased by perhaps 0.5 gallons.

Increasing oil content of oil seeds can be difficult if yield potential is to remain. Oil is expensive for the plant to produce, due to the associated high energy content. Current oil seed breeding programs largely focus on grain yields and maintaining an acceptable oil-to-protein ratio. Decreasing the harvest index of grain crops to produce more straw for cellulosic ethanol is unwise and not likely to succeed.

Preferred Candidate Feedstock Species & Varieties

The Sustainable Starch and Oil seed Crops discussion group examined a number of possible "best candidate" feedstocks. As indicated before, the Mid-South Region is diverse and currently produces a large number of starch, sugar, and oil seed crops. Each crop - including currently under-utilized crops and several new crops to the region - were discussed at length.

The Sustainable Starch and Oil seed Crops discussion group decided not to include any of the starch crops as best candidate feedstocks. The winter annual cereals (wheat, barley, triticale, oats, etc.) are not the most efficient crops for producing ethanol. However, they may fit into a double-cropping system with an energy crop. Summer annual cereal crops, such as corn and grain sorghum, are currently used as animal feed. Because the Mid-South Region is already starch deficient for feeds, these two crops were not considered "best candidates."

Best Options for Biofuel Production

The oil seeds crops hold the best promise for biofuel production in the Mid-South Region:

- A summer annual, such as a sunflower, and a group of related crops in the Brassica complex that can be incorporated into a double-crop system. Sunflowers are adapted to much of the upper-half of the region and perform well in locations subject to periodic droughts.
- Soybean will always be an appropriate choice in parts of the region where it is presently grown (all states except New Mexico and Colorado).
- The Brassica complex includes winter canola, camolina, and mustards. One advantage of these crops is they can be produced using existing wheat planting and harvesting equipment. Additionally, the meal by-product from these crops can be used in foods and feeds. These crops are efficient users of water, yet additional research is needed regarding their production.
- Some consideration should be given to use of sugarcane and sweet sorghum for ethanol. These crops may be limited to the southern areas of the region, but can be used for direct fermentation of sugars, thus bypassing an expensive step inherent in starch crops.

Significant Voids Concerning Sustainable Removal of Feedstocks

Currently, the Mid-South Region has few processing biorefineries. The lack of crushing facilities has limited the acceptance of canola production in the region and must be addressed if oil seeds are to be used. Additional infrastructure needs are not specific to the region, but include transportation arteries, seed and other input suppliers, and improved planting, harvesting, and grain handling capabilities.

Also, farmers and their crop advisers must be trained in best management practices for energy production, especially in environmentally sensitive and highly erodible areas. Crop management must be focused on energy production, not solely on yield. Soil carbon levels should be carefully monitored or practices developed that, at a minimum, maintain current soil carbon levels. It may be possible to use the NRCS soils data and crop management practice information to determine the most appropriate use for each parcel of land in the region. Energy balances, or life cycle analyses, may be performed on each crop to determine which crops are best options for producing biofuel feedstocks. This means that research is needed to develop appropriate management practices for new crops. Specifically, an understanding of how the conversion from grass or grain production (feed/food paradigm) to biofuel production (energy paradigm) will affect soil and environmental quality.

Furthermore, standardized yield trials should be conducted at multiple locations throughout the region using best candidate feedstocks and comparing them to traditional crops, such as soybean.

Finally, education modules related to energy crop production and use should be developed. Target audiences include farmers, crop advisers, the general public, and K-12 students.

Works Cited:

Daly, Christopher. PRISM Model: Annual Average Precipitation in the United States of America. Information provided by the 1951-1999 normals from NOAA Cooperative Stations and NRCS SNOTEL Sites. Sponsored by USDA-NRCE Water and Climate Center. Portland, OR. (See Page 23).

National Agricultural Statistics Service (NASS). www.nass.usda.gov. (See Pages 23, 24).

Natural Resources Conservation Service (NRCS). www.nrcs.usda.gov. (See Page 24).

USDA-NRCS National Soil Survey Center Staff - Map and Analysis; Soil Survey Staff of State Soil Geographic Database - Data. Root Zone Available Water Capacity Less Than or Equal to 6 Inches. 1994. (See Page 24).

Sustainable Starch and Oil Seed Crops Workgroup Members

Scott Staggenborg, Co-Leader	Kansas State University	Manhattan, KS
William J. Wiebold, C0-Leader	University of Missouri	Columbia, MO
Sangu Angadi	New Mexico State University	Clovis, NM
David Baltensperger	Texas A&M University	College Station, TX
Mark Burow	Texas A&M University	College Station, TX
Terry Collins	Oklahoma State University	Stillwater, OK
Jeff Dahlberg	National Sorghum Producers	Lubbock, TX
Thayne Dutson	Oregon State University	Corvallis, OR
John Ferrell	U.S. Department of Energy	Washington, DC
Maxine Jones	Conoco Phillips	Tulsa, OK
Armen Kemanian	Texas A&M University	College Station, TX
Phil Kenkel	Oklahoma State University	Stillwater, OK
Ron Lacewell	Texas A&M University	College Station, TX
Travis MIller	Texas A&M University	College Station, TX
Michael Popp	University of Arkansas	Fayetteville, AR
Allen Regehr	Texas Department of Agriculture	Austin, TX
Rick Roeder	University of Arkansas	Fayetteville, AR
Steve Searcy	Texas A&M University	College Station, TX
Mike Stamm	Kansas State University	Manhattan, KS

SUSTAINABLE CROPS RESIDUES WORKGROUP RESULTS

BACKGROUND

A Brief Introduction

Agricultural crop residues are lignocellulosic biomass that remains in the field after the harvest of agricultural crops. The most common residues include stalks and leaves from corn and sorghum (stover) and straw from wheat, barely, oats, and rye production. Agricultural crop residues play an important role in maintaining and improving soil tilth, protecting the soil surface from water and wind erosion, and helping to maintain nutrient levels. While agricultural crop residue quantities produced are substantial, only a percentage of them can potentially be collected for bioenergy use, primarily due to their effect on soil productivity and sustainability.

The amount of agricultural crop residue produced and could possibly be sustainably removed is a function of many factors: crop rotation, field management practices (tillage scenarios), timing of field management operations, physical characteristics of the soil type (soil erodibility, soil moisture retention), field topology (% slope), localized climate (rainfall, wind, temperature, solar radiation), and the amount of residue (cover) left on the field from harvest until the next crop planting.

Many energy, environmental, and economic unknowns exist with respect to the sustainable removal of agricultural crop residues. The purpose of this particular workgroup was to determine some of the more important areas that need addressing with respect to potentially utilizing this biomass resource base for alternate energy production on a local, regional, and national scale. Specifically, the group examined sustainable use of various types of residues as potential feedstocks for electricity and/or fuel production.

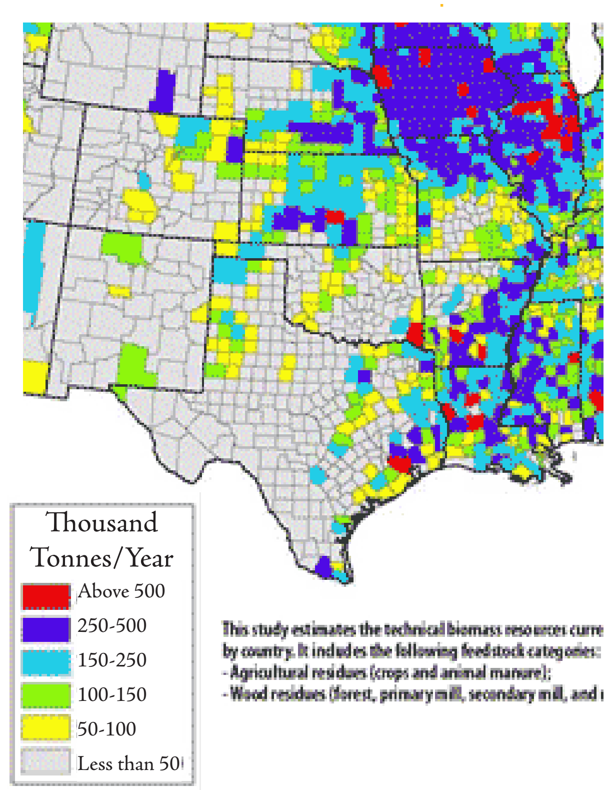
Available Feedstocks/Potential Quantities

Biomass resources available in the United States varies (see Figure 5). Of the biomass resources available, the following are thought to be the major crop residue feedstocks from a south-central United States regional perspective:

- Corn stover
- Small-grain straw (wheat, barley, oats, rye)
- Cotton gin trash
- Rice straw
- Sugarcane bagasse
- Oil seed residues (soybean, canola, and sunflower)

Corn stover and small-grain straw are the major agricultural crop residues/feedstocks from a national and regional perspective due to 1) production and 2) focus of interest by the United States Department of Energy. Assessments of the other feedstocks have historically been performed either on a regional and/or state-level basis due to the

Figure 5: Biomass Resources Available in the South Central Region - 2005 (*Milbrandt*)



geographic nature of production (e.g., rice straw and sugarcane bagasse). Available quantities of each of these feedstocks depend upon a number of factors dealing with energy inputs and outputs, environmental/sustainability impacts, and economics. Supply (quantity at a specific cost) is directly related to each of these three factors and should be evaluated on a localized basis.

POSSIBLE CHANGES

Existing Feedstock Enhancements and Expected Production Increases

Enhancement of existing feedstocks, such as the eight listed above, depends upon at least the following six factors:

- Breeding
- Agronomics
- Management and planning
- Equipment design and modification
- Convenience
- Education and outreach

Crop breeding, which has mainly been directed at improving grain yields, can also help in raising stover/straw production while agronomics and management/planning of crop production affect both the maintenance of the land base for sustainability purposes and cropping sequence, as well as timeliness of operations. Equipment design and modification is needed to help recover more "in field" residues while at the same time maintaining overall land base sustainability.

One important aspect of getting a major participation of producers for crop residue is the convenience of the stover/straw harvesting operations to the farmer or landowner with respect to his or her normal grain harvesting operations. Outreach and education are keys to having farmers and landowners understand all energetic, environmental/sustainable, economic aspects of crop residue removal and being comfortable in participating in sustainable residue management and removal on a continual basis.

Preferred Candidate Feedstock Species & Varieties

The best candidate agricultural crop feedstocks depend upon a number of factors and involve optimizing residue removal with land base sustainability. Examples of optimizing residue collection involve

taking into consideration: crop varieties, which can be somewhat region or location dependent; economics; residue quality; environmental and sustainability aspects; and site specific removal effects. Corn stover and wheat straw are the most well-known due to their "familiarity" on a national basis by the DOE (*United States Department of Energy*). However, limited agronomic, harvesting, and sustainability work for optimal residue removal has been performed.

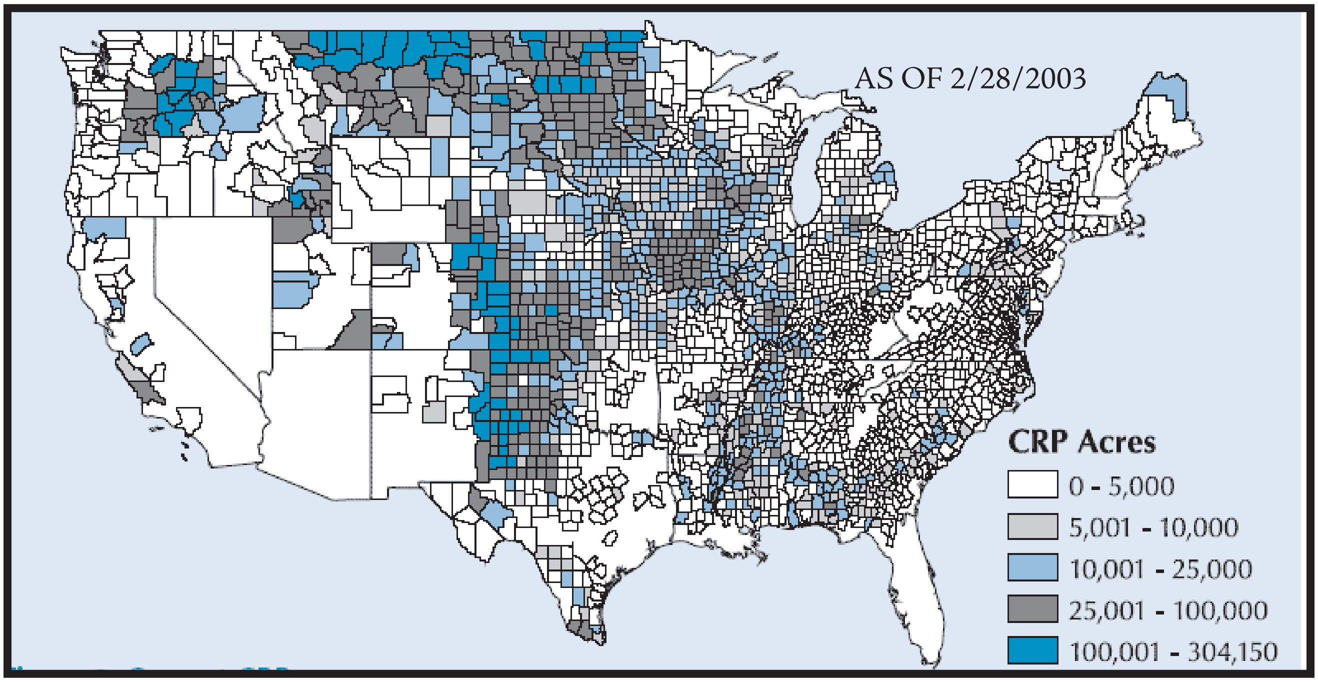
Potential Feedstock Enhancements and Quantities

Examples of "new" feedstocks that could potentially be utilized to enhance the current potential feedstock supply are:

- Corn cobs (3/4 to 1 ton/acre for 130 bushels/acre corn)
- Millet
- Unacceptable (e.g. moldy) hay
- Oil seeds (sunflower, canola)
- Sugarcane leaf residues
- Bagasse from sweet sorghum conversion
- Rice straw
- Municipal waste
- Use of Conservation Reserve Program (CRP) lands (see Figure 6)
- Other "subtropical" possibilities, such as double cropping along the Gulf coast
- "Weed" species, like mesquite and Chinese tallow

Knowledge about a few of these suggested feedstocks and cropping practices mostly concerns production practices and gross residue quantities. Potential use of each of these biomass feedstocks should be subjected to the same energetic, envi-

Figure 6: Current Conservation Resource Program (CRP) Acres in the United States (*www.usgs.gov*)



ronmental/sustainability, and economic criteria proposed for use of conventional agricultural crop residues, especially the utilization of CRP acreage for increased crop production. In addition, market forces will almost surely play a role as well.

Existing Feedstock Inventories

Several inventories exist for determining or estimating gross residue amounts or quantities that could potentially be removed with respect to one or more sustainability parameters (e.g. soil erosion). These include:

- National Agricultural Statistics Service databases - Crop production estimates for yields and harvested and planted acreages by county and agricultural statistic district (*www.nass.usda.gov*).
- Possible state reports - State-level estimates of agricultural crop residue production and estimates of removal rates.
- National Renewable Energy Laboratory Agricultural Crop Residue Study - Estimates of corn stover and wheat straw removal with respect to soil erosion.
- Natural Resources Conservation Service - "Localized" conservation compliance guidance with respect to potential removal of crop residues.
- Natural Resources Ecology Lab at Colorado State University - Carbon modeling with respect to crop production and the potential removal of crop residues.

Information may also be available from state crop breeding and agronomic programs, crop testing, and state and national commodity organizations concerning local and regional databases for varieties, yields, and adaptation. All of this information would contribute to a better understanding of residue production and sustainable crop residue removal rates.

CHALLENGES & OPPORTUNITIES

Significant Voids Concerning Sustainable Removal of Feedstocks

The workgroup felt the following concerns were critical for establishing and maintaining viable local, regional, and national agricultural crop residue removal programs:

- **Sustainability.** A number of different aspects concerning overall sustainability of crop residue removal have not been addressed in actual "in field" experiments. This includes residue retention levels and the total impacts on the soil resource, soil and crop productivity, and overall environmental quality with respect to the total crop production system.
- **Actual measurements** of biomass yields are desirable because national harvest indices, such

as 1:1 for corn, may not be applicable to all geographic locations in the South Central Region, as well as nationally. Also, most studies have a national focus with a variety of assumptions, at least some of which may not apply at a regional and local scale. This will have a pronounced effect on crop residue estimates and supplies.

- **Economics**. How to place value on biomass will determine crops and acres planted. Competing uses for residues will cause farmers and landowners to be subject to market forces of supply and demand. Markets for competing uses of crop residues, such as for animal use will need to be evaluated.

Constraints to Feedstock Development

- Education for sustainability, contractual issues, land grant research information, extension, private energy company agronomists, and consulting companies.
- Pricing of biomass (i.e. "What is the true value of agricultural crop residues?").
- Density characteristics of biomass - Goes towards improving harvesting and transport economics.
- Farm and field size constraints - i.e. "How do these play into the economics of crop residue removal and residue availability?"
- Equipment constraints - Current machinery was deemed unacceptable for optimal and sustainable harvesting.

Potential Co-Products

- Lignin and wastes from agricultural crop residue processing for bio-based products and electrical production.
- Potential problems with respect to metals and other chemical ingrained in the residues, such as salts ($CaSO_4$) from some processes which may affect by product use.

Potential Benefits and Consequences of Feedstock Production

- Sustainability issues - these will be site specific and need to be evaluated as such.
- Biases in assessments of what will and won't work - local or more geographically regional values would be best in examining assessments and supplies.
- Economic benefit for producers and rural communities - what might be the total direct and indirect benefits associated with agricultural crop residue removal for alternate energy and bio-based product production?
- Increased complexity - farmers and landowners are not accustomed to having their residue base utilized for alternate purposes directly after harvest. What are labor, availability of equipment, quality (one-pass harvest residue moisture content), and other relative concerns that must be factored into a systemic analysis?
- Consequences of bioenergy failure - if the first few enterprises are not successful due to lack of planning or lack of regard with respect to sustainability, how will this impact public confidence?

Societal Issues

- What will be the societal perception associated with a change from food production to a system of food and fuel, or just fuel alone?
- Consumer perceptions and reality concerning use of agricultural land for fuel production and its effect on food prices?
- Future citizen support for bioenergy if oil prices decrease; how will the public and the government react to increased biofuel production if petroleum prices fall in the future?

Discussion of the "Billion Ton" Study

The "Billion Ton" Study by the United States Departments of Agriculture and of Energy has received much attention (*Biomass*). After review, a few major questions were raised and discussed among members of the workgroup concerning some conclusions, especially with regard to the South Central Region.

- With regard to the yield increase of 50 percent by 2030 for corn and wheat, the numbers may be different for the South Central Region. Some areas may be above or considerably below 50 percent. Local assessment is needed.
- The study indicates the residue to grain ratio for soybean should increase from 1.5:1 to 2:1. However, the workgroup believes this is probably unlikely and removal of soybean residue may not be wise regarding sustainability, especially in a corn-soybean rotation where the corn stover has been removed.

- Significant research is needed regarding the study's desire to recover 75 percent of residues from the fields. The workgroup would like to see more research with respect to sustainability concerns and the economics of residue removal.
- The 100 percent use of no-till idea is overly simplified, as crops, rotations, and a number of other factors must be considered.
- With respect to the "No net change in cropland area and CRP is included" statement, there are significant environmental concerns regarding the use of CRP lands for increased crop production, especially after they were initially placed aside due to environmental concerns. Their set-aside has most likely increased carbon levels in the soil due to sequestration and improved water quality, both which may be undone with crop production. These issues need addressing.

Immediate "Action Items"

The workgroup felt the following six items merited immediate attention or action by the United States Department of Energy with respect to the potential utilization of agricultural crop residues on a local, regional, and national basis:

- Sustainability concerns (sustained crop productivity and soil quality)
- Feedstock delivery with regards to farm size and feedstock density
- Societal concerns in terms of consumer perceptions upon effect on food prices
- Actual "real world" data; localized or regional focus versus national averages (e.g. varieties used and harvest indices)
- Education of producers
- Definition of losses from field to refinery

Works Cited:

Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply. Joint project by the United States Department of Agriculture and United States Department of Energy. Oak Ridge National Laboratory: Oak Ridge, TN. April 2005. (See Page 31).

Milbrandt, Anelia. A Geographic Perspective on the Current Biomass Resource Availability in the United States. National Renewable Energy Laboratory, Golden, CO. 2005. (See Page 28).

National Agricultural Statistics Service (NASS). www.nass.usda.gov. (See Page 30).

United States Department of Energy (DOE). www.energy.gov. (See Page 29).

United States Geological Survey (USGS). http://www.usgs.gov/125/articles/conservation.html (See Page 30).

Sustainable Crop Residues Workgroup Members

Frank Hons, Co-Leader	Texas A&M University	College Station, TX
Richard Nelson, Co-Leader	Kansas State University	Manhattan, KS
Walter Armbruster	Farm Foundation	Oak Brook, IL
Jan Auyoung	Oregon State University	Corvallis, OR
Dani Bellmer	Oklahoma State University	Stillwater, OK
Henry Bryant	Texas Agricultural Experiment Station	College Station, TX
Bill Casady	University of Missouri	Columbia, MO
James Doolittle	South Dakota State University	Brookings, SD
Mark Gregory	Oklahoma State University	Stillwater, OK
Michael Halbleib	Oregon State University	Corvallis, OR
Richard Hess	Idaho National Laboratory	Idaho Falls, ID
Thomas W. Robb	Abengoa Bioenergy	Chesterfield, MO
Leon Schumacher	University of Missouri	Columbia, MO
Donghai Wang	Kansas State University	Manhattan, KS
Mark Wilkins	Oklahoma State University	Stillwater, OK

SUSTAINABLE WOODY ENERGY CROPS AND FOREST RESIDUES WORKGROUP RESULTS

BACKGROUND

Available Feedstocks & Potential Quantities

Available feedstocks and quantities of woody biomass are not well understood at this point. There are tremendous sub-regional differences, with the majority of forest residues and wood biomass coming from Arkansas, Louisiana, Oklahoma, Missouri, and Texas. However, opportunities exist for significant forest biomass in Kansas, New Mexico, and Colorado from public lands, tribal lands, and bioenergy plantations.

Table 3 summarizes sources, relative supply amounts, and important issues with each source of woody biomass.

Existing Feedstock Enhancements & Expected Production Increases

The feedstocks that can be captured most successfully are logging slash and urban wood waste. Shortening the rotations of existing timber plantations could also yield immediate biomass for feedstocks, but at a cost of tightened fiber supply to solid wood products and paper industries. Creation of woody biomass plantations on marginal agricultural lands, mine and land reclamation projects, and regions with limited water supply could increase biomass supplies within 3-5 years.

Preferred Candidate Feedstock Species & Varieties

Candidate species are very specific to soils, climate, and elevation. In the Gulf Coastal region, southern yellow pine, sycamore, and sweet gum are viable on upland sites. In bottom lands, cottonwood (many varieties and no consensus) and willow appear to be the most promising species. In high elevations, hybrid poplar has potential. In the Plains, red cedar and mesquite could be developed locally. Exotic species like Tung tree (Aleurites fordii), Salt cedar (Tamarix spp.), Eucalyptus spp., Tallow tree (Triadica sebifera), paulownia (Paulownia tomentosa), and Russian olive (Elaeagnus angustifolia) were mentioned.

Desirable Traits of Potential Feedstock Enhancements

Qualities of a desirable woody feedstock species for rapid growth include:

- Low nutrient and water requirements
- Drought tolerance
- Desirable stem:branch:bark:foliage ratios
- Emphasizing biomass accumulation in the stem
- Low lignin content
- An excurrent branching structure (a single main stem)
- Low costs for establishment
- Regeneration
- Maintenance
- Value for wildlife
- Co-production of other wood products

Existing Feedstock Inventory Requirements

The major forest inventories include the USDA Forest Inventory Analysis (FIA) and Timber Product Output (TPO) databases. Tree genome databases are needed, especially relating desirable bioenergy characteristics to genotypes.

Also needed is an annotated bibliography of previous woody bioenergy research. The bibliography should include genetics, whole-tree harvesting and economics, silviculture, and species (variety) selection research. Collaboration with the USDA Forest Products Laboratory Technology Marketing Unit and Woody Biomass Utilization Unit is important. And modeling tools, such as the National Scale Tree Biomass Equations (GTR-NE-319) and forest modeling tools like the Forest Vegetation Simulator need to be evaluated for their usefulness in predicting woody biomass feedstocks.

Significant Voids Concerning Sustainable Removal of Feedstocks

Research studies are needed to determine the quantity of logging residue that can be economically recovered without impairing the long-term produc-

Table 3: Woody Biomass Feedstock Sources, Relative Supply Amounts, and Costs within the South Central Region

LOCATION	FEEDSTOCK	SUPPLY	COST	COMMENTS
In-Forest Residues	Logging Residues	HIGH	LOW	Largest continuous supply of low cost biomass available; cost is almost entirely related to collection and transportation
	Non-Growing Stock Trees	MODERATE	LOW	Ability to harvest with high quality trees used for solid wood products and paper
	Shrub and Forest Understory Woody Plants	LOW	HIGH	Some forest productivity and health benefits from removal of this material; potential negative biodiversity and wildlife impacts
	Forest Health Thinnings	MODERATE	MODERATE	Similar to nongrowing stock trees; on public lands this may be a major source of biomass
	Forest Mortality	LOW	MODERATE	Irregular supply from catastrophic events like hurricanes, fires, and ice storms
	Forest Biomass from Land Use Conversion	LOW	LOW	Low cost of material due to proximity to road network; not a sustainable source of biomass
	Precommercial Thinnings from Timber Plantations	MODERATE	LOW	Possible to combine dedicated bioenergy plantations with solid wood production and jointly produce both energy and solid wood products
	Dedicated Woody Biomass Plantations	MODERATE	MODERATE	Initial cost of establishment high relative to value of wood for biomass only; advantages on marginal agricultural land include relatively low input requirements; may be well suited for reclamation projects on mine lands and other wastelands
Non-Forest Residues	Mill Residues	HIGH	MODERATE	Most mill residues already used for paper and energy; increased demand will raise price quickly
	Urban Wood Waste	MODERATE	LOW	In regions with large urban areas, urban forest trimmings can be a steady supply of biomass; some utilization landscaping mulch, but excess supply is believed to exist
	Wood Waste in Municipal Solid Waste and Landfills	MODERATE	HIGH	Cleaning costs and recovery of this material are paramount issues
	Trimmings and Orchard Removals	LOW	LOW	In some localities, this may contribute regular low cost biomass

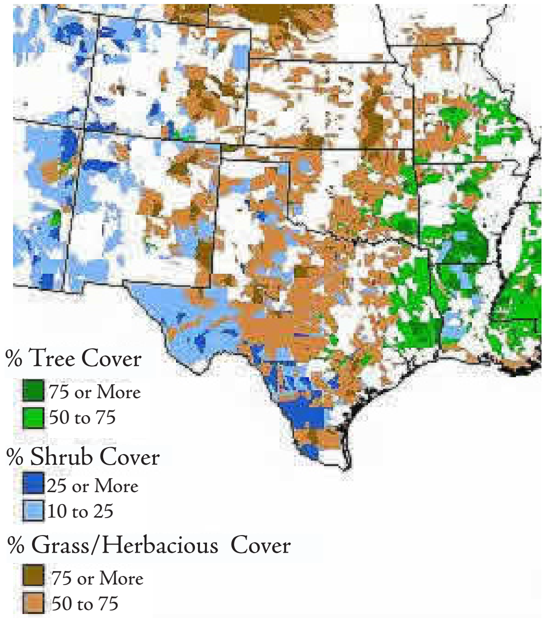


Figure 7: Ground Cover types in the South Central Region - 1992 (*www.nass.usda.gov*)

tivity of the forest. This value will vary by forest and soil type, as well as climate and elevation.

A bibliography and evaluation of previous bioenergy research needs to be completed. Woody bioenergy research dates back to the 1970's, and some of it will still be applicable to current needs (see *Existing Feedstock Inventory Requirements mentioned earlier in this section*).

The spatial resolution of FIA and TPO databases needs to be enhanced to perform adequate supply and transportation cost modeling. Linking these databases to satellite land cover data is a crucial research area.

Other areas of needed research are tree genome databases, the social acceptance of forest-based bioenergy, urban wood waste production, and the quality and quantity of woody biomass in landfills.

Sources of Information Available to Determine Land Feedstock Capability

The starting point for matching site and tree species is the NRCS Soil Maps and Natural Resource Database. There needs to be stronger coordination and linkages between the state land grant universities that bring together experiment station publications and cooperative extension service publications, which hold a great deal of vital management information. There also exists a body of biomass and bioenergy technology information for international audiences, including the Green Revolution and the IEA Bioenergy Tasks (*International Energy Agency*). Finally, another source of information is the National Agricultural Library.

Constraints to Feedstock Development

Transportation infrastructure is crucial for the expected large procurement zones for a biorefinery processing two million green tons of biomass annually. Intermodal facilities linking highway, rail, and water systems will factor into locations of biorefineries using woody biomass as a feedstock. The second most vital issue is commutation of woody biomass, or decreasing the volume: weight ratio to reduce the cost of transportation. Distributed preprocessing of logging slash will be a necessity due to material handling and transportation costs.

There is a labor shortage in truck transportation that is deeply felt in the logging industry. The logging industry does not have the conversion or preprocessing equipment to commutate woody biomass. For a biorefinery to process two million tons of woody feedstock, the regional logging infrastructure will need a $40m-$50m investment to purchase equipment. This would enable it to supply the biorefinery's demand for logging residues.

Finally, there is some seasonality associated with forest biomass. During wet weather, logging actions are typically suspended to protect soil resources and water quality. Thus, a biorefinery will, like a paper mill, require a six to eight week supply of biomass to ensure operations during winter months. Location of storage facilities and possible decay of ground or chipped woody biomass may require some form of commutation of logging residues that maintains woody stem integrity, such as slash bundling.

Technology Drivers for Feedstock Development

Politics and public or media hype are significant factors driving public opinion and policy on biofuels. The focus on ethanol production and transportation fuels is draining funding and development resources away from other promising aspects of biopower.

State and federal mandates on ethanol are having undesired impacts on food prices, soil and natural resource conservation programs, and have the potential to damage the United States pulp and paper industry.

Market forces that will drive feedstock development include the market price for the feedstock itself, the cost of collecting, handling, and converting technologies. Woody biofuels will likely have low market prices, and low to moderate collection and handling costs. Conversion technologies are in the formative stage, but once proven will likely emerge on the low end of the biofuel cost spectrum.

Process Co-Products and Costs

Process co-products include:

a. Co-generated heat, which can be used in wood and paper drying process
b. Co-products separated in the collection stream, such as pine straw and bark mulch
c. Ash from combustion of wood for bio power used as a soil amendment
d. Distillation products and naval stores

In addition, to co-products, reforestation costs are likely to be reduced by the collection of logging slash and better forest harvesting aesthetics. The forest will see "less waste" after timber harvesting.

Benefits/Consequences of Feedstock Production

Biofuel economic development will cause job creation and job losses with economic sector shifts. There is a strong possibility that market interventions in support of ethanol production could be harmful to the pulp and paper industry. Environmental benefits include a reduction in herbicides, fertilizer, and water for irrigation on marginal agricultural lands converted to forest bioenergy plantations. Soil conservation should be improved, as well as wildlife habitat and biodiversity. Favorable soil nutrient relationships and improved soil carbon sequestration would result from converting marginal agricultural land to forest bioenergy plantations.

In existing forest lands, better forest health and productivity could result from the removal of smaller, diseased, damaged, and non-desirable trees for biofuel feedstocks. Landowners could receive greater economic returns from additional merchandising of tree biomass.

Consequences and Social Issues

Benefits include diversification of domestic energy production with greater security from man-made and natural disruptions in the energy supply chain, also improving environmental security. Rural areas are likely to benefit most from forest-based bioenergy production, increasing local economic self-sufficiency through additional markets for forest and agricultural biomass. In many states in the South Central Region, woody biomass feedstock production would create opportunities for tribal lands and people.

Social acceptance of using wood as an energy source is questionable. Concerns regarding forest sustainability and environmental quality have been expressed in recent bioenergy studies conducted by the University of Florida.

Collaborative Discussion

There is new (ongoing) available research for high-elevation woody biomass production in New Mexico with hybrid poplar, as well as forest health thinning research on public lands.

Results from surface mine reclamation projects and research capacity in this field should be tapped to assist in woody biofuel feedstock production. Other collaborators are genetics and biotechnology experts (both commercial and government), land grant colleges and natural resource units, the forest industry (Price BioStock Services, Plum Creek, Weyerhauser) and public and private ecological research organizations (Jones Ecological Research Center in Georgia and The Nature Conservancy).

Recommended Action Steps

Research priorities for woody biomass are:

1. Review and evaluate previous biomass field trials, woody energy studies, and woody biomass harvesting technology studies; make bibliography readily avail able to researchers.
2. Find new research on economics and ecol ogy that is related to collection of logging slash residues in different regions, and forest types, as well as with different col lection equipment.
3. Review and evaluate existing supply mod els and forest projection systems to assess their value in projecting woody feedstock production and supply .
4. Develop better spatial linkages for FIA and TPO databases.

Some important feedstock research trial characteristics for future research RFPs include the integration of:

1. Productivity and economics
2. Ecosystem sustainability and impacts on ecosystem components
3. Social consequences, extension and public outreach

It is also vital that future research programs permit long-term (i.e. five to six year) project life spans, or allow "seed grants" to be part of the funding mix. Normal 2-4 year funding cycles are often inadequate for projects involving growing trees.

Additionally, funding agencies must have a landscape-level vision about woody biomass feedstocks. Various federal agencies are funding woody bioenergy research and they need better cooperation and coordination. Furthermore, funding agencies need to take into consideration conflicting agency and university goals, reward systems, and restrictions.

Works Cited:

National Agricultural Statistics Service (NASS). www.nass.usda.gov. (See Page 35).

International Energy Agency. "IEA Bioenergy Tasks." http://www.ieabioenergy.com/OurWork.aspx. (See Page 35).

Sustainable Woody Energy Crops and Forest Residues Workgroup Members

Matt Pelkki, Leader	University of Arkansas	Monticello, AR
Dick Carmical	The Price Companies	Monticello, AR
Mark Downing	Oak Ridge National Laboratory	Oak Ridge, TN
Jim Gan	Texas A&M University	College Station, TX
Steve Loring	New Mexico State University	Las Cruces, NM
Laura Neal	U.S. Department of Energy	Washington, DC
Mick O'Neill	New Mexico State University	Las Cruce, NM
Dave Patterson	University of Arkansas	Monticello, AR
Garvin Quinn	Oklahoma State University	Stillwater, OK
Tim Rials	University of Tennessee	Knoxville, TN
Ed Rister	Texas A&M University	College Station, TX
Bob Shaw	Texas A&M University	College Station, TX
Daniel Thomas	Louisiana State University	Baton Rouge, LA

AGRICULTURAL INDUSTRIES BY-PRODUCTS WORKGROUP RESULTS

INTRODUCTION

It has been said there is no such thing as an agricultural waste. However, what is called waste is, in fact, really undervalued commodities The purpose of this report is to investigate the potential for undervalued by-products of agricultural production to serve as feedstock for biofuel. The valuation process was as follows:

1. Five year average production (or production trends) of major crop and animal commodities were determined through information obtained from the United States Department of Agriculture National Agricultural Statistics Service (*www.nass.usda.gov*).
2. Mass of crop production by-products per mass of raw commodity was based on the best professional judgement of the experts present.
3. Mass of animal manure and bedding were based on ASABE standard D384.2, Manure Production and Characteristics, and the best professional judgement of the experts present.
4. Mass of by-product was converted to thermal energy potential using the following factors:
   - 16,000 Btu per pound wet weight of fats and oils
   - 9,000 Btu per pound of starches and sugars
   - 8,500 Btu per pound of dry volatile solids (VS) for manures
   - 8,000 Btu per pound dry VS for broiler litter
   - 7,000 Btu per pound wet weight of plant material
5. Potential for use as feedstock was evaluated by considering the dryness of the material, regional concentration of production, and comparison of the energy potential to that of bagasse produced in the region.

Bagasse is the fibrous material remaining after sugar cane is crushed in a sugar mill. It is a well-known energy source within the sugar milling industry. Bagasse burned at sugar mills is used for cogeneration. It is so abundant and energy dense that the mass produced by a sugar mill can create more than enough energy to run the mill. In pre-statehood Hawaii, bagasse produced by the C&H mill on Maui provided sufficient power to fulfill the electrical needs of the entire island. In Brazil, cogeneration from bagasse is used not only to run sugar mills, but to provide energy to ferment sugar and distill the alcohol that runs Brazil's biobased energy economy.

The following section details the production and energy potentials of the most likely candidate by-products found in the region. These were narrowed down from an exhaustive list that included fats and oils from animal slaughter; horticultural by-products; wheat, sunflower, and canola storage and processing by-products; and dairy processing by-products.

To stress the significance of these materials, consider this: In Louisiana alone, cattle manure or biogas could privide 9.9 billion cubic feet of gas annually - enough to supply energy to 22,000 homes (*Jackson and Mayfield*). It should be noted that the energy potentials used in this study are just that - potentials. They represent the total energy released if the commodity were dried and burned in a calorimeter. This was only used to compare the potential commodities for use as feedstocks. The actual energy produced from the by-products would be much lower, and would depend upon the conversion method used.

PLANT INDUSTRY BY-PRODUCTS

Sugar Cane

Sugar cane production in the South Central Region is concentrated in Southern Louisiana and the Rio Grand Valley of Texas (see Figure 8). Tons of raw cane harvested, tons of bagasse produced from the cane, and the energy potential of bagasse is given in Table 1. Waste production was calculated by estimating 500 lbs. bagasse produced per ton of harvested cane. The potential thermal energy currently tied up in bagasse in Louisiana alone is 42 trillion Btu per year.

Figure 8: Concentration of Sugar Production in the South Central Region (www.nass.usda.gov)

Each Dot Represents 2,000 Acres Planted in 2002

Table 4: Production of Sugar and Bagasse, and Potential Energy Value of Bagasse in the South Central Region (*www.nass.usda.gov*)

	Production		Energy Value
State	Sugar Cane	Bagasse	Bagasse
	Tons/Year	Tons/Year	1x10^12 Btu/Year
Louisiana	12,000,000	3,000,000	42.00
Texas	170,000	42,500	0.60
Region	*12,170,000*	*3,042,000*	*42.60*

Cotton

Cotton produced is concentrated in the Mississippi Delta of Louisiana, Arkansas, and Missouri; along the Gulf Coast of Texas; and on the High Plains of Texas, New Mexico, Kansas, and Oklahoma (see Figure 9). Bales of raw cotton harvested in the South Central Region are depicted in Table 5. Spindle type pickers harvest cotton in the Delta and Gulf Coast, whereas strippers are used on the high plains. Spindles collect less extraneous material (leaves, sticks, etc.) than strippers. Bale size varies greatly with the two harvesting methods. A bale of cotton may weigh anywhere from 500-800 lbs. To calculate mass produced in Table 4, assumptions include a 600 lb. bale in Texas, New Mexico, Oklahoma, and Kansas, and a 525 lb. bale in Arkansas, Louisiana, and Missouri.

In Table 5, it was assumed that one ton of raw cotton yields 400 lbs. of lint, 1,000 lbs. of seeds, and 600 lbs. of trash, regardless of bale size. The 1,000 lbs. of seeds are further processed to produce 800 lbs. of meal and 200 lbs. of oil.

Cottonseed oil is a major source of edible oil, but it does have the potential for conversion to biodiesel.

Figure 9: Concentration of Cotton Production in the South Central Region (*www.nass.usda.gov*)

Each Dot Represents 5,000 Acres Planted in 2002

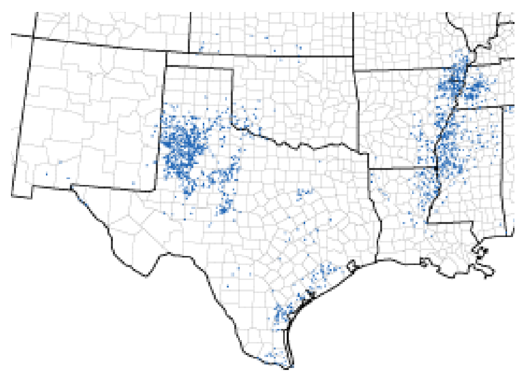


Table 5: Production of Raw Cotton and Cotton Products, and Potential Energy Value of Cottonseed Oil, Meal, and Gin Trash in the South Central Region (*www.nass.usda.gov*)

	Production					Energy Value		
State	Raw Cotton	Lint	Cotton-seed Oil	Cotton-seed Meal	Trash	Cotton-seed Oil	Cotton-seed Meal	Trash
	Bales/Year	Tons/Year				1x10^12 Btu/Year		
Arkansas	2,100,000	110,000	55,000	220,000	165,000	1.80	3.10	2.30
Kansas	82,000	5,000	2,500	9,800	7,400	0.08	0.14	0.10
Louisiana	990,000	52,000	26,000	100,000	78,000	0.83	1.50	1.10
Missouri	830,000	44,000	22,000	87,000	65,000	0.70	1.20	0.92
Oklahoma	270,000	16,000	8,100	32,000	24,000	0.70	0.45	0.34
New Mexico	110,000	6,600	3,300	13,000	9,900	0.11	0.19	0.14
Texas	6,900,000	410,000	210,000	830,000	620,000	6.60	12.00	8.70
Region	*11,282,000*	*643,000*	*336,900*	*1,291,800*	*969,300*	*10.82*	*18.58*	*13.60*

The region has the potential to produce nearly 11 trillion Btu per year of energy from cottonseed oil. Cottonseed meal is a valuable animal feed component, but if converted to biofuel the potential energy available in the region is almost 19 trillion Btu per year.

There are no competing uses for cotton gin trash. Currently, trash is land applied to fields near gins. If converted to heat energy, the potential value of gin trash is nearly 14 trillion Btu per year. Cotton gins are spread over a larger geographic area than sugar mills, but the large potential energy source is still concentrated in a relatively small area.

Rice

Rice production is heavily concentrated in the Grand Prairie region of Arkansas. Other rice growing areas are the Mississippi Delta of Arkansas, Louisiana, and Missouri; and the Gulf Coast of Louisiana and Texas (see Figure 10). Rice production is measured in cwt or 100 lb. units. Each cwt of rough rice yields 70 lbs. of grain (60 lbs. full, 10 lbs. broken), 25 lbs. of hulls, and 10 lbs. of other trash (such as stems). Rice production values for the region are given in Table 6.

Broken rice grains are used for brewing beer, but they can also be fermented to produce motor fuel ethanol. If the entire regional supply of broken rice were converted to energy, the potential would be nearly 14 trillion Btu per year.

Rice hulls are used by the poultry industry as bedding, but are also used extensively along with non-hull trash for cogeneration at the mill. Use in cogeneration is such that rice hulls have become almost too expensive for use as bedding. The heat energy value of rice hulls and trash is 32 trillion Btu per year.

Figure 10: Concentration of Rice Production in the South Central Region (*www.nass.usda.gov*)

Each Dot Represents 3,000 Acres Planted in 2002

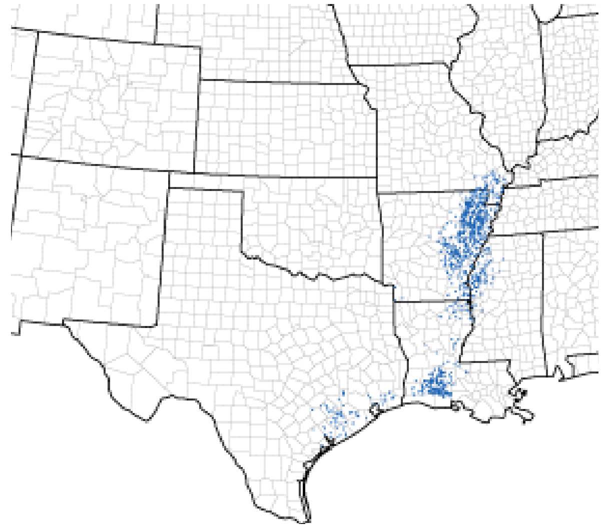


Table 6: Production of Rice and Rice Products, and Potential Energy Value of Broken Grains, Rice Hulls, and Trash in the South Central Region (*www.nass.usda.gov*)

	Production					Energy Value		
State	Rough Rice	Whole Grains	Broken Grains	Hulls	Non-Hull Trash	Broken Grains	Hulls	Non-Hull Trash
	Cwt/Year	Tons/Year				1x10^12 Btu/Year		
Arkansas	100,000,000	3,000,000	500,000	1,250,000	250,000	9.00	17.50	3.50
Louisiana	26,000,000	780,000	130,000	330,000	65,000	2.30	4.60	0.91
Missouri	13,000,000	390,000	65,000	160,000	32,500	1.20	2.30	0.46
Texas	12,000,000	360,000	60,000	150,000	30,000	1.10	2.10	0.42
Total	151,000,000	4,530,000	755,000	1,890,000	377,500	13.60	26.50	5.29

Poultry

Three types of poultry were considered in this report: broilers, laying hens, and turkeys. The broiler industry is concentrated along the western borders of Missouri, Arkansas, and Louisiana; and the eastern borders of Oklahoma and Texas (see Figure 11). There are large concentrations of turkeys and laying hens in northwestern Arkansas and southwestern and central Missouri (see Figures 12 and 13). Another concentration of layers is located in South Central Texas. Production and potential energy from poultry manures are also given in Tables 7 and 8.

Production and energy potential of broiler litter was based on current practices. Twenty tons of cake - the wet (40 percent moisture), heavy material concentrated beneath feeders and waterers in poultry houses - are collected after each 20,000 bird flock is removed. One hundred tons on cleanings (20 percent moisture) are collected per house each year (140,000 birds in seven flocks). The organic matter content of both cake and cleaning solids are 75 percent. Thirty trillion Btu of heat energy is produced as broiler litter in the South Central Region each year. This energy may also include part of the 26.5 trillion Btu included in Table 5 as rice hulls, since a portion of the hulls produced are used as poultry bedding.

Turkeys are raised in a similar system as broilers, however, they have longer growing periods; thus, less cake is produced. In Table 8, ASABE (American Society of Agricultural and Biological Engineers) Standard D384.2 was used to calculate volatile solids produced per turkey grown, with the assumption that 50 percent of the organic matter will be lost before collected.

Layers are raised in cages. Manure is collected daily by conveyors placed below the cages, or it is allowed to dry in deep stacks below the houses. Layer

Table 7: Broiler Production, Estimated Dry Tons of Broiler Litter, and Energy Potential of Broiler Litter in the South Central Region (*www.nass.usda.gov*)

	Production		Energy Value of Litter
State	Broiler Placements	Litter Produced	Litter
	Chicks/Year	Dry Tons/Year	1x10^12 Bty/Year
Arkansas	1,300,000,000	1,300,000	16.00
Louisiana	200,000,000	210,000	2.50
Oklahoma	250,000,000	260,000	3.20
Texas	640,000,000	670,000	8.00
Region	*2,390,000,000*	*2,440,000*	*29.70*

Table 8: Turkey and Egg Production, and Energy Potential from Collected Manure Organic Matter in the South Central Region (*www.nass.usda.gov*)

	Production		Collected Organic Matter		Energy Value	
State	Turkeys Raised	Layers Housed	Turkey	Layers	Turkey	Layers
	Birds/Year		Lbs VS/Year		1x10^12 Btu/year	
Arkansas	30,000,000	15,000,000	180,000,000	190,000,000	1.50	1.60
Colorado		3,800,000		50,000,000		0.42
Louisiana		2,350,000		31,000,000		0.26
Missouri	21,000,000	7,500,000	130,000,000	98,000,000	1.10	0.83
Oklahoma		3,200,000		42,000,000		0.36
Texas		18,000,000		240,000,000		2.05
Region	51,000,000	49,850,000	310,000,000	651,000,000	2.60	5.52

Figure 11: Concentration of Broiler Production in the South Central Region (*www.nass.usda.gov*)

Each Dot Represents 2,000,000 Broilers Sold in 2002

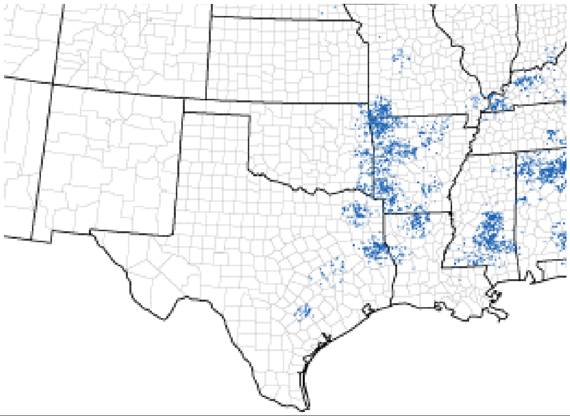


Figure 12: Concentration of Turkey Production in the South Central Region (*www.nass.usda.gov*)

Each Dot Represents 60,000 Turkeys Sold in 2002

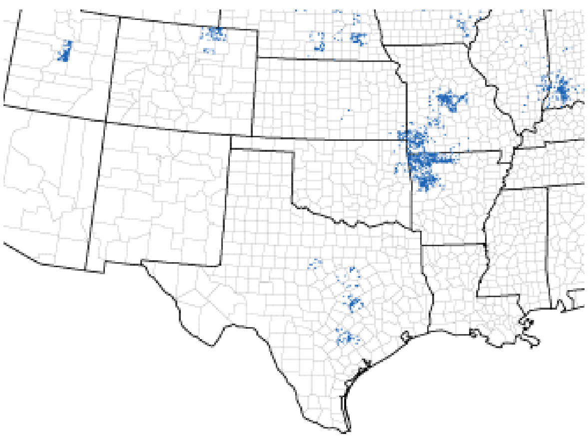
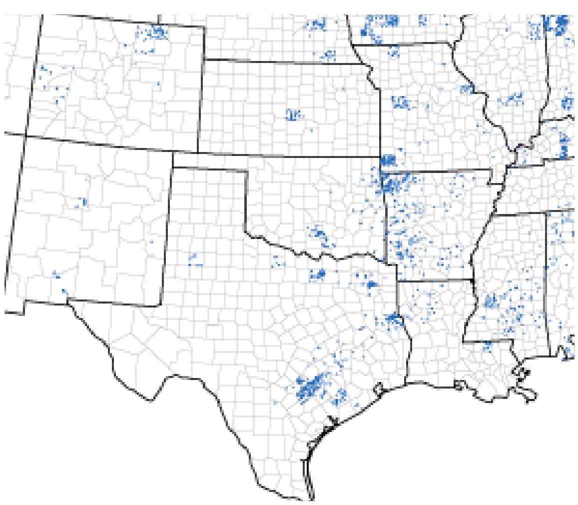


Figure 13: Concentration of Egg Production in the South Central Region (*www.nass.usda.gov*)

Each Dot Represents 60,000 Laying Hens in 2002



manure is wetter than broiler or turkey litter, but it is assumed there is no loss of organic matter during collection.

Energy potential from turkeys and layer production is relatively small: 8.1 trillion Btu per year for the region. If the turkey and layer manure produced along the Arkansas-Missouri border were collected with broiler litter, it would increase the broiler litter energy potential in the region by approximately 13 percent, to 32 trillion Btu per year.

Although not a goal of this report, the potential energy derived from biodiesel using intracellular fat collected during broiler slaughter is 18 trillion Btu per year. This is assuming a 5 lb. slaughter weight, 10 percent intramuscular fat, and all of this fat could be collected.

Beef Cattle on Feedlots

Beef feedlots are concentrated on the High Plains of Texas, Oklahoma, Colorado, New Mexico, and Kansas (see Figure 14). Approximately 12 million head of cattle are fed each year in a relative handful of feedlots. Production and energy potential of manure collected from these animals are given in Table 8. Feedlots use a scraping and stacking system to handle dry manure accumulating on the feedlot surface. Feedlot manure is a dry product easily converted to energy through gasification or combustion. Co-combustion with coal has also been investigated as a means of energy conversion. Runoff from feedlots is stored in retention basins and used for nutrient recycling through irrigation systems, and was not considered as a source of energy.

Cattle fed per year was estimated by average feedlot inventory times two animals fed per inventory. Organic matter for finished cattle was calculated from the ASABE standard, assuming 50 percent loss of feedlot surface. This gives an energy potential of 29 trillion Btu per year from feedlot manure.

Dairy Cattle and Swine

There is some concentration of dairies on the High Plains of Texas and New Mexico, around Stephensville and Sulphur Springs, Texas; and in Grady County, Oklahoma. However, dairy farms are mostly dispersed across the landscape (see Figure

Figure 14: Concentration of Beef Cattle on Feed in the South Central Region (*www.nass.usda.gov*)

Each Dot Represents 5,000 Beef Cattle on Feed in 2002

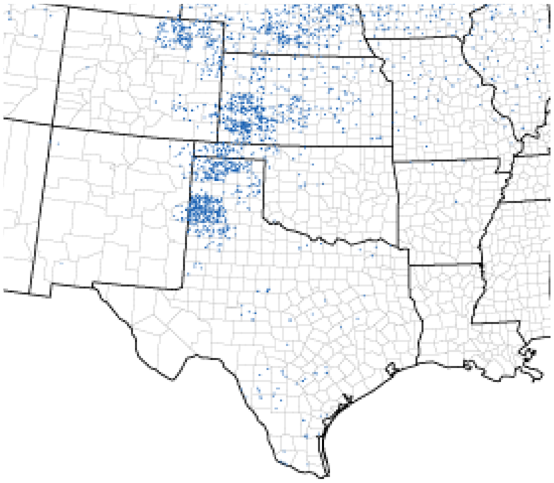
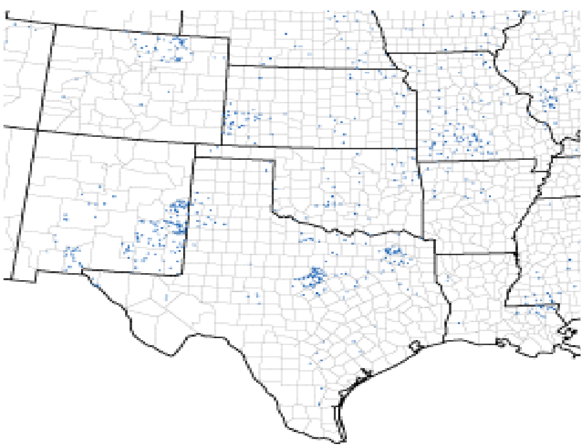


Figure 15: Concentration of Dairy Cattle in the South Central Region (*www.nass.usda.gov*)

Each Dot Represents 2,000 Milk Cows in 2002



15). Swine production is also scattered around the region with some concentration in the Oklahoma Panhandle and the northern portion of Missouri (see Figure 16).

Potential energy production from the organic matter content of dairy and swine manure is given in Tables 9 and 10. Organic matter production from milk cow inventory was determined through the ASABE standard with the assumption that all of the volatile solids are available for conversion. The average inventory of breeder swine was taken to be the population. The number of market hogs produced annually was calculated by multiplying the hog inventory by two and one-half turns each year. All of the organic matter predicted by the ASABE standard for swine was assumed to be available for energy production.

The greatest obstacle hindering biofuel production from dairies and swine farms is wet manure handling. The larger dairy farms are turning to freestall housing with flush systems for manure removal. The best method for energy recovery from flush dairies is on-farm anaerobic digestion. Research is also being conducted on gasification of dairy solids coupled with fixed-film anaerobic digestion of liquids.

Dairies on the High Plains use dry lot feeding systems similar to feedlots for beef cattle. Scrapings from dairy dry lots in New Mexico and Texas can be combined with beef feedlot scrapings. The energy potential from dairy manure in the region is 27 tril-

Table 9: Cattle Fed on Feedlots and the Energy Potential of Collected Feedlot Manure in the South Central Region (*www.nass.usda.gov*)

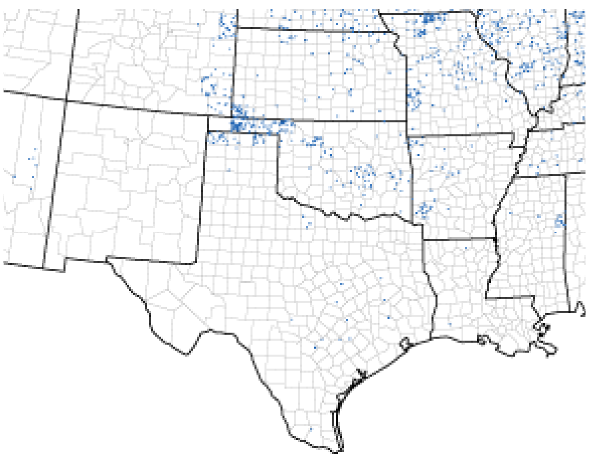
	Production Inventory	Collected Organic Matter	Energy Value of Feedlot Manure
State	Per Head	Lbs. VS/Year	1x10^12 Btu/Year
Colorado	1,100,000	560,000,000	4.70
Kansas	2,500,000	1,300,000,000	11.00
New Mexico	130,000	65,000,000	0.56
Oklahoma	360,000	180,000,000	1.60
Texas	2,800,000	1,000,000,000	12.00
Region	***6,890,000***	***3,105,000,000***	***28.86***

lion Btu per year. If the manure from New Mexico is combined with beef feedlots (and the potential reduced 50 percent due to loss of organic matter), the total potential for beef will increase 14 percent to 33 trillion Btu per year.

Almost all swine manure in the region is stored and treated in lagoon-based handling systems. Addition of anaerobic digestion to these systems could tap into a 23 trillion Btu per year potential. Retrofitting existing lagoon systems with anaerobic sequencing batch reactors is under investigation by researchers.

Figure 16: Concentration of Swine Production in the South Central Region (*www.nass.usda.gov*)

Each Dot Represents 2,000 Breeder Sows in 2002



SUMMARY

- Sugar production is concentrated in a small area of Louisiana. Thermal energy potential of by-products is 42 trillion Btu per year. Bagasse could be used as a feedstock for liquid fuel or used as a combustion energy source to make ethanol from sugar.
- Cotton production is concentrated in the Mississippi Delta and High Plains. Nearly one million tons of cotton gin trash are produced in the region each year with a 14 trillion Btu heat value. This is about one-third the energy potential of bagasse. Gin trash could be used as liquid fuel feedstock or burned to produce biodiesel from cottonseed oil. Energy potential of cottonseed oil is 11 trillion Btu per year.
- Rice production is concentrated in a relatively small geographic area in Arkansas and Louisiana. Heating value of the two and one-quarter tons of hulls and other by-products produced each year is 30 trillion Btu per year, or about three-fourths the value of bagasse. Rice hulls are used as bedding on poultry farms and some of their heat value may reappear as poultry litter.
- Rice milling by-products are currently used for cogeneration at the mill. Heat from cogeneration could be used to ferment and distill ethanol

Table 10: Pork Production and Potential Energy from Swine Manure in the South Central Region (*www.nass.usda.gov*)

	Production		Excreted Organic Matter	Energy Value of Excreted Organic Matter
	Breeders	Market Hogs		
State	Inventory	Inventory	Lbs. VS/Year	1x10^12 Btu/Year
Colorado	260,000	890,000	360,000,000	3.10
Kansas	220,000	1,600,000	540,000,000	4.60
Missouri	350,000	2,400,000	810,000,000	6.90
Oklahoma	360,000	2,000,000	710,000,000	6.00
Texas	100,000	860,000	280,000,000	2.40
Region	***1,290,000***	***7,750,000***	***2,700,000,000***	***23.00***

from broken rice hulls, which could potentially add another 14 trillion Btu of heat potential for liquid fuel.

- The two greatest sources of by-product from animal production are beef feedlot manure and broiler litter. The potential heat value of manure from feedlots on the High Plains augmented with New Mexico dairy manure is 33 trillion Btu per year. If the turkey and laying hen manure from the northwestern corner of Arkansas and southwestern corner of Missouri was added to the region's 2.4 million ton annual production of broiler litter, heat value would be 34 trillion Btu per year. Energy potential of both poultry litter and feedlot manure are about three-fourths the potential of bagasse.
- The potential energy stored in wet swine and dairy manure is approximately 60 trillion Btu per year, one and-a-half times the value of bagasse. This energy is best tapped through on-farm anaerobic digestion.
- Another potential source of biodiesel is animal fats. The region's broiler industry has the potential to contribute 18 trillion Btu per year if all intramuscular fat was collected - about half the energy value stored in broiler litter.

Jackson, Samuel W. and Chyrel Mayfield. Louisiana Biomass and Bioenergy Overview. Southeastern Sun Grant Initiative. Page 2. May 2007. (See Page 38).

National Agricultural Statistics Service (NASS). www.nass.usda.gov. (See Pages 38, 39, 40, 41, 42, 43, 44).

Agricultural Industries By-Products Workgroup Members

Doug Hamilton, Leader	Oklahoma State University	Stillwater, OK
Martin Hubert	State of Texas	Austin, TX
Monty Kerley	University of Missouri	Columbia, MO
Ned Meister	Texas Farm Bureau	Waco, TX
Al Parks	Prairie View A&M University	Prairie View, TX
Josh Payne	Oklahoma State University	Stillwater, OK
John Sweeten	Texas A&M University	College Station, TX

ENGINEERING AND RESOURCE ECONOMICS WORKGROUP RESULTS

ENGINEERING

Focus

The focus of this report is on identifying the engineering constraints to the delivery of feedstock to a refinery and the technology drivers affecting feedstock development. Discussion results are organized by starting with the establishment of the crops and residues, and following the supply chain through to the biorefinery gate. Throughout all aspects of the supply chain, the engineering needs can be characterized by the statement, "Systems are required to deliver dry matter to the refinery at minimal cost." Where current systems are not limited in terms of ability to produce and deliver biomass, continued refinement to cost reduction is required.

Main Issues

In his overview of Biomass and Bioenergy in Arkansas at the Arkansas Biomass Conference, Jim Wimberly best summarized the main issues of resource economics across the region (*Wimberly*). In terms of deployment considerations, he described the the main issues as:

- On-farm versus off-farm
- Supply of feedstocks - investors must have high confidence
- Product markets - "Don't make it if you can't sell it!" Investors must (again) have high confidence
- Selection of appropriate process, which is determined by target feedstocks and markets
  Investor considerations of 1) technology risk versus financial risk, 2) liability risk, and 3) access to equity and capital
- The key role of the public sector (*see the Policy Development Section for more information*)

The following secctions expand on Wimberly's considerations, as described by the Engineering and Resource Economics Workgroup.

Crop Establishment

Available engineering systems for the establishment of annual crops do not limit the potential adoption of those crops. Problems of stand establishment for small seeded perennials were identified, and potential solutions may be both engineering and biological. It was noted that no-till establishment of various crops (as anticipated in the Billion Ton Report) would not be feasible. Switch grass and miscanthus were discussed as particularly difficult to establish.

Crop Production

Likewise, current engineering systems for production practices, including site-specific inputs, were considered to be non-limiting. The Billion Ton assumption of 100 percent no-till of all biomass area was considered unrealistic, but it was not clear that this error would have a direct impact on the production of biomass. An indirect impact is possible if the operating expenses are high enough to discourage biomass production in those areas where no-till will not work.

Harvesting, Packaging, Storage Pretreatment, and Transport

The focus group immediately declined to consider harvesting, packaging, storing, pretreating, and transporting matters individually. There was a strong collective agreement that harvest through transport must be considered and evaluated as a system. A series of distinct, yet related, observations were made. General consensus supported the importance of these issues.

Harvest systems for more exotic biomass opportunities, such as Chinese tallow trees, do not currently have adequate harvesting techniques. Any adoption will be limited until mechanized harvest becomes available.

Forage harvesting equipment can be used for energy crops and residues, but re-evaluation is needed. Biomass for energy has different objectives than forage for animal feed. A fundamental difference is the need to harvest standing crops after a frost or freeze. Conventional forage systems are not designed for those conditions. Opportunities exist to enhance and optimize to reduce operating costs.

Yield mapping of biomass production is a needed feature for harvest systems. Sensors would be required to evaluate product quality for moisture content, lignin content, ash, etc. in real-time. Modeling tools that can simulate and evaluate potential logistical systems for energy crops and residues are needed. Those models need to be validated with ground truth data on the performance of various existing and prototype machines under a range of operating conditions. Validation is currently possible with residue collection, but the lack of large production areas of energy crops limits the potential for ground truth data collection. As pilot plant operations and research projects are conducted, opportunities for validation, both of specific model elements and overall systems, will be present. Both funding agencies and investigators or managers should be encouraged to incorporate model validation in their planned activities.

Minimizing the moisture content of hauled materials is critical to acceptable refinery gate dry matter costs. Accurate moisture extraction data will be a limitation for the design of biomass collection systems to achieve the desired moisture content. Depending on the local conditions and the specific crop, compromises will be required, and moisture loss prediction relationships are necessary.

Preprocessing of biomass at remote locations nearer to the source fields can have significant value. Removing dust emissions from the plant may reduce the regulatory impact, depending on the business model for harvesting and collecting the material. Size reduction to 25 mm or less is adequate for gasification and hydrolysis, but pyrolysis requires particle sizes of 2 mm. Additional pretreatment discussed included the application of anti-mold chemicals for moist materials. Also, the technology of the linear knife, as used in the paper and pulp industry, was suggested as an alternative to grinding for size reduction.

Summary

Existing engineering systems for most potential feedstocks will allow the development of the industry. However, improvements in energy consumption, overall cost, and available analytical or planning tools are needed.

ECONOMICS

Focus

The impact of biomass on an economy is huge, as described in Louisiana Biomass and Bioenergy Overview (*Louisiana State University*). In Louisiana alone, an estimated 22 percent of the states's homes could be powered by biomass energy resources. Of that, 111.8 trillion Btu (6.6 billion kWh) worth of energy would be available to power 367,799 homes at 18,000 kWh per home. To implement this sort of scenario, it is important to understand the economics of biomass and bioenergy. This section describes the supply and demand side of the matter at hand.

Availability of Cost of Production Budgets

Several key items are necessary for the economic evaluation of various feedstocks, ranging from dedicated energy crops to crop, forest, and processing residues. One issue discussed was the availability of cost of production budgets for various feedstocks.

For most of the lignocellulosic and crop feedstocks, budgets are readily available (with the exception of optimal harvest and storage for biomass crops). Another potential gap identified involves collection costs of forest residue and some agricultural residues where minimum residue requirements to be left in the field are either:

1. Undetermined for sustainability;
2. Difficult to collect due to moisture and field conditions at time of harvest (need to avoid field rutting as well as added cost of hauling and field access); or
3. Requires a yet to be determined fee to landowners and crop producers that needs to be paid before custom collection in a timely fashion before field preparation of next crop can commence.

A study of forest slash collection in bundles that are storable in Arkansas was quoted at costs ranging from $25 to $30 per dry ton with no cost for the material removed. Cost of animal manure collection and processing by-products are largely known. In some cases, transport of manures for reapplication to land is a problem from a transport cost point-of-view. Back haul opportunities, therefore, need to be evaluated as well.

Estimation of Supply Curves

A second economics issue involving feedstock resources involves the estimation of supply curves. While estimates exist (*Gallagher et al., Walsh et al*), there was a discussion regarding the regional level these supply curves need to be estimated. To be of value for plant location and feasibility studies, the region analyzed would be small and perhaps better left to private interests. For policy analysis, the region should cover the nation and include imports and exports to determine under what conditions energy crops would become economically feasible on any or all of the pasture, hay, and crop land.

There was also some discussion about existing models that may require some ground-truthing to validate model results. Work in this area could be quite costly and time-intensive. The alternative of calculating break-even cost of production and thereby minimum price levels for residues and energy crops. The additon of reasonable rate of return on land, capital, and labor will be based partially on relative profitability of farm enterprise alternatives, conservation, and other alternative uses or cost of nutrient replacement in the case of residue removal. This option brought third issue of seasonal potential availability of various biomass feedstocks.

Seasonal Potential Availability of Various Biomass Feedstocks

The information described previously is required to determine optimal harvest collection, transport, and storage for calculation of break even cost of production delivered to the plant. Growth curves or storage/yield losses for less than yield maximizing harvest times for different production environments would allow analysis of extending the harvest window and therefore capacity utilization of capital intensive harvesting equipment.

The trade-off between cost savings and yield losses of in-field storage, as well as other crop characteristics like nitrogen, ash content, and moisture condition at time of harvest has been evaluated to lower the cost of harvested material at seasonally opportune times, but not on a national or regional basis (numerous works by *Epplin*). This brought up the issue of contractual arrangements as producers with non optimal harvest times would suffer yield, quality, and/or nutrient losses that need to be quantified for long-term producer contracts with biorefineries that will coordinate or perform the harvest. The use of CRP contracts as a model of long-term contracting was mentioned. An alternative to producer contracts was provision of producer incentives via partial ownership in biorefineries. This also brought about the issue of fire insurance for in-field as well as satellite storage of large quantities of combustible materials which exists, but adds to the cost of raw material to the plant.

Economies of Size

Currently, the smallest scale envisioned is 3-400 DM ton per day for gasification to syngas with three to seven-fold larger volumes with biological conversion processes or pyrolysis, respectively. Government incentives to mobilize resources for these plants were considered, but the group also realized that current subsidies for the corn-to-ethanol industry has made the feasibility of growing energy crops compared to currently highly profitable corn

and other commodity crop production an additional hurdle. Most of these benefits get capitalized in land prices and lead to additional cost for land rental or leasing. These large plant size requirements can also lead to additional risk management considerations related to crop disease and insect pressures (the trade-off of high-yielding mono cropping to reduce transport cost versus crop rotations or inter cropping at potentially lower yields and at higher transport cost). Perhaps some efforts are needed to make smaller scale biorefineries economically viable via special treatment with respect to government aid.

At the same time, agricultural, energy, environmental, and water (currently lacking at the national level) policies need to become more aligned to move the goal of sustainable renewable energy production that would lead to increased energy independence as well as provision of adequate food, feed, and fiber production in a sustainable fashion.

Impact of Farm Size Operations/Land Ownership

A final issue is that current size of farm operations, as well as land ownership, is expected to impact adoption of long-term contracts and potential plant site decisions. For perennial crops, the model of the timber industry was suggested (i.e. purchase of large tracts of land for plants). The sugarcane mill industry may also offer insights to potential for integration. This may suggest that smaller producers are less likely to benefit from energy crops early on, as transaction costs of dealing with fewer larger operations would be smaller based upon larger operations. Small farms will benefit indirectly, as over time using agricultural and forestry resources towards energy production (even if not on their land) would either raise their land value or make production of non-energy related food, feed, and fiber products more profitable.

SUMMARY

There is a significant amount of information available that may best be summarized by providing break even prices for various potential feedstocks both at the national and local level. This information is costly to acquire due to the nature of required communication with producers, and perhaps extension agents at local levels. With this information, detailed harvest, storage, and transport analyses, and determination of the level of developing vertical or contractual integration is possible. A system or complete supply chain perspective is required for this, as the presentation of potential seasonal supply of feedstocks for energy production without due consideration and analysis of competing uses is merely the beginning.

Epplin, Francis. "Millions of Acres for Dedicated Energy Crops." Presented at Transition to an Agricultural Economy conference. Atlanta, GA. February 12-13, 2008. http://www.farmfoundation.org/news/articlefiles/378-Epplin%20Ppt%202-5-08.pdf. (See Page 48).

Gallagher, P., M. Dikeman, J. Fritz, E. Wailes, W. Gauthier, and H. Shapouri. Supply and Social Cost Estimates for Biomass from Crop Residues in the United States." Environmental and Resource Economics. Chapter 24, Pages 335-358, 2003. (See Page 48).

Louisiana State University Ag Center. Biomass Energy Resources in Louisiana. Research Information

Sheet 102. November 2006. http://www.louisiana4h.org/NR/rdonlyres/79EA5231-C815-433A-8031-BC-84CAC423B8/32124/RIS102BiomassEnergy.pdf. (See Page 47).

Wimberly, Jim. Biomass Energy in Arkansas. Foundation for Organic Resources Management. Arkansas Biodiesel Conference. Fayetteville, AR. December 2002. (See Page 46).

Walsh, M.E., D.G. De La Torre Ugarte, H. Shapouri, and S.P. Slinsky. "Bioenergy Crop Production in the United States: Potential Quantities, Land Use Changes, and Economic Impacts on the Agricultural Sector." Environmental Resource Economics. Chapter 24, Pages 313-333, 2003. (See Page 48).

Engineering and Resource Economics Workgroup Members

Michael Popp, Co-Leader	University of Arkansas	Monticello, AR
Steve Searcy, Co-Leader	Texas A&M University	College Station, TX
Dani Bellmer	Oklahoma State University	Stillwater, OK
Bill Casady	University of Missouri	Columbia, MO
Terry Collins	Oklahoma State University	Stillwater, OK
Mark Downing	Oak Ridge National Laboratory	Oak Ridge, TN
Francis Epplin	Oklahoma State University	Stillwater, OK
Jim Gan	Texas A&M University	College Station, TX
Gregory Gressel	John Deere Technical Center	Moline, IL
Richard Hess	Idaho National Library	Idaho Falls, ID
Carol Jones	Oklahoma State University	Stillwater, OK
Maxine Jones	Conoco Phillips	Tulsa, OK
Dave Jordan	MacDon Industries	Kansas City, MO
Ron Lacewell	Texas A&M University	College Station, TX
Ed Rister	Texas A&M University	College Station, TX
Thomas W. Robb	Abengoa Bioenergy	Chesterfield, MO
Bill Rooney	Texas Agricultural Experiment Station	College Station, TX
Leon Schumacher	University of Missouri	Columbia, MO
John Sweeten	Texas A&M University	College Station, TX
Donghai Wang	Kansas State University	Manhattan, KS
Mark Wilkins	Oklahoma State University	Stillwater, OK

POLICY DEVELOPMENT AND ANALYSIS WORKGROUP RESULTS

Sources of Information for Finding Land

The Farm Service Agency (FSA) has extensive information on crop production at the individual field level. Public access to this data is restricted due to privacy concerns. The data are also currently not linked with farm-level yield data, which is also reported to the United States Department of Agriculture (USDA). If these limitations could be addressed, the FSA data could provide a rich source for the calibration of Landsat data.

Current cropland inventories have several deficiencies. The portion of cropland that is organized as "mini-ranches" or "lifestyle farming operations" is not reported. Although some of the land in these operations may be improved using native grass species that could be used as a feedstock, it is unlikely that landowners will be willing to place their land into long-term contracts with a biorefinery. It is also difficult to determine what portion of the acreage currently enrolled in the conservation reserve program is appropriate for biofuel feedstock production.

Information on livestock numbers and the location and density of confined livestock feeding operations needs to be integrated with information on potential biofuel feedstock production resources. Integrating this information would help identify trade-offs between feed and biofuel feedstock production and identify animal waste-based resources.

Current efforts to inventory biofuel feedstocks do not attempt to estimate the size and scale of the individual production units. The scale and degree of decentralization, or fragmentation, in feedstock production could impact transportation costs, the efficient size and scale of biorefineries, and the need for pretreatment. For this reason, future assessments of inventories should incorporate information on the number of production units (farm operations) involved in each geographical area.

Constraints to Plant Delivery

As previously discussed, biofuel feedstocks, like other crops, are impacted by weather and other production variables. Cropland may also shift into or out of biofuel feedstock production based upon the perceived relative profitability of biofuel, food, fiber, and feed crops. The stability of biofuel production is therefore a constraint to feedstock delivery to the biofuel refinery. The availability of federal crop insurance for alternative bioenergy crops is also a potential limitation to feedstock production. Research to establish projected loss ratios for biofuel feedstock crops is needed.

Water availability may be the most binding, long-run constraint on biofuel feed stock production. Information on the relative water to biofuel production efficiency of alternative feedstocks should be developed and integrated into feedstock inventory projections. The infrastructure needed to get biomass to the biofuel refinery and biofuels into the current fuel distribution system are also indirect constraints to biofuel feedstock production and delivery.

Technology Drivers

Tax incentives and government subsidies for biofuel production are one of the drivers for feedstock development. In order to retain public support for biofuel incentives, there is a need to explore how incentives can be linked to environmental benefits through decreased air pollution. Genetic engineering is a potential tool for the development of improved biofuel feedstocks. However, current policies on GMO crops may limit the development of biofuel feedstocks. For example, consumer reaction against the introduction of GMO peanuts is a constraint to the development of high oil GMO peanuts, which could serve as a biodiesel feedstock.

Co-Products & Associated Cost or Value

There is a need for better understanding of the economic value of multiple product streams that might be associated with a biofuel production process. There is also a need to forecast the impacts on food, feed, and fiber markets. The development of a matrix that contrasts benefits and the environmental, social, and infrastructure problems associated with all potential feedstocks should be explored. In considering process and co-products' value, the advantages of on-farm usage of biofuels and animal waste-based biofuel production should also be examined.

Potential Benefits

Biofuel feedstock production provides a diversification alternative for agricultural producers. Biofuel incentives, as currently structured, may partially offset agricultural commodity payments. The potential exists to restructure biofuel incentives to allow them to better replace commodity payments. The development of biofuel processing infrastructure can generate increased economic activity and jobs in rural communities. At the same time, the substitution of lower input or perennial biofuel cropping systems for traditional crops can reduce activity for agribusiness input, crop protection, and marketing firms. Some biofuel production processes, such as gasification, may create a fertilizer by-product which may become increasingly valuable as biofuel crop production creates greater pressure on the fertilizer supply chain.

Potential Consequences

Increased biofuel feedstock development may create greater competition for water resources. The net environmental impact of biofuel production is unknown and may be negative (ex: impact on wildlife). The potential loss of residue from harvesting residues may reduce soil quality. The increased production of biofuel feedstocks has and will continue to increase the reliance on imported fertilizers. The United States currently imports over 85 percent of its nitrogen fertilizer, much of which is supplied by the same Middle Eastern countries that supply petroleum. At the producer level, the production of alternative crops may impact commodity base payments.

Consequences of Biofuel Production

On the positive side of the equation, biofuel

production can have positive impacts on rural communities, and may provide some environmental benefits. Offsetting these benefits are unintended negative environmental consequences, the risk that the energy balance is low or negative, the market risks of matching biofuel production with demand and the impacts of transporting biofuel feedstock and final products on the transportation infrastructure of rural communities.

Possible Social Issues of Biofuels

The social issues related to biofuel feedstock production and biofuel manufacturing and distribution are numerous. The competition for land use between biofuel feedstock production and food, feed, and fiber production has received much attention. The impact of biofuel production on global food production, food security, and food prices continues to be an important issue. As discussed previously, biofuel production infrastructure may have positive impacts on the economic base of rural communities, but also negatively impact transportation infrastructure and water supply. Biofuel feedstock production may accelerate a shift towards large scale, contract farming systems.

Increased production of biofuels may improve the United States energy security. At the same time, the production and processing of biofuel feedstocks may have negative environmental consequences. United

States taxpayers and consumers ultimately fund biofuel incentives and mandates. The specific policy goals of biofuel production and the consumer benefits must therefore be carefully weighed against these costs. There is a clear need for public education of the goals, benefits, and trade-offs of biofuel production. This could result in an improved understanding of biofuel issues, and hence, could lead to an informed debate of the complex trade-offs inherent to biofuel production.

Impacts and Linkages

Land and resources which can be used for biofuel feedstocks have alternative uses, and must be diverted from current usage. The production of biofuel feedstocks will therefore have a variety of impacts, positive and negative, on all aspects of the economy. For example, biofuel feedstocks may provide a diversification alternative for farm producers. However, the transition from food and fiber crops to low input biofuel feedstocks may decrease economic activity in rural communities.

Incentives

The success of the free market system in efficiently allocating resources and encouraging innovation is widely recognized. Government-backed subsidies and incentives are generally justified as a means of supporting "infant industries," with the expectation that the subsidy will allow the industry to develop to the point where it can effectively compete. Unfortunately, biofuel incentives can also be influenced by specific interest groups that have a stake in developing a specific technology or feedstock supply. The introduction of government backed incentives can, therefore, have the unintended consequence of undermining efforts to develop the most efficient industry structure. Incentives and subsidies for biofuel feedstock production should be broadly structured to allow the market to develop the most efficient sources of biofuel.

Current biofuel-related incentives have played a key role in the rapid development and expansion of the corn-based ethanol industry. These incentives may need to be "tweaked," or modified, to support the development of cellulosic-based ethanol. The concept of linking biofuel subsidies to market fuel prices, which would reduce expenditures during periods of high market prices, should also be explored. Also to be noted, current agricultural subsidies influence cropping decisions and will impact decisions to shift land into biofuel feedstocks.

Biofuel Policies at the State Level

Individual states have developed biofuel-related incentives.

- Some states have also developed mandates for biofuel usage. These incentives have and will impact the regional distribution of biofuel refineries.
- While state level incentives have positive

impacts, they may not lead to the most efficient biofuel industry structure.

- To show their dedication to biofuel, some states are currently implementing biodiesel policies for use in fleet vehicles (*Wimberly*).
- Tax credits, grants, and incentives are needed at the state-level to promote biofuel growth and usage (*Wimberly*).
- Guaranteed loans for producers are needed (*Wimberly*).

National Policy Issues

- The rationale and impact of the current United States tariff on imported ethanol has been a topic of heated discussion. Elimination of the tariff would diversify the U.S. supply of ethanol and put downward prices on ethanol.
- Because of their dependence on biological systems that are influenced by water and other risks, biofuel feedstocks are inherently variable.
- Because of this variability, the U.S. should consider developing a strategic reserve of bioenergy feedstocks and biofuels.
- The issue of carbon sequestration has had a greater influence on the development of the biofuel industry in Europe relative to the U.S. It is important to consider how the issue of carbon sequestration and carbon credits will or should influence the future development of the U. S. biofuel industry.
- To provide motivation for biofuel production, it would be necessary for the permitting process to be streamlined (*Wimberly*).

Work Cited:

Wimberly, Jim. Biomass Energy in Arkansas. Foundation for Organic Resources Management. Arkansas Biodiesel Conference. Fayetteville, AR. December 2002. (See Page 54).

Policy Development and Analysis Workgroup Members

Jon Biermacher, Co-Leader	Samuel Roberts Noble Foundation	Ardmore, OK
Phil Kenkel, Co-Leader	Oklahoma State University	Stillwater, OK
Walter Armbruster	Farm Foundation	Oak Brook, IL
David Baltensperger	Texas A&M University	College Station, TX
Henry Bryant	Texas Agricultural Experiment Station	College Station, TX
Dick Carmical	The Price Companies	Monticello, AR
Jeff Dahlberg	National Sorghum Producers	Lubbock, TX
James Doolittle	South Dakota State University	Brookings, SD
Thayne Dutson	Oregon State University	Corvallis, OR
Mark Gregory	Oklahoma State University	Stillwater, OK
Michael Halbleib	Oregon State University	Corvallis, OR
Martin Hubert	State of Texas	Austin, TX
Ron Justice	Oklahoma State Senate	Chickasha, OK
Monty Kerley	University of Missouri	Columbia, MO
Ned Meister	Texas Farm Bureau	Waco, TX
Laura Neal	U.S. Department of Energy	Washington, DC
Terry Nipp	Sun Grant	Washington, DC
Mick O'Neill	New Mexico State University	Las Cruces, NM
Allen Regehr	Texas Department of Agriculture	Austin, TX
Rick Roeder	University of Arkansas	Pine Bluff, AR
Vincent Russo	Lane Research Center	Lane, OK

ENVIRONMENTAL INTERACTIONS WORKGROUP RESULTS

The scope of this report involves recognizing how biomass feedstock production affects native diversity, wildlife habitats, water quality and availability, global changes in land use, carbon sequestration, and overall system sustainability. These environmental effects may be acerbated by changes in current production and management systems if biomass becomes an ever-increasing component of our energy portfolio. The team of individuals involved in this report recognize that current feedstock production and management systems have environmental consequences. The key to this discussion is whether enhanced feedstock/biomass production improves or intensifies potential environmental issues. Sources of information to help determine what lands are capable of producing specific feedstocks include the primary literature, field trials, modeling studies, soil surveys and databases, forest inventory surveys, the United States Department of Agriculture's "Agricultural Research Service" and "National Resources Conservation Service," cooperative extension services, and experiment station bulletins and reports. It has been noted that it is essential to glean useful information from existing literature before significant efforts are expended towards potential duplication of existing knowledge.

Environmental Constraints

Environmental constraints to feedstock delivery include transportation-related issues. Expanded distances between sources and processing facilities will increase road traffic and the environmental consequences of road traffic and maintenance. Distributed production facilities may help reduce distances, but road traffic will still increase. New roads will need to be built to access more remote locations, such as CRP lands and forests that weren't used previously. Systems will need to be developed to provide staged intermediate processing, storage, and transport of feedstocks. A new source of feedstock may be roadsides that are currently or could be mowed and baled. Ready transportation access raises their potential for use.

Technology Drivers

Technology drivers will also result in environmental consequences. There are many technology drivers that will enable feedstock development. Regulatory requirements will become important. Crop breeding using traditional or transgenic techniques will be critical to optimize feedstock yield. High yielding species will need to maintain integrity against potential contamination of invasive species, while not becoming invasive themselves. Incentives for carbon sequestration will drive new techniques to achieve it. New harvesting equipment and technologies will reduce the energy costs for collection and transportation of feedstocks. A reduced harvest and transportation footprint will be needed. Environmental quality and optimum vegetation production models will be developed to help select the optimum crops for each available soil type. Selection of the best combination of species for polycultural production systems and sustainability will be important. Conversion systems will be needed to convert mixed feedstocks. Best management practices will be defined to optimize land and water use in a sustainable system.

Effects of Process Co-Products

There will be environmental effects from process co-products. There will be more ash, lignin, glycerol, and distiller's grain to dispose of with economically favorable options. Biorefineries will evolve that produce a range of chemicals, solvents, and polymers to replace those currently produced from petroleum. Meal volumes from oil seeds will increase and new uses will need to be identified. Heat, odor, and noise will be increased near the conversion plants.

Potential Benefits of Feedstock Production

There are several potential benefits of feedstock production with proper crop management. They include the potential of improved water cycle, carbon cycle, and other nutrient cycles. Biotic diversity may be increased with mosaic management practices. Reduced greenhouse gas, global warming, and mitigation of climate modification may be achieved. Economic development of rural communities is a probable result. Sustainability - in terms of improved yields, soil quality, and water use - is possible. A smaller footprint could reduce land required and transportation impacts. Reduced fertilizer, pesticide, and energy may be required in the production system. These benefits need to be confirmed by practice and research.

Potential Negative Environmental Consequences

Some potential negative environmental consequences are also possible. They include potential reduction of wildlife habitat, and biodiversity with invasive species potential - even from the biofuel crops themselves.

Higher water consumption is possible. Excess removal of residue will affect soil quality and increase erosion and runoff, resulting in nutrient loss and reduction of water quality. Conversion of marginal lands towards production and increased conversion of virgin sod to energy crops could have similar effects. Cultivation practices could increase NO_X production from soil. New monocultures could result in emergence of more destructive pest pressure. Global impact of increased energy footprint could shift demand for commodities and result in cultivation of sensitive lands, such as rainforests. Some systems may have lower yield and potentially larger footprints.

Environmental Consequences of Biofuel Production

Biofuel production may also have environmental consequences. The conversion process will require increased water consumption. Distiller's grain replacing feed grain in animal production systems will result in changes. Air pollution from production facilities is a potential issue. Change, or reduction, in the use of fossil fuels is expected. More intensive infrastructure will be needed to transport the biomass to the factories and distribute biofuels. New industries will emerge to serve new needs of this growing industry.

Social Issues Linked with Bioenergy Production

Finally, there are social issues with which to deal. There is a need to educate the general population on the complex issues resulting from large scale bioenergy production. Society will need to discuss the issue of food, livestock, and environmental trade-offs with fuel production. Ultimately, a better comprehension of conservation should emerge. There will be a change in land use patterns between crops. Rural economic development should be a positive impact, along with some mitigation of global climate change through reduced greenhouse gas emissions. There may be improved recreation use of lands, but trade-offs with aesthetics in some areas. A nuisance factor may emerge from refineries, truck traffic, noise, and odor as the industry grows. There will also be subsidies, tax incentives, and policy changes that will affect society in general. This will raise points of discussion regarding general acceptance of the dramatic changes that bioenergy can bring to society overall.

Environmental Interactions Workgroup Members

Ron Madl, Co-Leader	Kansas State University	Manhattan, KS
Daniel Thomas, Co-Leader	Louisiana State University	Baton Rouge, LA
Sangu Angadi	New Mexico State University	Clovis, NM
Joe Brummer	Colorado State University	Fort Collins, CO
Edmund Buckner	University of Arkansas	Pinebluff, AR
Felix Fritschi	University of Missouri	Columbia, MO
Alison Goss Eng	U.S. Department of Energy	Washington, DC
Doug Hamilton	Oklahoma State University	Stillwater, OK
Frank Hons	Texas A&M University	College Station, TX
Armen Kemanian	Texas A&M University	College Station, TX
Steve Loring	New Mexico State University	Las Cruces, NM
Mark Marsaillis	New Mexico State University	Clovis, NM
Travis Miller	Texas A&M University	College Station, TX
James Muir	Texas A&M University	College Station, TX
Richard Nelson	Kansas State University	Manhattan, KS
Mike Palmer	Oklahoma State University	Stillwater, OK
Al Parks	Prairie View A&M University	Prairie View, TX
Matt Pelkki	University of Arkansas	Monticello, AR
Tim Rials	University of Tennessee	Knoxville, TN
Bob Shaw	Texas A&M University	College Station, TX
Scott Staggenborg	Kansas State University	Manhattan, KS
Mike Stamm	Kansas State University	Manhattan, KS
Chuck West	University of Arkansas	Fayetteville, AR
Yanqi Wu	Oklahoma State University	Stillwater, OK

COMMUNICATIONS WORKGROUP

Scope

The scope of this report relates to general communications concerns and opportunities in light of the workshop's goal of facilitating development of biomass feedstock resources in the South Central Region. Although this workgroup did not address individual feedstock questions per se, this report offers relevant observations and suggestions.

Key Topics

Audience targeting, message content development, and communications delivery options are key topics to keep in mind. Communications-related planning for the feedstock partnership and the total Sun Grant Initiative should recognize the need to enhance both internal and external communications.

Target Audiences

Multiple audiences should be considered, including biofuel researchers, administrators, the biofuels industry, policy makers, the environmental community, and, of course, the public at large. An overarching message explaining the importance of current and planned efforts can be stated simply: to reduce dependence upon foreign oil.

Message Delivery

The Sun Grant Initiative, in general, and the South Central Region bring together a unique and diverse group possessing strong expertise across disciplines important to bioenergy. This message needs to be communicated repeatedly through news releases, feature stories, and other media appearances. Part of message consistency is mentioning the Sun Grant connection in a variety of communications and in interviews with writers and broadcasters. Capitalizing on this linkage, whenever possible, will pay off with enhanced visibility overall.

Internally, the Department of Energy Web site used for the South Central Feedstock Workshop should continue to share information and expand content offerings as needed for those individuals directly or indirectly involved with the issues raised during the workshop. Along with other Sun Grant Web sites, the United States Department of Energy Web site can serve as an important communications vehicle for South Central Sun Grant projects. Also, using the electronic mailing list approach is another avenue for effective information sharing, allowing interested persons to keep up with what's happening across individual projects.

From an external communications perspective, the workgroup encourages land-grant university communicators in the South Central Region to provide continuing support in a proactive fashion. Information should be released at the appropriate times, not too soon and not too late. A targeted media relations approach will be most effective. Well-planned media relations contacts and production of timely bioenergy-related news releases and features will yield results. A significant challenge will be capturing success stories and interpreting results so that communication products make important contributions to public understanding of ongoing efforts.

Key Contacts

The workgroup recommends designating key communicator contact people at land-grant universities in the South Central Region. Having an identified list of key people can improve efficiency and timeliness of media efforts. As a group, contacts can form a valuable team to tackle substantial bioenergy issues in a coordinated fashion.

Sun Grant BioWeb

The workgroup recognizes the importance of the Sun Grant BioWeb as an external communication tool. BioWeb, a joint effort of the five regional Sun Grant Centers, is a public Web site that provides information about biomass resources. A significant strength of the BioWeb is that all information is peer reviewed before being posted, ensuring accuracy and consistency. Possible enhancements could include creating an access point for media and university communicators, developing materials especially for school teachers, and using video in innovative and creative ways.

Importance of Education

Land grant university communicators, extension specialists, and researchers need to be prepared to face important bioenergy issues with a balanced and objective approach. The issue of food versus fuel and various environmental considerations are examples of topics that already provoke considerable interest and debate. Now is the time for extension and experiment station programs to provide bioenergy education and information.

Public Awareness

Public awareness can be enhanced through ongoing activities, such as special events, field days, and direct contacts with clients. Demonstrations and field trials are great sources for on-site activities that can include farmer groups and others. Print and electronic publications can aid public understanding of project emphasis areas, and university specialists can conduct a variety of programs to spark increased interest in bioenergy topics. In general, education and outreach can play a pivotal role in cultivating public interest and support.

EXtension

As eXtension continues its development, steps should be taken to ensure that bioenergy information is among the subject matter offerings. EXtension is an educational partnership of more than 70 universities designed to provide access to objective, research-based information and educational opportunities. This Internet-based service is dynamic and evolving, seeking to provide timely information to everyone.

ORNL-Based GIS Database

The ORNL-based GIS Database is expected to become an important information tool and clearinghouse for data. Researchers can make valuable use of the various features being planned for the database.

Industry and Professional Partners

The continued development of industry and professional organization partners is encouraged, as a way to better communicate and work together. Keeping everyone informed and "in the loop" is essential. Conference calls, meetings, and other points of contact can provide multiple opportunities to interact.

Summary

In summary, effective communications should continue to be an integral part of all Sun Grant efforts. Many short-term and long-term benefits can result from reaching desired audiences with the right kinds of information at the appropriate times.

Communications Workgroup Members

Garvin Quinn, Leader	Oklahoma State University	Stillwater, OK
Jan Auyoung	Oregon State University	Corvallis, OR
Mark Burow	Texas A&M University	College Station, TX
John Ferrell	U.S. Department of Energy	Washington, DC
Dave Patterson	University of Arkansas	Monticello, AR
Josh Payne	Oklahoma State University	Stillwater, OK
David Porter	Oklahoma State University	Stillwater, OK
Lee Tarpley	Texas Agricultural Experiment Station	College Station, TX
Anthony Turhollow	Oak Ridge National Library	Oak Ridge, TN
William J. Wiebold	University of Missouri	Columbia, MO

IN CONCLUSION...

Written by *Dr. Clarence Watson, Ph.D.*
Director, South Central Sun Grant Initiative Regional Center

The South Central Feedstocks Workshop groups identified several significant potential sources of feedstocks for bioenergy production. Major types of feedstocks addressed were:

Ligno-cellulosic feedstocks: Promising ligno-cellulosic feedstocks within the South-Central (SC) region include perennial grasses (both warm- and cool-season) (e.g., switchgrass, tall fescue, bermudagrass, native prairies grasses, Johnsongrass, etc.). Many of these are grown under relatively low-input conditions in areas such as pastures, hay meadows, roadsides, native grasslands, CRP lands, etc, which do not compete directly with food/feed crops. Incorporation of legumes may offer potential for increasing yields under these low-input conditions. Another source of ligno-cellulosic feedstocks within the region is cereal residues, primarily wheat, barley, triticale, and rice; however, work is needed to determine how much residue can be safely removed to prevent excessive soil erosion, nutrient loss, and soil organic matter. "New" crops with potential within the region include energy canes and Miscanthus. Among annual crops, sweet sorghums hold tremendous potential for both a sugar crop for direct fermentation and a ligno-cellulosic feedstock utilizing the bagasse.

The group identified approximately 40 M acres of cropland and 182 M acres of non-cropland within the South Central region which could be used for feedstock production based on NASS data. Biomass yields were estimated to be up to 74 M tons from cropland and 289 M tons from non-cropland, assuming relatively modest yields (1.5 T/A) for non-cropland acreage. These estimates assume complete use the entire acreage for biomass, which is highly unlikely. Yioeld potential of all crops will vary widely across the SC region (1 to 10 T/A)depending on inputs, particularly water.

Starch and Oilseeds: The SC region currently produces approximately 40M A of cereal crops (primarily wheat corn, grain sorghum and rice), 11M A of oil seed crops (primarily soybean) 600 K A of sugar crops with annual production of 3.1B bu, 24B lbs, and 14M tons, respectively. Assuming complete utilization, this translates to approximately 20B gal of ethanol annually. Yields of starch and oilseed crops are highly dependent on inputs. Because of competing demand for animal feed, some summer annuals such as sorghum/corn may not be the best candidates for feedstocks. It was the groups assessment that oilseeds such as sunflower or Brassicas (e.g., canola, camolina, and mustards) offer the best candidates for biofuel production in the SC region. Sweet sorghum should also be considered, particularly in the southern parts of the region, as a potential source of sugar for direct fermentation.

Sustainable residues: Residues with cellulosic feedstock potential in the SC region include corn and small grain stover, cotton gin trash, rice straw, sugarcane bagasse, and oilseed residues. There is a need to determine optimal residue removal for sustainability. Estimates of potential stover yields can be derived from existing databases (e.g., NASS, State reports, NRCS, National Resources Ecology Laboratory at Colorado State university, and the National Renewable Energy Laboratory (NREL) Agricultural Crop Residue Study). There are significant voids concerning removal of crop residues, and further research is needed to determine how much residue can be safely removed to prevent excessive soil erosion, nutrient loss, and soil organic matter. The "Billion Ton Study" assumption of a 50% yield increase for corn and wheat may not be applicable across the entire south Central region and local assessment is needed.

Woody Energy Crops /Forest Residues: Potential woody feedstocks can be derived from forest resources including dedicated energy crops (e.g., pine, poplar, cottonwood, etc.) and logging residues, as well as non-forest sources such as mill residues, urban wood waste, landfills, orchard trimmings/removal. Major forest resource inventories include the USDA Forest Inventory Analysis (FIA) and the Timber Product Output (TPO) databases. As with crop residues, there is a need to determine optimal residue removal of woody crops for sustainability. Problems with labor shortage, transportation, collection equipment, storage, and seasonality of harvest must be addressed.

Agricultural Industry by-products: Agricultural industry by-products constitute a large and potentially undervalued biomass resource within the SC region. Yield estimates of potential by-products in the SC which could supply large amounts of biomass include sugar cane bagasse (3.0 M tons/yr), gin trash (1.0 M tons/year), rice hulls (1.9 M tons/year), broiler litter (2.4 M tons/yr), turkey and egg litter (1.0 M tons/yr), beef feedlot manure (3.1 M tons/yr), and pork production manure (2.7 M tons/yr). An additional resource for biodiesel production would be animal fats which could potentially contribute 18 trillion BTU's. Many of these resources are concentrated in relatively small geographic areas within the region could be beneficial if a conversion facility is located nearby.

The groups also addressed several overarching issues and identified various constraints and opportunities within the SC region. Major issues within the SC region include:

Engineering:

1. Comparison of the efficiency of on-farm vs. off-farm processing is needed.
2. Systems analysis to identify the optimal system for crop establishment, harvesting, packaging, storage, pretreatment and transport is requuired. It is ultimately the combination of these factors that will determine the profitability of energy production from biomass.
3. Mapping of feedstock resources is needed to identify the best sites of plant construction.

Economics:

1. Reliable assessments of the availability of feedstocks are needed which address the issues of regionality and seasonality of feedstocks.
2. Development of budgets (cost of production) and supply curves to aid producers in decision making and risk assessment. These budgets need to address the issues of plant size, farm size operation, and land ownership.

Policy Development and Analysis:

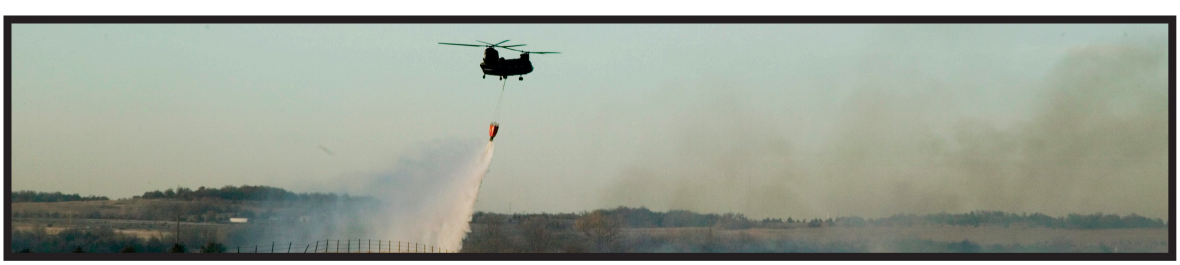
1. One of the most pressing issues for feedstock production in the SC region is water availability and competition for water resources.
2. Carbon sequestration and carbon trading policy will also greatly influence biofuel production.
3. Incentives such as tax credits and subsidies are likely needed to sustain and grow the biofuel industry at all levels from feedstock production to distribution.
4. Demands on infrastructure (roads, bridges, railroads, water systems, etc.) must be considered.

Environment Interactions:

1. Environmental constraints to feedstock delivery include increased road traffic and fuel consumption.
2. Some potential feedstocks, particularly "new crops", have invasive species potential which needs to be adequately research before widespread production is advocated.
3. Environmental impact of disposal of co-products (e.g., ash, lignin, glycerol, distillers grains (DDG's), etc.) needs to be addressed. Some products such as DDG's have value-added potential and have established markets.
4. On the positive side, biofuel production may reduce greenhouse gases and global warming and offer improvements in water, carbon, and nutrient cycling.
5. Possible negative environmental impacts include loss of wildlife habitat and biodiversity, increased water consumption, greater erosion and runoff with excess biomass removal, and higher water consumption.

Communications:

1. Targeting audiences for communication is essential in promoting the biofuel industry and enhancing public awareness.
2. All traditional means of communication should be employed to communicate the message.
3. Web sites such as the SC SunGrant Web site and the BioWeb are excellent resources for communication and public education.
4. eXtension should be considered as vehicle for information delivery.
5. Development of key contacts and industry partners is encouraged.
6. It is anticipated that the ORNL-based GIS database will become an important information source and data clearinghouse.



ATTENDEE DIRECTORY

LAST NAME	FIRST NAME	AGENCY	STATE	E-MAIL	PHONE
Angadi	Sangu	NMSU	NM	angadis@nmsu.edu	505/985-2292
Armbruster	Walter	Farm Foundation	IL	walt@farmfoundation.org	630/571-9393
Auyoung	Jan	Oregon State University	OR	jan.auyong@oregonstate.edu	541/737-1915
Baltensperger	David	Texas A&M University	TX	DBaltensperger@ag.tamu.edu	979/845-3041
Bellmer	Dani	Oklahoma State University	OK	danielle.bellmer@okstate.edu	405/744-6626
Biermacher	Jon	Noble Foundation	OK	jtbiermacher@noble.org	580/224-6410
Brummer	Joe	Colorado State University	CO	Joe.Brummer@colostate.edu	970/491-4988
Bryant	Henry	Texas Ag. Experiment Station	TX	h-bryant@tamu.edu	979/845-2119
Buckner	Edmund	Univ. of Arkansas-Pine Bluff	AR		
Burow	Mark	Texas A&M University	TX	m-burow@tamu.edu	806/746-4025
Carmical	Dick	The Price Companies	AR	dick@thepricecompanies.com	870/367-9751
Casady	Bill	University of Missouri	MO	CasadyW@missouri.edu	573/882-4370
Collins	Terry	Oklahoma State University	OK	terry.collins@okstate.edu	
Dahlberg	Jeff	Natl. Sorghum Producers	TX	jeff@sorghumgrowers.com	
Doolittle	James	South Dakota State Univ.	SD	James.Doolittle@sdstate.edu	605/688-6816
Downing	Mark	Oak Ridge National Library	TN	downingme@ornl.gov	
Dutson	Thayne	Oregon State University	OR	thayne.dutson@oregonstate.edu	541/737-5815
Epplin	Francis	Oklahoma State University	OK	f.epplin@okstate.edu	405/744-6516
Ferrell	John	U.S. Department of Energy	DC	john.ferrell@ee.doe.gov	202/586-6745
Fritschi	Felix	University of Missouri	MO	fritschif@missouri.edu	573/882-3023
Gan	Jim	Texas A&M University	TX	j-gan@tamu.edu	979/862-4392
Goss Eng	Alison	U.S. Department of Energy	DC		
Gregory	Mark	Oklahoma State University	OK	mark.gregory@okstate.edu	
Gressel	Gregory	John Deere	IL	GesselGregoryR@JohnDeere.com	309/765-3713
Halbleib	Michael	Oregon State University	OR		
Hamilton	Doug	Oklahoma State University	OK	dhamilt@okstate.edu	
Hess	Richard	Idaho National Library	ID	jrh@inel.gov	
Hons	Frank	Texas A&M University	TX	f-hons@tamu.edu	979/845-3477
Hubert	Martin	State of Texas	TX	martin.hubert@cpa.state.tx.us	512/463-4002
Huhnke	Raymond	Oklahoma State University	OK	raymond.huhnke@okstate.edu	405/744-8417
Jones	Carol	Oklahoma State University	OK	jcarol@okstate.edu	405/744-6667
Jones	Maxine	Conoco Phillips	OK	Maxine.J.Jones@ConocoPhillips.com	580/767-6203
Jordan	Dave	MacDon Industries	OK	Djordan@macdon.com	918/258-6389
Julian	Sheila	Oklahoma State University	OK	sheila.julian@okstate.edu	405/744-5401
Kemanian	Armen	Texas A&M University	TX	akemanian@brc.tamus.edu	254/774-6107
Kenkel	Phil	Oklahoma State University	OK	phil.kenkel@okstate.edu	
Kerley	Monty	University of Missouri	MO	KerleyM@missouri.edu	573/882-0834
Lacewell	Ron	Texas A&M University	TX	r-lacewell@tamu.edu	

LAST NAME	FIRST NAME	AGENCY	STATE	E-MAIL	PHONE
Loring	Steve	New Mexico State University	NM	sloring@nmsu.edu	505/646-1464
Madl	Ron	Kansas State University	KS	rmadl@ksu.edu	
Marsallis	Mark	New Mexico State University	NM	Marsalis@nmsu.edu	505/985-2292
Meister	Ned	Texas Farm Bureau	TX	nmeister@txfb.org	254/751-2457
Miller	Travis	Texas A&M University	TX	td-miller@tamu.edu	979/845-4008
Muir	James	Texas A&M University	TX	j-muir@tamu.edu	
Neal	Laura	U.S. Department of Energy	DC	laura.neal@ee.doe.gov	202/586-7766
Nelson	Richard	Kansas State University	KS	rnelson@ksu.edu	785/532-6026
Nipp	Terry	Sun Grant	DC	tlnipp@ilioco.com	888/454-6264
O'Neill	Mick	New Mexico State University	NM	moneill@nmsu.edu	505/327-7757
Palmer	Mike	Oklahoma State University	OK	mike.palmer@okstate.edu	
Parks	Al	Prairie View A&M University	TX	alfred_parks@pvamu.edu	
Patterson	Dave	University of Arkansas	AR	pattersond@uamont.edu	870/460-1652
Payne	Josh	Oklahoma State University	OK	joshua.payne@okstate.edu	
Pelkki	Matt	University of Arkansas	AR	pelkki@uamont.edu	
Popp	Michael	Univrsity of Arkansas	AR	mpopp@uark.edu	
Porter	David	Oklahoma State University	OK	david.r.porter@okstate.edu	405/744-6130
Quinn	Garvin	Oklahoma State University	OK	garvin.quinn@okstate.edu	
Regehr	Allen	Texas Dept. of Agriculture	TX		
Rials	Tim	University of Tennessee	TN	trails@utk.edu	865/946-1129
Rister	Ed	Texas A&M University	TX	e-rister@tamu.edu	979/845-4911
Robb	Thomas	Abengoa Bioenergy	MO	thomas.robb@bioenergy.abengoa.com	636/728-0508
Roeder	Rick	University of Arkansas	AR	rroeder@uark.edu	
Rooney	Bill	Texas Ag. Experiment Station	TX	wlr.@tamu.edu	979/845-2151
Russo	Vincent	Lane Research Center	OK	vruss-usda@lane-ag.org	580/889-7395
Schumacher	Leon	University of Missouri	MO	SchumacherL@missouri.edu	573/882-2126
Searcy	Steve	Texas A&M University	TX	s-searcy@tamu.edu	979/845-3668
Shaw	Bob	Texas A&M University	TX	rbshaw@tamu.edu	979/845-0409
Staggenborg	Scott	Kansas State University	KS	sstaggen@ksu.edu	785/532-7214
Stamm	Mike	Kansas State University	KS	mjstamm@ksu.edu	785/532-3871
Sweeten	John	Texas A&M University	TX	J-Sweeten@tamu.edu	
Tarpley	Lee	Texas Ag. Experiment Station	TX	ltarpley@ag.tamu.edu	409/752-2741
Thomas	Daniel	Louisiana State University	LA	thomasdl@lsu.edu	225/578-3153
Turhollow	Anthony	Oak Ridge National Library	TN	turhollowaf@ornl.gov	
Wallace	Bob	Natl. Renewable Energy Lab.	DC	Robert_Wallace@nrel.gov	303/384-6215
Wang	Donghai	Kansas State University	KS	dwang@ksu.edu	785/532-2919
Watson	Clarence	Oklahoma State University	OK	c.watson@okstate.edu	405/744-5398
West	Chuck	University of Arkansas	AR	cwest@uark.edu	
Wiebold	William	University of Missouri	MO	WieboldW@missouri.edu	573/882-0621
Wilkins	Mark	Oklahoma State University	OK	mark.wilkins@okstate.edu	405/744-8416
Wu	Yanqi	Oklahoma State University	OK	yanqi.wu@okstate.edu	405/744-9627

REFERENCES

Tables

- **Table 1:** Sub-Regional Climate Zones Categorized by Workgroup and Associated Best Fit Crops (*Compiled by Workgroup*); (Page 20).
- **Table 2**: Acres and Production for Cereal, Oil Seed, and Sugar Crops in the Mid-South Region (*www.nass.usda.gov*); (Page 24).
- **Table 3**: Woody Biomass Feedstock Sources, Relative Supply Amounts, and Costs within the South Central Region (*Compiled by Workgroup*); (Page 34).
- **Table 4**: Production of Sugar and Bagasse, and Potential Energy Value of Bagasse in the South Central Region (*www.nass.usda.gov*); (Page 39).
- **Table 5**: Production of Raw Cotton and Cotton Products, and Potential Energy Value of Cottonseed Oil, Meal, and Gin Trash in the South Central Region (*www.nass.usda.gov*); (Page 39).
- **Table 6**: Production of Rice and Rice Products, and Potential Energy Value of Broken Grains, Rice Hulls, and Trash in the South Central Region (*www.nass.usda.gov*); (Page 40).
- **Table 7**: Broiler Production, Estimated Dry Tons of Broiler Litter, and Energy Potential of Broiler Litter in the South Central Region (*www.nass.usda.gov*); (Page 41).
- **Table 8**: Turkey and Egg Production, and Energy Potential from Collected Manure Organic Matter in the South Central Region (*www.nass.usda.gov*); (Page 41).
- **Table 9**: Cattle Fed on Feedlots, and the Energy Potential of Collected Feedlot Manure in the South Central Region (*www.nass.usda.gov*); (Page 43).
- **Table 10**: Pork Production, and Potential Energy from Swine Manure in the South Central Region (*www.nass.usda.gov*); (Page 44).

Figures

- **Figure 1**: Acres of Switchgrass in the South Central Region (*www.bioenergy.ornl.gov*); (Page 20).
- **Figure 2**: Percent Area Having Grass/Herbacious Cover in the South Central Region - 1992 (*www.nrcs.usda.gov*); (Page 20).
- **Figure 3**: Annual Average Precipitation in the South Central Region (*www.nrcs.usda.gov*) (Page 24).
- **Figure 4**: Drought Vulnerable Soil Landscapes (Root Zone AWC Less Than/Equal to 6”) in the South Central Region (*USDA-NRCS*); (Page 24).
- **Figure 5**: Biomass Resources Available in the South Central Region - 2005 (*Milbrandt*); (Page 28).
- **Figure 6**: Current Conservation Resource Program (CRP) Acres in the United States (*www.usgs.gov*); (Page 30).
- **Figure 7**: Ground Cover Types in the South Central Region - 1992 (*www.nass.usda.gov*); (Page 35).
- **Figure 8**: Concentration of Sugar Production in the South Central Region (*www.nass.usda.gov*); (Page 39).
- **Figure 9**: Concentration of Cotton Production in the South Central Region (*www.nass.usda.gov*); (Page 39).
- **Figure 10**: Concentration of Rice Production in the South Central Region (*www.nass.usda.gov*); (Page 40).
- **Figure 11**: Concentration of Broiler Production in the South Central Region (*www.nass.usda.gov*); (Page 42).
- **Figure 12**: Concentration of Turkey Production in the South Central Region (*www.nass.usda.gov*); (Page 42).
- **Figure 13**: Concentration of Egg Production in the South Central Region (*www.nass.usda.gov*); (Page 42).
- **Figure 14**: Concentration of Beef Cattle on Feed in the South Central Region (*www.nass.usda.gov*); (Page 43).
- **Figure 15**: Concentration of Dairy Cattle in the South Central Region (*www.nass.usda.gov*); (Page 43).
- **Figure 16**: Concentration of Swine Production in the South Central Region (*www.nass.usda.gov*); (Page 44).

Works Cited

- **Bioenergy Feedstock Information Network (BFIN).** Hosted by the U.S. Department of Energy, Oak Ridge National Laboratory, Idaho National Laboratory, National Renewable Energy Laboratory. www.bioenergy.ornl.gov *(See Page 20).*
- **Biomass as Feedstock for a Bioenergy and Bioproducts Industry**: The Technical Feasibility of a Billion-Ton Annual Supply. Joint project by the United States Department of Agriculture and United States Department of Energy. Oak Ridge National Laboratory: Oak Ridge, TN. April 2005. *(See Page 31).*
- **Bransby, David**. U.S. Agriculture: A Major Player in the U.S. Energy Scene. Presented at Energy in Agriculture: Managing the Risk workshop. www.farmfoundation.org/projects/documents/BransbyFORWEB.pdf. Kansas City, MO. June 27-28, 2006. *(See Page 19).*
- **Casler, M.D.** and K.P. Vogel, C.M. Taliaferro, N.M. Ehlke, J.D. Berdah, E. C. Brummer, R.L. Kallenbach, C.P. West, and R.B. Mitchell. Latitudinal and Longitudinal Adaptation of Switchgrass Populations. Crop Science, Volume 47. November-December 2007. Crop Science Society of America, Madison, WI. *(See Page 20).*
- **Daly, Christopher**. PRISM Model: Annual Average Precipitation in the United States of America. Information provided by the 1951-1999 normals from NOAA Cooperative Stations and NRCS Snotel sites. Sponsored by USDA-NRCS Water and Climate Center, Portland, OR. *(See Page 23).*

- **Epplin, Francis.** "Millions of Acres for Dedicated Energy Crops." Presented at Transition to an Agricultural Economy conference. Atlanta, GA. February 12-13, 2008. http://www.farmfoundation.org/news/articlefiles/378-Epplin%20Ppt%202-5-08.pdf. *(See Page 48).*
- **Gallagher, P.**, M. Dikeman, J. Fritz, E. Wailes, W. Gauthier, and H. Shapouri. "Supply and Social Cost Estimates for Biomass from Crop Residues in the United States." Environmental and Resource Economics. Chapter 24, pages 335-358. 2003. *(See Page 48).*
- **International Energy Agency**. "IEA Energy Tasks." http://www.ieabioenergy.com/OurWork.aspx. *(See Pages 19, 37).*
- **Jackson, Samuel W. and Chyrel Mayfield**. Louisiana Biomass and Bioenergy Overview. Southeastern Sun Grant Initiative. Pages 1-2. May 2007 revision. *(See Pages 18, 38).*
- **Louisiana State University Ag Center.** Biomass Energy Resources in Louisiana. Research Information Sheet 102. November 2006. http://www.louisiana4h.org/NR/rdonlyres/79EA5231-C815-433A-8031-BC84CAC423B8/32124/RIS102BiomassEnergy.pdf. *(See Page 47).*
- **Milbrandt, Anelia**. A Geographic Perspective on the Current Biomass Resource Availability in the United States. National Renewable Energy Laboratory, Golden, CO. 2005. *(See Page 28).*
- **National Aeronautics and Space Administration (NASA)**. www.nasa.gov. *(See Page 19).*
- **National Agricultural Statistics Service (NASS)**. www.nass.usda.gov. *(See Pages 12-16, 19, 23, 24, 30, 35, 38-44).*
- **Natural Resources Conservation Service (NRCS)**. www.nrcs.usda.gov. *(See Pages 20, 24).*
- **Sala, O.E.** and W. J. Parton, L. A. Joyce, W. K. Lauenroth. "Primary Production of the Central Grassland Region of the United States." Ecology: Vol. 69, No. 1, pp. 40-45. 1988. *(See Page 19).*
- **Tilman, Jason**, and Jason Hill and Clarence Lehman. Carbon-Negative Biofuels from Low-Input High-Diversity Grassland Biomass. Science Magazine, Volume 314. December 8, 2006. *(See Page 19).*
- **United States Department of Agriculture (USDA)**. www.usda.gov. *(See Page 19).*
- **United States Department of Energy (DOE)**. www.energy.gov. *(See Page 29).*
- **United States Forestry Service (USFS)**. www.usfs.gov. *(See Page 19).*
- **United States Geological Survey (USGS)**. http://www.usgs.gov/125/articles/conservation.html *(See Page 30).*
- **USDA-NRCS National Soil Survey Center** Staff - Map and Analysis; Soil Survey Staff of State Soil Geographic Database - Data. Root Zone Available Water Capacity Less Than or Equal to 6". 1994. *(See Page 24).*
- **Walsh, M.E.**, and D.G. De La Torre Ugarte, H. Shapouri, and S.P. Slinsky. "Bioenergy Crop Production in the United States: Potential Quantities, Land use Changes, and Economic Impacts on the Agricultural Sector." Environmental Resource Economics. Chapter 24, pages 313-333. 2003. *(See Pages 19, 48).*
- **Wimberly, Jim**. Biomass Energy in Arkansas. Foundation for Organic Resources Management. Arkansas Biodiesel Conference. Fayetteville, AR. December 2002. *(See Pages 18, 46, 54).*

NOTES:

The Sun Grant Initiative's mission is to grow renewable energy and biobased industries that revitalize rural communities by harnessing science and technological capacities of Land-Grant University research, education, and Extension programs.

South Central Region Sun Grant Initiative

Oklahoma State University

214-A Agricultural Hall

Stillwater, Oklahoma 74078-6021

Phone:405-744-3255

Fax: 405-744-6059

Email: sungrant@okstate.edu

Web Site: www.sungrant.okstate.edu