ATTRIBUTES OF A VIABLE LIGNOCELLULOSIC BIOFUEL FORAGE CROP

Chad Martin, Renewable Energy Extension Specialist
Klein Ileleji, Assistant Professor & Extension Engineer
Purdue University, Agricultural and Biological Engineering Department

The production of energy from biomass feedstocks has received much attention across the U.S. in recent times. This is due in part because of the country's desire for domestically produced energy, and to minimize carbon emissions and other greenhouse gases. Lignocellulosic biomass feedstocks can be categorized into woody feedstocks (e.g. dedicated fast growing trees for energy such as hybrid poplars and willows, wood residues, wood chips and mill wastes), agricultural crop residues (e.g. corn stover and wheat straw) and herbaceous energy crops (e.g. switchgrass and miscanthus) The imposing opportunity for production of energy crops may create a diversification strategy for agriculture producers especially those on marginal farm ground or to collect crop residues such as corn stover where soil erosion and residue management levels permit. However, new challenges exist for advancing the supply chain from production to marketing of the biomass feedstock which is a very low density feedstock when compared to corn grain or soybean. A greater interest in this area has evolved, and involvement in research and development is underway in the area of biomass energy crops at Purdue University and other institutions around the world.

How this will impact the agricultural sector will be determined through new policies and subsequently new market demand. This article will present introductory concepts of how lignocellulosic biomass may be considered as a viable biofuel crop, and challenges with handling of low density bulky materials.

Bioenergy from Lignocellulosic feedstocks

Lignocellulosic biomass refers to plant based materials used as an energy source. The components of lignocelluloses are cellulose, hemicellulose, and lignins, which can be found in dense fibrous forage crops. The utilization of these biomass feedstocks can either be adopted in the following applications:

- Co-fired as a supplement with a primary fuel such as coal for the purpose of electricity generation;
- production of cellulosic ethanol through chemical conversion processes;
- in solid fuel pellets for home space heating;
- biomass gasification which is a process which converts the material to synthesis gas used to generate electricity or can be converted to liquid fuel distillates such as Fischer-Tropsch Diesel.

A recent study by the U.S. departments of Agriculture and Energy of biomass availability reported that there was about 1.3 billion dry tons of biomass available for fuel and power production in the U.S. (Perlack et al., 2005). From the study, corn stover had the potential to be the largest source of agriculture-derived biomass. Switchgrass is considered a bioenergy crop which is a warm season, sod forming grass, allowing it to combine good forage attributes and soil conservation benefits typical of perennial grasses. The deep and substantial root system of switchgrass provides it an advantage over adverse weather conditions as it relates to water and nutrient availability. Switchgrass has been viewed as a model plant species because of its perennial growth habit, high yield potential, compatibility with conventional farming practices, and high value in improving soil conservation and quality (Moser and Vogel 1995).

Cofiring Biomass with Coal

Coal is currently the primary source of electricity generation in the United States. When biomass materials are cofired with coal, decreases occur in emissions of greenhouse gases such as carbon dioxide (CO_2), Sulfur Dioxide (SO_2), Nitric Oxide and Nitrogen Dioxide (NO_X), and Mercury (Hg), (Grabowski, 2004). Cofiring has been a traditional method of introducing new or different fossil fuels in power plants. Cofiring biomass with coal is a low cost method for power plants to generate "green power" while maintaining adequate performance and generating capacity, as well as controlling their emissions to regulatory levels. When combusted, the Btu value of various biomass feedstocks ranges from 6,500- 8,500 Btu per pound on a dry basis. Coal has a Btu rating at 10,000 – 12,000 per pound (Ileleji, 2008).

Biomass has properties which may be favorable, but could also be not as favorable for cofiring. Biomass material with high moisture content decreases the Btu value. Managing this primary consideration may involve indoor storage to maintain quality and Btu value.

Table 1. Biomass Energy Utilization Depends on the Following Variables

Fuel Availability	Supply of biomass fuel must be within economical production radius usually at 50 miles or less.
Fuel Characteristics	When combusting biomass: Low-ash, low chlorine, low alkali fuels like wood waste are recommended to minimize ash deposition, slagging and fouling rates compared to high-alkali, high-ash, and high-chlorine fuels like straws
Fuel Logistics	Fuel preparation, handling and storage: • This will depend on the fuel type to be used, • Preparation such cleaning, size reduction and feeding are very site specific and so application in one project might not apply to another, • Particle size will depend on the type of combustion system and fuel handling needs for feeding into the reactor, Plan for fuel storage and sampling for quality control.

Source: Ileleji, 2008.

Cellulosic ethanol

The production of ethanol from cellulosic feedstocks is a pending opportunity on the forefront of research and development efforts. Compared to other crops for energy sources such as corn to ethanol, the sugars found within cellulose and hemicellulose are tightly bound to lignin which is a dense and cellular composition. The cellulose and hemicellulose must be released from the lignin before the sugar can be available for fermentation to take place.

Biomass sources for cellulosic ethanol are not only energy crops such as switchgrass, but also other feedstocks such as woody biomass, and other lignocellulosic feedstocks. Cellulosic ethanol poses challenges unique to become competitive with corn to ethanol production because of the lack of infrastructure associated with costs of production, harvest, transportation, and processing (Eggeman and Elander, 2005).

The current status of biomass energy crops is that none are not being commercially grown in the United States at present although a few demonstration projects are underway with DOE funding in Iowa and New York (Haq, year?). Purdue University has been conducting research on cofiring switchgrass at the coal fired electric utility plant on the campus in West Lafayette. One of the major focus of this research is to understand and develop robust handling systems for fuel preparation and feeding of lignocellulosic biomass into thermochemical reactors such as boilers in a power plant for power generation. Below are photos of the project at Purdue University.

Switchgrass plot at Purdue's Agricultural Research Center in Throckmorton

Switchgrass harvesting at Throckmorton

Switchgrass bales being unloaded at Purdue University's Wade Power Plant Facility, West Lafayette, IN

Biomass supply chain

To establish lignocellulosic biomass as a reliable resource for effective energy production, the infrastructure for production, harvest, transportation, storage, pre-treatment, and handling needs to be established.

Harvesting biomass
The scenario for removing the stover is not appropriate for all areas in which the soil characteristics and operational resources available should be considered. Table 2. Shows some of the harvest methods investigated in a study by Tyner and Brechbill (2008).

Table 2. Corn Stover Removal according to Harvest Method

Harvest Methods	**Percent of Available Stover Removed**
Windrow behind combine, bale	38.0 %
Rake into windrow, bale	52.5 %
Shred stalks, rake into windrow, bale	70.0%

Source: Tyner, 2008.

Transportation of biomass
A major consideration of the use of biomass energy crops in the U.S. is that it has a low bulk density hindering the economics of transporting the feedstock to the energy production facility. This creates a localized economic opportunity, and energy production facilities designed to cater to the local available resources. The costs of transportation of both corn stover and switchgrass are based upon the following assumptions from distances from 5 to 50 miles in intervals of 5 miles, and either utilizing custom, or owned equipment.

- Highway diesel: $3.93 per gallon (EIA, 3/31/2008
- Truck driver wage rate: $14.37 per hour (BLS, 2006)
- Semi-tractor and flatbed trailer
- Gas mileage: 6.73 miles per gallon
- Driving speed: 50 miles per hour
- 26 bales per load
- Loading/unloading time: 20 minutes (Tyner, 2008).

The following tables document the incremental costs associated with the costs of transporting relevant biomass energy crops such as corn stover and switchgrass.

Table 3. Cost of Transporting Corn Stover per Ton

	Custom	**500 acres**	**1000 acres**	**1500 acres**	**2000 acres**
5 miles	$35.94	$42.18	$37.91	$36.49	$35.78
10 miles	$37.33	$42.85	$38.58	$37.16	$36.45
15 miles	$38.71	$43.52	$39.25	$37.83	$37.12
20 miles	$40.10	$44.19	$39.92	$38.50	$37.79
25 miles	$41.48	$44.86	$40.59	$39.17	$38.46
30 miles	$42.87	$45.53	$41.26	$39.84	$39.13
35 miles	$44.25	$46.20	$41.93	$40.51	$39.80
40 miles	$45.64	$46.87	$42.60	$41.18	$40.47
45 miles	$47.02	$47.55	$43.28	$41.85	$41.14
50 miles	$48.40	$48.22	$43.95	$42.52	$41.81

Source: Tyner, Purdue University. 2008

Table 4. Cost of Transporting Switchgrass per Ton

	Custom	**500 acres**	**1000 acres**	**1500 acres**	**2000 acres**
5 miles	$55.76	$57.80	$55.16	$54.28	$53.84
10 miles	$57.15	$58.48	$55.83	$54.95	$54.51
15 miles	$58.53	$59.15	$56.50	$55.62	$55.18
20 miles	$59.92	$59.82	$57.17	$56.29	$55.85
25 miles	$61.30	$60.49	$57.84	$56.96	$56.52
30 miles	$62.69	$61.16	$58.51	$57.63	$57.19
35 miles	$64.07	$61.83	$59.18	$58.30	$57.86
40 miles	$65.46	$62.50	$59.85	$58.97	$58.53
45 miles	$66.84	$63.17	$60.52	$59.64	$59.20
50 miles	$68.22	$63.84	$61.19	$60.31	$59.87

Source: Tyner, Purdue University. 2008

Processing Biomass

Opportunities in the future may exist to locate a holding and conditioning facility in rural areas to prepare the biomass for the export and utilization on the biorefinery (cellulosic ethanol) or power plant (cofiring). The processes considered would be:

1. Cleaning of the biomass material
2. Sorting and size reduction
3. Grading and densification of the material
4. Blending
5. Compaction for bulk transportation
6. Pre-processing to upgrade stover feedstock
7. Bulk material transported by rail or truck

Conclusion

Many questions remain unknown about biomass supply for biofuels within Indiana and surrounding states. More research and development will be occurring before producers become involved in the production and distribution of energy crops across the U.S. In addition, market stimulation must occur first before production of biomass energy crops can be established, and the subsequent supply chain to make these types of biomass energy a viable opportunity.

References:

Eggeman, T.; Elander, R. T. "Process and Economic Analysis of Pretreatment Technologies," *Bioresource Technology* 96(18): 2019-2025, (2005).

Ileleji,K. "Cofiring Biomass with Coal: Biomass Burn Research at Purdue," Presentation to the Indiana Association of Soil and Water Conservation Districts. June 6, 2008.

Moser, L.E. and K.P. Vogel. "Switchgrass, Big Bluestem, and Indiangrass," p. 409–420. In: R.F. Barnes, D.A. Miller, and C.J. Nelson (eds.), Forages. Vol 1, An introduction to grassland agriculture. Iowa State Univ. Press, Ames. (1995)

Perlack, R. 2005. Biomass as a feedstock for bioenergy and bioproducts industry: The Technical Feasibility of a billion ton annual supply. UT-Battelle, LLC for the U.S. Department of Energy under contract DE-AC05-00OR22725

Tyner, Wally. Presentation to the Indiana Biomass Energy Working Group. May, 2008.

Weber, G.F. and Zygarlicke, C.J. "Barrier Issues to the Utilization of Biomass," Semiannual Technical Report to the United States Department of Energy. (2001)

Zia Haq, "Biomass for Electricity Generation," Energy Information Administration, U. S. Department of Energy. (2002)

Grabowski, P. 2004. Biomass cofiring. Office of the Biomass Program, A presentation given on March 11, 2004 in Washington D.