GROWING A NEW ECONOMY AROUND CELLULOSIC FEEDSTOCK AS RAW MATERIALS FOR BIOREFINERIES

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Biomass can play the same role as oil in refineries producing fuels and chemicals and such biorefineries, have been identified as a cornerstone for decreasing US dependency of oil. Ethanol is an example of a liquid transportation fuels for motor vehicle applications that can be derived from renewable resources. In the United States, virtually all fuel ethanol is produced using primary grains (especially corn). In 2008, the United States consumed approximately 138.18 billion gallons of gasoline. 9 billion gallons of ethanol was produced in 2008 and represent about 4.6% of gasoline consumption. In year 2020 the plan is to produce 30 billion gallons of ethanol of which 15 billion gallons will be produced from cellulosic raw materials. The Midwest has been the major player for developing corn ethanol. The Northwestern states sit on major biomass resources such as agricultural and forest residues and have the potential for growing dedicated energy crops such as Yellow Poplar or switch grass. The Northwestern states therefore hold the potential for playing a major role in exploitation of Biorefineries producing for instance cellulosic ethanol in addition to other products.

In Oregon and Washington, recent biomass energy studies have documented an abundance of cellulose feedstocks for ethanol production. A study conducted in 2000 for the Oregon Office of Energy projected that if all the state's 8.5 million bone dry tons of cellulosic material was utilized for ethanol production it would produce 680 million gallons of ethanol per year. A similar study conducted by University of Washington in 2009 (Wood to Energy in Washington: Imperatives, Opportunities and obstacles to Progress, June 2009), showed that Washington State has an annual production of 14.2 million dry tons of lignocellulosic biomass mainly in the form of forest residues and forest trimmings. This is sufficient to produce 1.4 billion gallons of ethanol per year at 80 gallons per dry ton.

The USDA Agricultural Research Station in Prosser, WA has studied the agronomics and economic viability of crops and cropping systems in the irrigated Columbia Basin. In recent years they have studied test plots of various crops of interest to biofuels producers, including oilseeds and switchgrass. They have achieved the highest published yields of switchgrass in the country at test plots in Paterson, WA: 8.5 dry tons/acre in the first cutting, and after the second cutting they expect 15 dry tons/acre per year. There are also three established plantations of hybrid poplar trees in the area, which produce over 10 tons per acre on a sustained basis.

The Columbia Basin is a very productive farming region, with some of the highest yields of corn, wheat and potatoes. For example, corn yields of 225 – 250 bushels/acre are common, as are 120

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– 130 bushels/acre wheat. Farmers can choose among many profitable crops. A common rotation is to grow potatoes every third or fourth year, and a mix of wheat, corn and alfalfa the other years. In this context of highly productive farming, residuals of straw and stover are also high, at 1.5 dry tons per acre which can be sustainably removed. The five county draw area that contains Morrow and Umatilla counties in Oregon, and Benton, Franklin and Walla Walla counties in Washington has over 500,000 acres of irrigated farmland. The non-irrigated ground in this area is mostly in wheat production. The moderate rainfall areas around the southern and eastern sides of the basin produce 60 to 80 bushels/acre wheat, and 1 ton or more of straw per acre. Feedstock input can be managed to achieve an economical average cost and mitigate feedstock price risk.

A full scale Biorefinery will demand at least 400,000 metric tons of dry raw materials. From this amount of Biomass it is possible to produce approx. 32 million gallons of ethanol per year. However, ethanol will only be produced from the carbohydrate fraction of the biomass and therefore it will be possible to produce other energy products from the Biorefinery such as a solid fuel from the lignin fraction and methane from all other organics. The Biorefinery will attempt to maximize its income though production of highly valuable compounds before bulk products such as energy products. Therefore, the parts of the carbohydrates fraction might be used for microbial or chemical conversion into sugar-based building blocks such as succinic, fumaric and malic, 2,5 furan dicarboxylic acid, levulinic acid, 3-hydroxybutyrolactone, glycerol, sorbitol, and xylitol/arabinitol (US DOE, Top Value Added Chemicals from Biomass, 2004). Furthermore, the lignin fraction could be used for new chemicals or materials, which would be much more economically favorable than making electricity. Making phenolics in addition to ethanol could potentially pay for all expenses for production of cellulosic ethanol making this fuel fare cheaper than oil-based gasoline.

In the Biorefinery a significant fraction of the organic carbon will be other organics than carbohydrates or lignin. Pretreatment of biomass materials and fermentation will result in production of dissolved organic compounds such as formic and acetic acids or low molecular lignin products. Anaerobic digestion of the waste stream will be an excellent way of converting this fraction into useful methane. Anaerobic digestion in UASB reactors has been widely applied on wastewater from distilleries based on sugar cane juice, sugar cane molasses, sugar beet molasses, wine or corn (Driessen et al. 1994). We have tested UASB reactor in pilot scale (0.8 cubic meters) for treating the residual stream from the ethanol fermentation process of the biorefinery concept converting straw into bioethanol, lignin and biogas. This process has previously been successfully tested in lab-scale (Torry-Smith et al. 2003). In the pilot plant the long-term performance of the UASB reactor system was tested for both thermophilic and mesophilic operation. Thermophilic operation of a UASB reactor system for anaerobic digestion of the effluent from the ethanol fermentation steps gives higher methane yields than at mesophilic operation at OLR below 4 kg-VS/m^3/d, but the system is more sensitive to higher loading rates. The effluent from the conversion processes including wet oxidation pretreatment and sugar fermentation is less toxic for the anaerobic microbial consortia than for example cane molasses vinasse. The degradation of the biorefinery effluent in a UASB system is rather hindered by the content of suspended matter. Removal of the suspended matter prior to the UASB reactor will reduce the degradation time.

The future for growing a new Biorefinery industrial area around cellulosic biomass material is bright and new technologies are being developed on a daily basis. A major implementation is awaiting investments from for instance the oil industry which is expected to be launched off by implementation of carbon credits and other promoting instruments.

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