Talking About Corn Stover with Jim Hettenhaus Volume No. 4, Issue No. 2, Summer 2002

The single largest source of low cost cellulose in this country is corn stover. To understand its commercial prospects, we invited Jim Hettenhaus to join us in a conversation. We can think of no better teacher on the subject than Mr. Hettenhaus. His credentials are impressive: A B.S. in Chemical Engineering from the University of Wisconsin; an M.S. in Chemical Engineering from St. Louis University; senior official at Gist-brocades, Monsanto and Anheuser Busch overseeing the production of fine chemicals, commodity chemicals, food ingredients, fibers, enzymes and largescale fermentation products; and co-founder of three business start-ups in the areas of analytical instrumentation and control systems, membrane separation systems and nylon fiber manufacturing. In 1993 Jim started his own company, Chief Executive Assistance (www.ceassist.com). Since 1997, Jim has worked with the federal government and private companies to accelerate the production of ethanol, chemicals and other value added products from biomass. What is corn stover? Corn stover is the other half of the corn plant that remains on the surface aside from the corn kernels. The stover is 50% stalks, 22% leaves, 15% cob, and 13% husk. Stover does not include the crown and its surface roots. What happens to corn stover now? Most is plowed into the soil. Less than 5% is baled for animal bedding and feed. The remainder is left on the surface to retain soil moisture and control soil erosion. How much corn stover is available? About one ton of corn stover is produced for every one ton of corn grain. Corn grain yields per acre have increased by 60 percent from the early 1970s, from about 85 bushels per acre nationwide to about 135 today. Corn stover yields have increased proportionately. About 250 million dry tons of stover are produced each year. How much corn stover do you estimate can be extracted from a farm without causing soil erosion? Some surface residue—a minimum of 30 percent coverage—is required by USDA guidelines for erosion protection. Relating mass to soil cover is guess work. The actual amount of stover that must remain to prevent soil erosion varies greatly, depending on local conditions such as soil type, slope of the field, length of slope, tillage practice and crop rotation. With no-till cultivation, about 150 million dry tons could be taken off the land. For no-till fields with slopes less than 4%, the required cover varies from 0.5 to 1.5 tons/acre. So if the yield is 180 bu/acre (5 tons/acre), 3.5 to 4.5 tons can be removed while complying with Best Management Practices (BMPs) for residue set down by the USDA. For mulch till, the required cover amount is about doubled to 1 to 3 tons/acre, leaving 1 to 2 to 3 tons/acre available for removal. Generally, no stover can be removed from conventional tilled fields and still comply with

BMPs. Does this depend on soil composition? Soil composition is just one of many factors. The USDA National Resources Conservation Service has models that determine the required amount of cover to prevent both water and wind erosion. These should be applied to individual fields to determine the amount of removal consistent with BMPs. Doesn't the stover need to remain on the land to enhance soil fertility? Surface cover primarily controls erosion and retains moisture. Most of the soil fertility comes from the roots. Studies by the National Soil Tilth Lab in Ames, Iowa, show that after a year, 75% of the new carbon moving into the soil came from roots and only 25% from surface residue. They also observed, incidentally, that two-thirds of the carbon contained in the surface residue had been released into the atmosphere as CO2. Withdrawing corn stover does withdraw nutrients. What kind of nutrients would a farmer have to replace and what would the cost be for those nutrients? The value of the lost nutrients is as follows. For potash, with a content of 0.1%, the value is 40-60 cents per dry ton of corn stover removed. For potassium, with a content of 1.0% it is about $2.60 a ton. The N value computation is more complex. Corn stover nitrogen content varies from 0.5% to 6%, or 10 to 120 pounds per ton, dropping rapidly after harvest. If all of that nitrogen were available, the value of lost N would be $1.60-$9.60 per ton. However, adding additional N fertilizer when plowing under stover is common with continuous corn cultivation and varies with soybean/corn rotation. Some use a starter, with the N costing $3.20 per ton buried. Thus the calculation is highly dependent on crop rotation methods. I use a cost of $3.20 to make up for the lost P and K nutrients. Is it true that in some cases withdrawal of corn stover can actually enhance soil fertility? Could you explain why? After the surface cover required for erosion control is met, removing the excess stover can actually aid soil fertility by eliminating the need to plow. Many studies by the USDA and others show that plowing results in a burst of CO2 as the soil organic material (SOM) is oxidized when the surface is ripped open, exposing the material to air. Plowing depletes the SOM. Researchers in the Soil Science Department of the U of MN found that about 6 tons of stover must be buried just to keep the SOM even, if the field is plowed—the residue equivalent of a 200+ bu/acre yield. Mulch tilling can reduce this loss, but still causes a major disruption to the habitat below the soil surface and some loss of SOM. This is why no-till cultivation is a key to generating large amounts of available stover. Interestingly, removing the stover may also be a key to expanding no-till cultivation. Why does removing stover encourage no-till farming? In northern states, the cold, wet soil in the spring slows seed germination. The residue cover acts as insulation, retarding soil-warming. Farmers plow under the excess stover, to enable the soil to warm earlier and thereby allow earlier spring planting. By removing the excess stover this plowing could be avoided, encouraging no-till cultivation. How does no-till help the environment? Field operations are reduced, saving fuel. Reduced tilling or no-till sequesters more carbon in the soil, increasing its fertility. Soil erosion is reduced, wildlife habitat is improved and using the stover as a feedstock in lieu of fossil fuels can offset greenhouse gas emissions. Chemicals and nitrogen fertilizer application can be reduced, decreasing their leaching into groundwater and run-off into streams. Is corn stover currently collected? For what purposes? In addition to bedding and animal feed, some has been harvested for niche markets like hydro-mulch, the green-dyed material that is and retain seeds while a cover is grown. Particle board is another application. Both are highly competitive markets and have been proven difficult to enter. Describe the Harlan County, Iowa project. For many years, Great Lakes Chemicals (GLC) had been converting oat hulls into furfural in their Omaha plant. In 1995, oat hull prices soared to more than $100/ton. GLC searched for an alternate, more economic feedstock. Corn stover was selected. GLC contracted with 440 corn farmers around Harlan, Iowa. In 1997, stover from 50,000 acres was successfully harvested around Harlan using contract harvesters. In 1998, GLC was bought by Penn Specialty Chemicals which suffered financial problems. That led to the closing of the Omaha plant and the sale of the other parts of its business. Nevertheless, despite its shortlived operation, the Harlan enterprise established the viability of large-scale stover harvesting and generated concrete cost figures. What are the current costs of collecting the corn stover? For delivery within a 50 mile radius, $30 to $35/dry ton delivered is a good number. The major cost is baling. Using contract balers, the baling price is about $12 to $16/dry ton for 1,000 to 2,000 acres. "Load and Go" wagons hauled by high speed tractors can pick up the bales in the field and deliver them to the storage area for $6 to $12/dry ton depending on the distance What is the increased net income per acre for the farmer from collecting corn stover? How much increased net income might this translate into for the average midwestern corn farmer? Based on the Harlan cost information, we could reasonably expect to increase the farmer's net income $20/acre or more while delivering stover to the processor at $25 per dry ton. For 500 acres of corn, that translates into an additional $10,000 in the pocket of the farmer. That assumes 3 tons of stover removed per acre. Since there needs to be a win-win relationship between the growers and the processors, one plan put forward is offering equity ownership in processing facilities. Some industrial developers are proposing to license to growers and growers co-ops on a preferential basis to integrate them into the value chain and out of the commodity market. What do you envision will be done with the corn stover once collected? It should be converted into sugars. Removing just one-third of the stover and converting its 38 percent cellullose content into sugars would result in the production of 29 million tons of glucose, twice the amount of sweeteners shipped in 1997. Low-cost sugars can be the feedstock for replacing many petroleumderived fuels and chemicals. These industrial sugars complement the food sugars from the grain, enabling the corn farmer to benefit from the other half of his crop that is now left in the field. What is the cost of sugars produced from corn stover? Do you see these sugars as competitive with other sources? Until recent advances in biotechnology, these sugars were too expensive. The cost of sugar in Brazil, the low-cost world producer, is more than 8¢/lb. Now, using biotech tools, 4¢/lb sugar from cellulosic materials is on the horizon. Improved enzymes and microbes are emerging that can economically process the stover and other lignocellulosic material like cereal straw and prairie grass to value added products that can effectively compete against fossil feedstocks. Progress is being accelerated through partnering between DOE funded laboratories like the National Renewable Energy Laboratory (NREL), Universities – University of Florida and Purdue – and private companies like Iogen, Genencor, Novozymes, Diversa, Maxygen and Cargill-Dow LLC, a joint venture between Cargill and Dow. Iogen, with Shell and Petro-Canada, is moving ahead on the fuel side while Cargill-Dow is pursuing a similar route for plastic materials. Dow, Dupont, BASF and DSM in the chemical industry have a similar strategy. Why should we focus on collecting corn stover? Corn stover is the largest underutilized ag resource in the United States. It has an inherent cost advantage over crops grown for industrial uses since those have production costs. Stover requires no more land. The material is already in the field. Moreover, today more than 80 percent of corn acreage is tilled. If removing the excess stover encourages conservation and no-till cultivation, it would dramatically reduce the CO2 generated from the decay of this residue on the soil and reduce soil erosion even further. Why not focus instead on municipal organic wastes or energy crops? They can both play a role, but their volume is much less than corn stover. In addition, they create other problems: While municipal waste is already collected and offers a negative cost material (that is, the cellulose processor will be paid to take the material), the composition of this waste varies widely and the risk of contamination is high compared to stover. Moreover, there has been considerable citizen opposition to waste-toenergy plants even when the output is ethanol or other biochemicals. Energy crops require additional land and have higher costs—they are a crop, not a “leave-behind”. Longer term, they may offer a more diversified and sustainable feedstock, but initially few, if any, farmers will grow them if a market does not exist. When yields are measured in tons of stover in addition to bushels of grain, the corn plant is an amazing solar energy converter to foods and biomass feedstock. At 180 bushels per acre, corn generates about 10 tons of surface matter, 6–8 tons of which can be commercially harvested. An equal amount of matter is contained in the root and crown of the plant. Plant science and biotechnology advances continue to improve yields, produce value-added kernels and stover with reduced chemicals and less need to till. If you were the Secretary of Agriculture or the Secretary of Energy, what steps would you take to make corn stover an important new raw material for energy and industrial products? Sustainable harvesting and economical processing are key issues. Joint development of Request for Proposals (RFPs) that have broad goals and require multi-disciplinary partnerships with industry are required. Some specific additional support needs include the following: From the USDA, addressing sustainable agriculture issues—determining optimum production using life cycle analysis—is essential. For example, local studies of no-till practices, one-pass harvest and storage with grower and industry participation can help provide a credible foundation for sustainability. From DOE, continued process development for conversion of cellulosic materials to fuels, chemicals and materials is needed. This includes ongoing enzyme development as well as integrated process validation at a minimum engineering (pilot) scale for prehydrolysis, hydrolysis and sugar fermentation, and biocatalyst development under industrial leadership. The basics have been over-investigated and proven; it's time for industry to cost-share significantly and prove the technology From both agencies, support of carbon credits will accelerate the move to economic sustainability. How can people learn more about the potential of corn stover as an industrial and energy raw material? For soil carbon and residue see: www.nstl.gov/papers/96354.html and other papers by C. Cambardella, W. Gale plus www.soils.umn.edu/Research/ and the research publications of R. Allamaras, E. Clapp, D. Linden and T. Dowdy. For plowing impact on SOM see www.mrsars.usda.gov/ and search for papers by D. W. Reicosky and M. Lindstrom. For stover harvest and farmer benefits, Conservation Tillage Information Center's web site, www.ctic.purdue.edu/Core4. The Harlan, Iowa operation report is at www.ctic.purdue.edu/Core4/bio98paper.pdf An overview of current DOE and NREL feedstock and process research is at www.ott.doe.gov/biofuels/cornbridge.html and specific information on the "sugars platform" begins with www.ott.doe.gov/biofuels/ enzyme_sugar_platform.html