The IBSS Partnership: Reducing Barriers To the Deployment of an Advanced Biofuels Industry in the Southeastern U.S.

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INTRODUCTION

The Energy Independence and Security Act (United States Congress 2007) mandates the use of 21 billion gallons of advanced biofuels by 2022. The 2010 USDA Biofuels Strategic Production report (USDA 2010) estimates that the southeastern United States (SE US) will be the leading region for biofuels production due to “the most robust growing season in the US”. In addition, the SE US can produce a variety of biomass feedstocks including dedicated herbaceous crops such as switchgrass and biomass sorghum, woody crops, as well as forest residues (Perlack et al. 2011). These feedstocks can be used to produce advanced “drop in” fuels through biochemical (e.g., butanol) and thermochemical technology platforms (e.g., green diesel, jet fuel, etc.). The SE US has the agricultural and forestry culture and infrastructure to readily adopt and advance biomass-to-biofuels systems.

THE IBSS PARTNERSHIP

The Southeast Partnership for Integrated Biomass Supply Systems (IBSS), led by ArborGen, Auburn University, Ceres, North Carolina State University, and The University of Tennessee, was formed in 2011 with support from a USDA-NIFA competitive grant. The team is structured to help meet the USDA goal of producing almost 50% of the next generation of biofuels in the SE US. Reducing the barriers to the use of multiple, complementary feedstocks will reduce economic and supply risks, ensure the best use of the available land base, and give individual landowners the opportunity to select feedstocks that are best suited for their lands, experience, and objectives. The IBSS Partnership is working to:

1. Demonstrate and validate the sustainable deployment of herbaceous crops, including a perennial grass (switchgrass); and short-rotation woody crops (hardwoods and pine).

Each of these biomass sources has inherent performance and cost advantages for specific conversion technologies.

2. Reduce the risks associated with growing, harvesting, storing, and converting biomass by developing, testing, and demonstrating improved genetics, agricultural/silvicultural practices, and harvesting and processing logistics that achieve optimized biomass crop productivity while maintaining an appropriate balance with economic and environmental sustainability.
3. Develop economic and environmental modeling tools that utilize data generated from our demonstration and testing systems, as well as existing data, to assist policy-makers, landowners, and financiers in decision-making for biomass system implementation.
4. Provide highly integrated and coordinated E2O activities that rely on traditional and innovative content delivery methods to reach key members of the biomass value chain, to prepare the current and future workforce, to contribute to the growth and sustainability of this new industry, and to address public and societal concerns; all critical for the economic and social viability of a lignocellulosic biofuel industry in the SE US.

RESEARCH PROGRESS

The IBSS Partnership is uniquely structured to leverage existing knowledge of feedstocks to develop and demonstrate sustainable production scenarios that create innovative deployment solutions for leading conversion technologies. Research and development activities will target specific economic and environmental barriers in each step of the supply chain, generating solutions that in combination will define the approaches needed to launch a regional biofuels industry. System performance metrics for economic and environmental sustainability will be utilized to assist in directing the work within the Partnership. Those same metrics will also be used by E2O tasks to generate credible, science-based data to inform the public discussion on the benefits and costs of sustainable biofuels.

Biomass Production

The southeast has almost 40 million acres of commercial pine plantations that provide raw material for an existing forest products industry. Much like the increases in per acre productivity of row crops the productivity of these pine forests also increases with new plantings. Ongoing harvest and manufacturing operations generate significant residue that represents an immediately available biomass source for energy. This can significantly reduce the risk associated with obtaining a sustainable, reliable, and consistent supply of feedstock; however, pine biomass is not efficiently converted in biochemical processes. Instead, it is best suited for thermochemical technologies producing either synthesis gas, or pyrolysis oils as intermediates for further refining. The IBSS partnership is addressing opportunities to reduce transportation and preprocessing costs, while improving feedstock characteristics that impact the efficiency of conversion in this platform.

While pine is the primary source of lignocellulosic biomass that is available in the southeast today, the supply is limited due to demand for building materials, paper products, and biomass power (the pellet industry is growing rapidly in the region). To supplement supply, The IBSS Partnership is producing the information needed to introduce new energy crops onto the landscape. With a significant acreage of switchgrass under production in east Tennessee, research continues to evaluate production alternatives for this high-yield crop. Short-rotation woody crops (SRWC's) also represent a potentially important addition to the biomass portfolio in the region. Both poplar and eucalyptus promise high biomass yields throughout the region, provide a feedstock that can be tailored for either thermochemical and biochemical processes, and may reduce logistical challenges as they can provide a year-round feedstock supply. Despite these advantages, the detail on the costs and productivity of SRWC in the region has received only limited attention over the years. As such, considerable investment has been directed toward generating the information needed to further adoption of this innovative system in the region.

Responding to this opportunity, the research team installed three field trials (ca. 10 acres) with improved poplar varieties at sites near Knoxville, Tennessee, Huntsville and Auburn, Alabama. The trees were planted at spacings of 3×7, 4×7 and 7×7 feet to assess management options. (Eucalyptus trials are in place in south Alabama, Florida, and North Carolina). Fig. 1 shows the height of the trees in the different treatments (poplar clone and spacing) after two growing seasons for the east Tennessee trial. The heights range from almost 21 feet for the top-performing clone to less than 10 feet for the poorest performer with an overall site average of 15 feet. The north Alabama site exhibited similar growth (*not shown*); however, the Auburn site had extensive mortality after year 1 and was re-planted in year 2. Although the data is very preliminary, significant productivity gains in excess of 20 percent over current commercial varieties are suggested by the results. The trees will continue to be measured for productivity, and monitored for disease and insect susceptibility for the lifetime of the program.

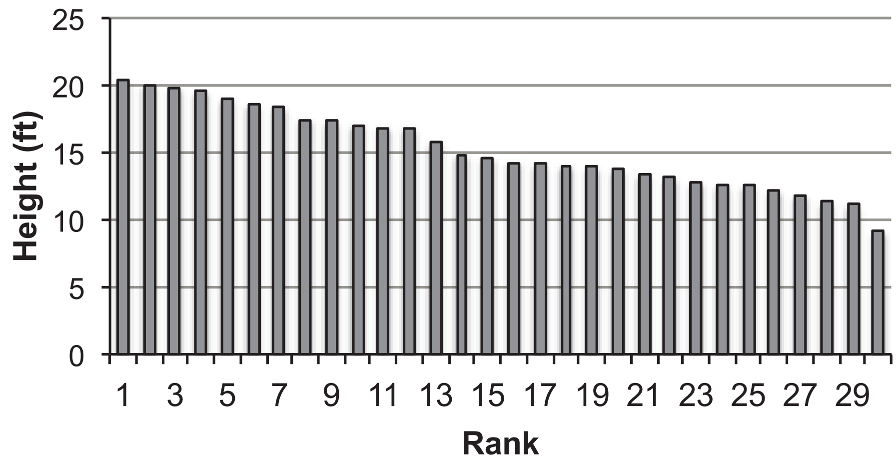

Fig. 1. Ranking by height of hybrid poplar treatments after two growing seasons at the East Tennessee Research and Education Center.

The baseline data on productivity, along with management input information, is vital to calibrate the financial and life-cycle analysis of these bioenergy systems (Gonzalez et al. 2011; Santos et al. 2012; Daystar et al. 2014). Research is also providing data to validate SWAT analyses for these new energy crop systems where little, if any, data is available. This element of the program is critical to further advance our capacity to comprehensively assess sustainability.

Feedstock Characterization

There is little argument that biomass yield represents the greatest opportunity to positively impact key sustainability factors. Higher yields per acre can reduce the footprint of a biorefinery, or increase the scale of the biorefinery operation to gain processing efficiencies. Improved production practices can reduce establishment inputs, reduce delivery distances and costs, improve water quality, and expand the available land base by accessing marginal sites. Equally important, however, is the quality of the biomass delivered to the conversion facility. Because lignocellulosic biomass has not historically been utilized as a chemical feedstock, the characteristics that determine performance in different conversion technologies are poorly understood. In particular, the relative impacts of specific unit operations that comprise the supply chain (and their interaction) on delivering a consistent feedstock for fuels production is far from understood. The IBSS Partnership has invested considerable resources toward defining basic chemical and physical properties of the SE regions biomass source, including southern pine, SRWC's, and switchgrass. One use for this data is to inform the improved engineering process models that are being used and improved by IBSS conversion team (Treasure et al. 2012, 2014; Daystar et al. 2013).

As an example, Fig. 2 shows the frequency distribution for lignin content (left) and total ash content (right) for a subset of switchgrass samples produced on different farms in east Tennessee. Consistent with past reports, the average lignin content for switchgrass is approximately 21 percent. Surprisingly, the amount of lignin ranges from roughly 18 percent to almost 25 percent—an observation with important implications. First, considerable opportunity to manipulate lignin content through traditional breeding methods exists. Second, the variability in lignin content will impact the amount of sugars available for biochemical processes, ultimately impacting fuel yield and process viability. For total ash content (right) of switchgrass, most observations occur from 2–3 percent, but the total range spans almost 3 percent. This is surprisingly lower than values commonly found in the literature. Ash is particularly problematic for thermochemical processing of biomass, impacting catalyst performance and presenting disposal challenges. It also negatively impacts process efficiencies associated with pumping and cleanup up the sugar stream for further refining. Importantly, these results suggest that considerable control is available over feedstock properties.

This data on feedstock properties has been used in related work to create highly robust, near infrared (NIR) and pyrolysis molecular beam mass spectroscopy (py-MBMS) based, multivariate models to predict chemical composition of the different biomass sources (Xiao et al. 2014). This enables the time and expense of wet chemical analysis to be dramatically reduced. Perhaps more importantly, the prospect of on-line or at-line analysis of feedstock is now accessible, introducing the ability to further merchandise the delivered biomass by routing the feedstock to specific conversion processes for optimal performance and maximum profitability. The improved process models mentioned earlier will make it possible to better define the effect of feedstock characteristics on performance, including vital sustainability considerations.

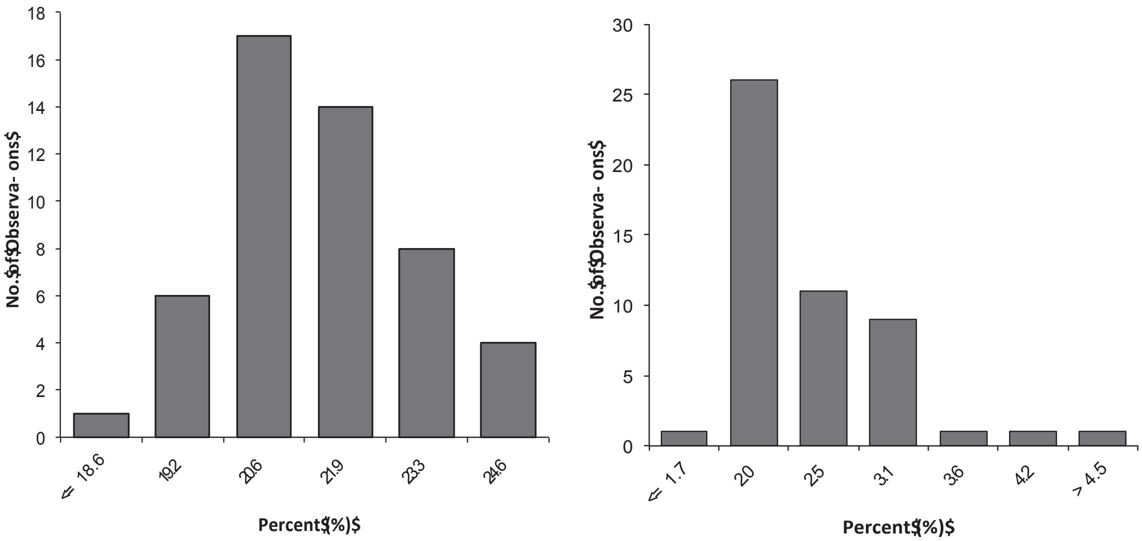

Fig. 2. Frequency distribution of lignin content and total ash content for a subset of switchgrass samples produced on different farms in east Tennessee.

Feedstock/Process Interface

There has been limited research on the effect of feedstock characteristics on conversion efficiency in different thermochemical processes. This type of information is vital to improve the performance of both gasification and pyrolysis technologies. Through collaboration with the National Renewable Energy Laboratory, py-MBMS was used to analyze hundreds of biomass samples collected across the southeast. This analytical method allows the conditions of pyrolysis and gasification to be mimicked, providing insight into the chemistry of the process. Principal component analysis was used to mine the large amount of data. Fig. 3 shows the plot of principal component 1 and principal component 2 for the pine, eucalyptus, and switchgrass investigated.

The preliminary results of this analysis allow several important conclusions to be drawn. First, the distinct clusters formed by the three biomass types confirm the obvious—switchgrass is different from wood. It is important to emphasize, though, that the difference is clearly reflected under gasification conditions with subtle differences in the type and amount of tars. Also of interest is that both pine and switchgrass are separated along the PC-1 axis from eucalyptus. This suggests that similar molecular features are driving the process behavior of the two, relative to eucalyptus. Finally, the pine and switchgrass samples show very tight clusters with limited variation in their behavior. In contrast, eucalyptus stretches expansively along PC-2, highlighting the wide variations in eucalyptus. This approach has generated additional data for calibrating process models that are under development in The IBSS Partnership.

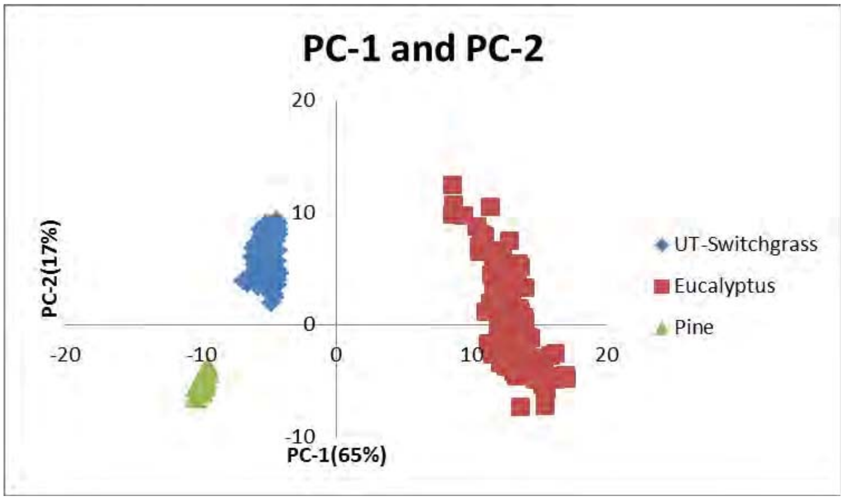

Fig. 3. Principal component analysis of molecular beam mass spectrometry data for three types of lignocellulosic biomass.

EDUCATION, EXTENSION AND OUTREACH ACTIVITIES

Central to The IBSS Partnership's program is the need to provide new information and insights on the use of biomass as a feedstock for the production of fuels and industrial chemicals to a variety of stakeholders in the southeast. Our interaction with industry has reinforced this view as they seek trained workers, and recognize that new skills are needed to procure, manage and prepare a renewable biomass feedstock for a new industry. While media reports attempted to educate the public about cellulosic ethanol in 2007 and 2008, the transition to drop-in fuels and the technology challenges of producing fuels from biomass has not been as widely presented. To accomplish the outreach challenge, traditional and innovative means are being used to widely share the results generated by this program.

Advanced Fuels Education

Seed Fellowship. As a part of the IBSS project, the Southeast Energy Development (SEED) Fellowship was created to train a capable, effective and safe workforce for biomass production, harvesting and biofuels processing (Fig. 4). The program was specifically targeted to undergraduate students who have limited exposure to this emerging field. The SEED fellows work in a multidisciplinary team and are assigned real-world problems that could include either research or field deployment challenges in feedstock production, logistics, conversion, or markets and distribution of biofuels. In a traditional curriculum model, students are often not trained on conducting scientific research, working on multidisciplinary teams, and communicating science to the public. This fellowship experience is helping to fill the gap in capacity development for biofuel industries.

Fig. 4. 2012 SEED Fellows at Rentech's BioEnergy Center of Excellence in Commerce City, CO.

The SEED Fellowship program was successfully piloted in 2012 with five students from Tuskegee University and Auburn University. The fellowship experience was enriched by a number of field trips to biomass harvesting sites, national laboratories, and an internship at the BioEnergy Center of Excellence, learning various aspects of converting biomass to biofuels. The students worked with large volumes of woody material (clean and dirty pulp chips and micro-chips) that the IBSS Partnership procured and shipped to the Commerce City, Colorado facility for evaluation. With information gained through the student's work, we were able to successfully demonstrate the technical feasibility of producing green diesel using IBSS-provided biomass from the region. Over two thousand gallons of "RenDiesel" was produced and shipped to Auburn University, North Carolina State University, and the University of Tennessee to fuel several outreach demonstrations. The featured demonstration was a 900-mile mobile "Whistle

Stop" tour to highlight the student's efforts, this production milestone, and elevate the profile of renewable diesel as a drop-in fuel.

IBSS Whistle Stop Tour. Using synthetic diesel made from IBSS feedstocks southern pine and switchgrass, the mobile biomass gasifier from Auburn University traveled a three-state tour route and demonstrated to hundreds of students and adults how to turn biomass into electricity and drop-in fuels like diesel (Fig. 5). Visitors to the display learned first-hand about how plant-based materials, including wood and switchgrass, are being intensively studied for conversion into biobased fuels. Five tour stops touted the successes of the first two years of the regional research partnership focused on bioenergy production in the Southeast including: the McWane Science Center in Birmingham, Alabama; the American Museum of Science and Energy in Oak Ridge, Tennessee; the University of Tennessee's Ag Day in Knoxville; the University of Georgia's Bioenergy Day in Athens; and Auburn University's College of Ag Roundup in Auburn, Alabama.

Fig. 5. The Whistle Stop Tour informed a range of public interests on the potential of biomass to fuels, demonstrating energy production with the mobile gasifier from Auburn University.

At the University of Tennessee's annual alumni event, the unit demonstrated electricity being generated from biomass by powering large screen TVs that had game day coverage of college football. Also, an all-terrain vehicle (ATV) fueled with "green" diesel highlighted real life farm-to-fuel technology. The ATV even helped escort alumni to and from the event's parking and individuals, young and old, got to see "green" diesel produced by IBSS in action. More than 1,200 are estimated to have attended Ag Day.

Following Ag Day, the tour traveled to the University of Georgia's Bioenergy Day in Athens. That community event, which was held as a precursor to National Bioenergy Day, was hosted by UGA's Bioenergy Systems Research Institute and held at the State Botanical Gardens in Athens. Key features included grade-specific, kid-friendly educational exhibits linked to Georgia's 5th grade science curriculum and activities regarding biofuels research, development and use. At the UGA stop alone, approximately 250 individuals attended with 230 being middle school students.

The mobile tour was listed as part of the larger National Bioenergy Day with events held all over the country. Sponsored by the Biomass Power Association, Biomass Magazine, the U.S. Industrial Pellet Association, the Forest Landowners Association, the Biomass Thermal Energy Council and the American Council On Renewable Energy, this event highlighted different types of bioenergy work and research around the country. The IBSS mobile tour was selected to participate and inform the general public on the benefits of bioenergy.

The mobile tour returned to Auburn in time for homecoming activities where over 2,000 visitors had a chance to learn about biofuels at the annual College of Ag Roundup. Ultimately, the 900-mile tour, spanning three states and reaching thousands of individuals in the Southeast, was a huge success.

CONCLUSIONS

The IBSS Partnership is committed to reducing barriers to the deployment of an advanced, drop-in biofuels industry in the southeast, which includes the risk associated with a long-term, sustainable supply of feedstock. The immediate availability of residue from ongoing operations in almost 40 million acres of commercial southern pine plantations has prompted activity by thermochemical technology companies. Information is needed, however, to create supplemental supplies of tailored feedstock for both thermo- and biochemical processes, and to improve production practices for woody crops and perennial grass alternatives. Increased biomass yield, integrated logistical systems, and improved feedstock performance will ultimately provide greater system efficiencies and better process economics. The successful outcome requires innovative outreach and extension efforts to educate diverse stakeholder groups. With new educational programs under development, a highly qualified workforce will be available to accelerate expansion of this new southern industry.

ACKNOWLEDGEMENTS

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