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Editorial

Biomass feedstock production systems: Economic and environmental benefits

The time is ripe for expanding bioenergy production capacity and developing a bio-based economy. Modern society has created unprecedented demands for energy and chemical products that are predominately based on geologic sources. However, there is a growing consensus that constraints on the supply of petroleum and the negative environmental consequences of burning fossil fuels require that modern societies adopt alternative sources. These alternatives must be both renewable and environmentally sustainable. Biomass is an important alternative for both energy and chemical production that meets these requirements.

At the same time alternative energy sources are in demand, significant transformations are occurring in the pulp and paper industry due to fierce competition, which has led to heightened interest in "biorefineries" that expand on the already substantial use of biomass to produce chemical feedstocks and energy as a byproduct of the pulping process. Technologies are readily available for producing a range of biochemical products from biomass feedstocks, including liquid transportation fuels, but until now, they have been overshadowed by petroleum-based alternatives.

Continued development of bioenergy and bio-based production systems requires a reliable biomass supply at a reasonable cost. That supply will likely involve dedicated crops growing near production facilities as well as residual biomass from forestry and agriculture. Local biomass feedstock production appeals to both landowners and the general public for various reasons. Forest landowners seek new fiber markets, while farmers seek to diversify crops with lower fertilizer and pesticides requirements. Locally produced bioenergy and chemical feedstocks favor rural economic markets by creating demand for goods and services, with obvious advantages over the political, economic, and environmental consequences of intra- or international fossil-fuel imports. Yet despite numerous social and environmental benefits, markets have been slow to develop, largely due to economic and resource uncertainty and reluctance to adopt new technology. Industry is concerned by the risk of investing in new or retrofitted facilities at many locations because of concerns over limited or uncertain forest or agricultural residuals feedstock supplies. While this is largely due to the industries interest in centralized processing facilities with greater supply needs compared to distributed facilities sized to match local supplies, there are important solutions currently available. Biomass cropping systems can easily meet the demand with proper advanced planning. However, the cost for biomass crops is greater than utilizing residuals, and without creating markets by building new facilities, there is no incentive for landowners to establish these perennial biomass cropping systems. Determining ways to lower biomass production costs including handling and transportation, reduce uncertainty of supply, capturing the value of environmental benefits and transferring them to the producer will be necessary for development of this industry.

Implementing biorefineries clearly requires accurate information on biomass feedstock supply, production and harvesting costs, and environmental impacts. Numerous examples worldwide provide practical examples of woody and herbaceous biomass feedstock production systems supplying significant amounts of energy in the form of power, liquid fuels and gas. Freely sharing information about biomass feedstock production systems and research on bio-based production systems among private, public and academic organizations is crucial for development of the industry.

To boost information exchange on bioenergy production from biomass feedstocks a joint meeting titled "Biomass and Bioenergy Production for Economic and Environmental Benefits" was held in Charleston, SC, USA. The meeting was sponsored by the Short Rotation Woody Crops Operations Working Group (http://www.woodycrops.org/), the International Energy Agency Bioenergy, Task 30, Short Rotation Crops for Bioenergy Systems (http://www.shortrotationcrops.com/), and the International Union of Forest Research Organization, Working Unit 1.09.01, Integrated Research in Temperate Short-Rotation Energy Plantations. The occasion marked the 10th anniversary of the Short Rotation Woody Crops Operations Working Group. This organization focuses on sharing information on practices and equipment for the culturing, harvesting and handling large-scale woody biomass plantings. The meeting was held in conjunction

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with the international organizations to encourage the flow of various perspectives, evaluate common problems, and seek innovative solutions.

The meeting included pre- and post-meeting tours of Florida eucalyptus and New York willow operations, as well as technical sessions and a local tour with emphasis on intensive management of loblolly pine and the Savannah River short rotation woody crop project (http://www.srs.fs.usda.gov/srwc/). Technical discussions included background on the history of short rotation woody crops, the state of modern bioenergy production, regional reports from IEA member countries, woody and herbaceous production systems from around the globe, environmental benefits focusing on phytoremediation, a diverse section on the biology of biomass production, as well as pertinent discussions of energy processing techniques, and economics of production. This issue of Biomass and Bioenergy includes papers prepared from the presentations at the Charleston meeting.

The first articles help set the stage by showing the history of biomass production systems and the potential for biofuels as an alternative energy supply. The history of short rotation woody crops is described by Dickmann. He discusses important historic examples of products such as basket and fuel wood plantings to demonstrate how this ancient cropping system has repeatedly met human needs. This engaging report takes us through the bioenergy feedstock production programs initiated following the Arab Oil Embargo and culminates in the potential for genomics to revolutionize cropping systems through engineered varieties to meet numerous crop management needs and industrial product requirements. The stage is further developed by Wright's timely description of the importance of biomass as a renewable energy source. Important perspectives are placed on the historic roll of bioenergy and the potential ease with which biofuels can step in to meet much of our energy needs.

The next set of articles involves descriptions of developed cropping systems. Each example demonstrates the integration of cropping systems with market and application development. Willow has been developed for bioenergy production in Sweden, UK, Canada and the US. Volk et al. describe a diverse willow feedstock production program that includes numerous private companies, public agencies and university collaborators. Applications are focused on power production, but other facets include phytoremediation, stream-side management and living snow fences. Genetics, biodiversity, crop management, and farming operations are integrated throughout each component. Similarly, the woody crop research of Rockwood et al. in Florida is focusing on numerous applications in a wide-ranging program involving eucalyptus and poplar. A brownfield (abandoned industrial site) resulting from phosphate-mine clay-settling basins has created a significant land base for biomass production and he describes activities occurring there. In addition, he describes how a renewable portfolio standard in a region with limited water sources has encouraged biofuel production through the use of effluent and reuse irrigation supplies. These well-balanced research teams working with willow and eucalyptus are programs to watch for continued innovation in lowering the cost and production efficiency of bioenergy feedstocks.

Robison et al. report what might be termed a final report from a well-integrated papermill feedstock production operation based on alluvial land supplemented with upland intensively managed land. Since the Charleston meeting we have learned that this mill and land base has been sold by the parent company and the research program terminated. This paper reports aspects of a deep research program including advance genetic screening work for southeastern US species and intensive-management research. Such dramatic business decisions are symptomatic of the transformation occurring in the fiercely competitive pulp and paper industry.

Other papers included from the Charleston meeting include primary research reports on biological aspects of biomass production, a phytoremediation applications, economic analysis and fermenting technology. Studies on production biology describe fertilizer responses by Coleman et al. for hybrid poplar growing in Minnesota, USA, two reports on poplar genetic screening trial for both production and pest resistance conducted the southeastern USA costal plain by Coyle et al. operational scale production for sycamore and sweetgum by Davis and Trettin, as well as long-term coppice trials in Midwestern USA focusing on the interaction between spacing and species by Geyer.

Phytoremediation solutions to numerous brownfield municipal and industrial problems have met public and private industry approval based on low cost and the natural or "green" approach. Adoption has been rapid despite limited understanding of processes involved. Significant research is occurring to develop necessary understanding. Zalesney et al. report transpiration rates from a phytoremdiation trial designed to create a vegetation barrier between a vaulted landfill and nearby surface waters where contaminated water has been leaching. Such riparian buffer strips are an economical solution for the small municipality with which these authors are working. Their information provides critical data on the quantities of water interception to be expected. Rockwood et al. also report how short rotation woody crop plantations can be used to purify reuse and waste water while growing feedstock for power production or other end uses. Such integrated approaches demonstrate that phytoremediation has tremendous potential to meet societies need for both biomass production and at the same time can be an effective natural solution for cleansing municipal and industrial waste streams.

Understanding the cost and the quality of biomass production is critical for industries evaluating the competitiveness of biomass as feedstock. Gallagher et al. have prepared a thorough evaluation of the costs of short rotation woody crop production in southeastern US. Their analysis demonstrates that production costs are high relative to less intensive production systems and emphasizes the need to maximize growth rates to lower unit costs. Francis et al. compare the pulping characteristics of various poplar varieties. The Crandon clone (*Populus alba* × *P. grandidentata*) displayed superior qualities, while a pure *P. deltoides* clone produced paper with superior fiber and strength characteristics.

One of the most promising areas for biomass feedstocks is in the production of liquid transportation fuels. Ethanol has the greatest market penetration with global availability and a large variety of fully developed vehicles available to run on various blends with petrol ranging from 10% ethanol up to pure ethanol. Both starch based and lignocellulosic ethanol production systems offer tremendous bioenergy opportunities. Much of the development of ethanol production is based on optimizing microbial or enzymatic conversion processes. Davis et al. report optimization of ethanol production using *Zymomonas mobilis*, a Gram-negative bacterium, and alternative growth promoters to replace costly yeast extracts. Much greater ethanol yields were achieved at a faster rate with *Z. mobilis* compared with yeast (*Saccharomyces cerevisiae*). Use of such ethanol culture systems will improve the efficiency of ethanol production over yeast-based processes. Similar optimization of biorefinery processes will be required in the future as biomass is converted into useful chemical products.

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