Michael Ladisch, Nate Mosier, LORRE, Department of Agricultural and Biological Engineering
Purdue University

A Snapshot of Biofuels in Indiana

January 28, 2007

The production of corn ethanol in Indiana was at 102 million gallons per year in September, 2006. This will significantly increase when plants under construction begin production within the next 6 months to 2 years. Plants that are under construction correspond to 550 million annual gallons of capacity. There are an additional 10 plants in various stages of planning with a projected annual capacity of an additional 1 billion gallons. The Indiana ethanol plants that are either under construction or in various planning stages are listed in Table 1.

The corn currently consumed in Indiana for ethanol production is about 38 million bushels (corresponds to about 102 million gallons of ethanol). An additional 203 million bushels will be consumed when plants, that are currently under construction, become fully operational. If all of the plants that are in various stages of planning are brought on-line, annual corn use would grow by another 367 million bushels. The total capacity of current, under construction, and planned plants is equivalent to 1.65 billion gallons/year or about 608 million bushels of corn per year. Based on current technology, this volume of ethanol production will generate approximately 9 to 10 billion pounds of the co-product DDGS. DDGS has a composition that includes 5% starch, 14% cellulose, 13% hemicellulose (xylan + arabinan), and 26% protein. Currently used as an animal feed, this co-product may be processed further using cellulose pretreatment and conversion technology to increase ethanol yield by 7%.

The estimated total corn produced in Indiana in 2005 was 929 million bushels (data source: National Agricultural Statistics Service, January, 2005). Hence, estimated future ethanol production could consume between 44 to 78% of the Indiana corn crop based on the 2005 numbers, although this will depend upon yields and the acreage of corn planted, as well as the impact of the introduction of cellulose conversion technology. While it is difficult to predict the acreage that will be planted in corn and how much average yields will increase over time, the plants under construction once operational will consume a significant fraction of the corn produced, and this will probably be over 40% of the Indiana corn crop. If all of the plants in planning stages are brought into production, this could double the amount of the corn crop that would go into ethanol production.

At a national level, current ethanol production is 5.12 billion gallons, with plants under construction corresponding to an additional 3.84 billion gallons. The total corn that is being consumed by these plants is estimated to be on the order of 1.8 to 1.9 billion bushels, with expansion capacity to account for an additional 1.4 billion bushels. This calculation assumes average ethanol yields are 2.7 to 2.8 gallons/bushel. According to the National Corn Growers Annual Report, Corn Production in the U.S. was 11 billion bushels in 2005, with 4 billion gallons of ethanol consuming 1.43 billion bushels of corn. This would correspond to an average yield of 2.8 gal/bushel. The estimates in Table 1 and potential improvements in yields are based on 2.7 gal/bushel and are based on the Indiana Department of Agriculture website. Of these plants, a fact sheet released on January 16, lists 12 plants (blue font in Table 1) receiving financial incentives (see http://www.in.gov/isda/biofuels/factsheet-biofuels-010307.pdf).

Michael Ladisch, Nate Mosier, LORRE, Department of Agricultural and Biological Engineering
Purdue University

Table 1. Yields based on average yields of 2.7 gal/bushel (www.in.gov./isda/biofuels).

New ethanol plants	Town/County	Corn needed in millions of bushels	Estimated production level in million gallons
Producing			
New Energy	South Bend/St. Joseph	37.76	102
	Subtotal	38	102
Under Construction			
ASAlliances Biofuels LLC	Linden/Montgomery	37.04	100
Iroquois BioEnergy	Rensselaer/Jasper	14.81	40
Central Indiana Ethanol	Marion/Grant	14.81	40
The Andersons	Clymers/Cass	40.01	110
ASAlliances Biofuels LLC	Tipton/Tipton	37.04	100
Cardinal Ethanol	Harrisville/Randolph	37.04	100
Premier Ethanol LLC	Portland/Jay	22.22	60
	Subtotal	203	550
Planned			
Putnam Ethanol	Cloverdale/Putnam	22.22	60
Rush Renewable Energy	Rushville/Rush	22.22	60
Central States Enterprises Inc.	Montpelier/Blackford	40.01	110
ASAliances Biofuels LLC	Mt. Vernon/Posey	37.04	100
Aventine Renewable Energy/CGB	Mt. Vernon/Posey	80.00	220
Renewable Agricultural Energy, Inc.	Cayuga/Vermillion	37.04	100
Ultimate Ethanol	Alexandria/Madison	22.22	60
Hartford City Bio-energy, LLC	Hartford City/Blackford	32.59	88
U.S. Ethanol Holdings, LLC	Muncie/Delaware	37.04	100
Indiana Bio-Energy	Bluffton/Wells	37.04	100
	Subtotal	367	998
	TOTALS	608	1651

The principal activity for production has centered around the use of corn, and the construction of plants that are based on dry-grind processes for ethanol production. The dry-grind processes are based on grinding of corn into a fine powder, cooking and adding enzymes to break it down to sugars, and then fermenting the sugars to ethanol. The use of corn for ethanol production may expand further. Limits on overall production of ethanol from corn are estimated to be in the range of 12 to 15 billion gallons per year. Further expansion of ethanol production above 15 billion gallons per year will require that cellulose be used as a source of fermentable substrate.

Research at Purdue University.

Purdue University and the Laboratory of Renewable Resources Engineering (LORRE) have been active in the cellulose conversion and ethanol areas since 1978. Developments have included a pretreatment process for pressure cooking DDGS and other types of cellulosic materials in water in order to release more material that ultimately results in fermentable sugars and additional

ethanol. The conversion of agricultural residues such as corn stover, wheat straw, sugarcane bagasse, or wood chips will release both glucose and five carbon sugars, including xylose. The five carbon sugars are not readily fermented to ethanol. A genetically-engineered yeast that is capable of fermenting both xylose and glucose to ethanol, thereby increasing yields by a third, has also been developed by Dr. Ho and her colleagues in LORRE. This is another major step towards the production of fuel ethanol from cellulosic materials. In addition researchers are examining other biocatalytic routes that will improve efficiency of cellulose ethanol production.

The College of Agriculture at Purdue University also has major programs in examining the genetics of corn, and the genetics of poplar (a potential source of cellulose for biofuel production). These programs are examining ways of increasing the yield of biomass per acre. Some researchers believe that yields of 10 tons/acre are possible so that ultimately 1 thousand gallons of ethanol could be produced from an acre of cellulosic material such as switchgrass, certain types of forages, or poplar. Current technology would enable corn stover to be collected from farm land at the rate of approximately 1 ton to 2 tons per acre, and this provides a starting material for testing and developing cellulose ethanol plants from which the industry would expand. In addition, there is an initiative underway that is addressing utilization and markets for DDGS that will result from these new plants.

Various scenarios for the development of the cellulose ethanol industry are being considered. One is the addition of cellulosic conversion technology to existing dry grind facilities, as this technology becomes available. There are other types of projects on-going at Purdue University, addressing fundamental research in:

1. Cellulose conversion and pretreatment;
2. Ethanol fermentation, and particularly the genetic modification of yeast for co-fermentation of glucose and xylose to ethanol;
3. Separations for ethanol from water; and
4. Systems integration of ethanol conversion plants to be able to process both cellulose and starch to ethanol.

These projects are being carried out under the auspices of LORRE, and many other departments. The Agricultural Economics Department, (Wally Tyner), is carrying out economical analysis of the impact of government policy on corn prices, land utilization, and the economics of ethanol production from various renewable resources for both corn and cellulosic materials. Overall systems modeling, being carried out through a cooperative effort between several departments at Purdue, as well as other universities is generating data for use in initial process analysis and design of plants that convert corn fiber. Efforts specifically addressing the utilization of DDGS in the dry grind industry are being carried out through the Midwest Consortium, which is a consortium led by Purdue University and includes cooperators from Iowa State, Michigan State, University of Illinois, USDA NCAUR, and Ames Laboratory, as well as DOE. LORRE also carries out research through the biomass pretreatment Consortium for Applied Fundamentals and Innovation led by Charles Wyman (University of California, Riverside), and includes Michigan State, Auburn, Texas A&M, UBC (Vancouver), and NREL as well as Dartmouth and Purdue as cooperators.