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Transporting Biomass

An initial techno-economic analysis for the NARA biojet scenario has been completed. With the premise of constructing totally new facilities and current feedstock availability and costs, we estimate the manufacturing cost to produce biojet fuel derived from woody residuals at 2-3 times above the current market price for petrochemical-based jet fuel. Our current efforts are now aimed at reducing this initial cost estimate on many fronts. In the analysis, feedstock cost, handling and transport represents up to 20% of the overall biojet manufacturing costs; opportunities to reduce these costs could significantly reduce the current price gap between petrochemical-based jet fuel and biojet fuel derived from wood residuals.

A recent publication, authored by John Sessions and his team and partially funded by NARA, entitled "*Pricing Forest Biomass for Power Generation*", explores how moisture content in wood residuals contributes to feedstock and transportation costs and provides opportunities for suppliers to improve competitiveness.

The primary audiences for this publication are feedstock suppliers and customers involved with using woody biomass to generate power and heat. For this purpose, burning efficiency increases with lower moisture content, and a premium value is placed on dry biomass material. The paper provides useful data addressing how moisture affects feedstock value and methods used to verify the moisture content in a truckload.

Conversely, for the production of biofuels, woody biomass material is not being burned but converted to biofuels which actually needs water; so the moisture content of woody biomass upon delivery is not as critical in this case as for the bioenergy production industry. Where NARA and the bioenergy industry share interest, however, is the intent to maximize the amount of wood biomass per truckload so that transportation costs are reduced. The following summary addresses this topic.

Moisture And Volume

The paper provides an equation that relates wood moisture content to the volume that can be transported in a typical 48-foot rectangular trailer given that the trailer has a weight maximum:

$$H=[(1-MC)/D*W_g]/(L*w)$$

H is average height of biomass in the trailer (ft), MC is moisture content (decimal percent), D is the dry density of the grindings (lb per ft3), Wg is the green weight of the trailer load (lb), L is length of the trailer (ft), and w is the inside width of the trailer(ft).

As moisture content increases, the height of the load decreases, given that the remaining variables are constant, and the trailer with load is weight limited. A decrease in moisture content allows for greater biomass volume (height); thus reduced moisture content allows for a greater volume of biomass per load.

Reducing Moisture Content

Tables in the paper indicate the average percent moisture content of sapwood and heartwood of common softwoods (moisture content in species can vary two-fold) and the average moisture levels of delivered forest residuals for each month of the year. Recently cut forest residuals can have moisture content above 60% (wet basis). If allowed to field dry, the moisture content can be reduced to below 30%. The paper points out that managing wood residual moisture content is a supply chain challenge dependent on harvest season, storage opportunities and road and equipment capacity.

Increasing Biomass Density

The denser the load, the more cost effective is the transport provided the load is volume limited and not weight limited. As wood residuals are transported, load consolidation occurs and can reduce the total volume by up to 20%. Addressing ways to simulate load consolidation before transport could provide a denser load. The paper also points out that chipped feedstock packs more densely than feedstock that is ground, and use of a blower increases load density over a conveyor system that drops the chips. Chipping opportunities are limited, however, upon the condition of the forest residuals. Rocks and dirt can damage the knives. The paper also notes that load density is affected by species with Douglas-fir chips weighing more per unit volume compared to species with lower specific gravity such as white fir and ponderosa pine.

Further Research

Under NARA, the team lead by John Sessions, first author of the paper and NARA Feedstock Logistics Team Leader, is tasked to develop moisture management strategies and models to be used to determine the best time to haul forest residuals; evaluate chipping and grinding strategies, and work with trailer manufacturers to increase load efficiencies and performance for transporting woody biomass. “Our goal”, says Sessions, “is to increase biomass per trailer load 20% or more above that commonly achieved today”. Published results from these efforts will contribute to reducing the cost of transporting biomass.

Coordinated Agricultural Projects (CAPs)

With 18 affiliated organizations, over 150 personnel and $40 million investment over five years, NARA is a pretty significant undertaking. Yet NARA is just one of six Coordinated Agricultural Projects (CAPs) within the Sustainable Energy challenge area currently funded by the USDA National Institute of Food and Agriculture (NIFA) Agriculture and Food Research Initiative (AFRI). Reprinted below is a excerpt from a statement by Dr. Sonny Ramaswarmy, Director of the National Institute of Food and Agriculture, to the U.S. House of Representatives Subcommittee on Agriculture, Rural Development, Food and Drug Administration, and Related Agencies that defines the intent of the Sustainable Bioenergy CAPs:

AFRI sustainable bioenergy funding will support regional projects that link research for sustainable biomass production, logistics of handling feedstocks for biofuels, and education programs to develop skills needed in the workforce. Ongoing targeted research will focus on enhanced value co-products, crop protection, land-use changes resulting from feedstock production and conversion, implications of the development of bioenergy delivery systems on water, and identification of socioeconomic impacts of biofuels in rural communities in order to enhance sustainable rural economies.

NIFA supports the President’s comprehensive plan to invest in alternative and renewable energy. AFRI is funding six CAPs that focus on the development of regional systems for the sustainable production of advanced biofuels and biobased products from non-food dedicated biomass feedstocks such as perennial grasses, sorghum, energy cane, oilseed crops, and woody biomass. These projects will ultimately enhance national energy security and rural prosperity through bioenergy.

The six AFRI Regional Bioenergy CAPs in Sustainable Energy include:

- System for Advanced Hardwood Biofuels in the Pacific Northwest (AHB-PNW) is led by the University of Washington which is using purpose-grown hardwoods as the feedstock for the production of gasoline and aviation fuel.

- Northwest Advanced Renewables Alliance (NARA): A New Vista for Green Fuels, Chemicals, and Environmentally Preferred Products is led by Washington State University and is working with the region’s forest products industry to convert waste from logging and thinning operations into butanol (compatible with gasoline) and other industrial chemicals.

- Central USA (CenUSA) Agro-ecosystem Approach to Sustainable Biofuels Production Via the Pyrolysis-Biochar Platform is led by Iowa State University and will grow switchgrass and other perennial grasses on marginal lands and buffers bordering traditional row crop production for the production of advanced Biofuels and biobased products.

- Sustainable Bioproduct Initiative (SUBI): A Regional Program for Production of Multiple Agricultural Feedstocks and Processing to Biofuels and Biobased Chemicals led by Louisiana State University is using energy cane and sweet sorghum to produce butanol and other industrial chemicals.

- Southeast Partnership for Integrated Biomass Supply Systems (IBSS) led by the University of Tennessee is using switchgrass and woody biomass to produce butanol and aviation fuel.

- Northeast Woody / Warm-season Biomass Consortium (NEWBio) led by the Pennsylvania State University is using switchgrass Miscanthus and purpose-grown willow to produce advanced biofuels and industrial chemicals.

Cap Interaction

NARA interacts with the other CAP programs in various ways. The NARA Outreach Team distributes quarterly briefings for NARA and AHB-PNW to policymakers in the Pacific Northwest. One such briefing described the distinctions between the two programs. The NARA Outreach Team also holds monthly meetings with Sustainable Energy CAP outreach team members to coordinate messages and share information on how to improve outreach activities. Plans are underway to share stakeholder assessments with other CAP institutions to generate a “National Biomass to Biofuels Stakeholder Assessment” meta-analysis. Both AHB-NW and IBSS representatives showcased their achievements at the 2012 NARA annual meeting.

The Sept. 10-12th, 2013 NARA annual meeting will occur just after the AHB-NW annual meeting at the same location with both CAP programs hosting a joint poster session. All Sustainable Energy CAP program representatives meet annually to share results to report progress to USDA-NIFA. Discussions to coordinate reverse site visits have begun between NARA and NEWBio, the newest CAP, and periodic meetings between Sustainable Energy CAP representatives occur.

Estimating Forest Biomass

Developing improved tools and methods used to estimate the amount of residual biomass potential contained in a softwood plantation or forest is a key task for the NARA project. The amount of forest residues available affects how much biojet fuel and co-products are produced, the location sites for depots and conversion plants and the overall sustainability of the residual wood to biojet fuel industry.

A report, partially funded by NARA and entitled "Estimating Tree Biomass, Carbon, and Nitrogen in Two Vegetation Control Treatments", was recently published and advances knowledge on how softwood biomass growth can best be estimated and how vegetative treatments affect growth. Data in the report was obtained from an 11-year old Douglas-fir tree plantation situated on the Fall River Long-term study site. The report takes on two objectives:

Objective 1: Sample Douglas-fir trees on the site to develop estimates for total-tree aboveground biomass, carbon and nitrogen content with and without competing vegetative control.

Objective 2: Compare biomass estimates obtained in objective 1 with estimates obtained using previously published equations and protocols.

Sampling trees to determine biomass, carbon and nitrogen

All of the trees on this site were planted in the year 2000, In 2011, total height, height to live crown (HLC), diameter at breast height (BDH) and the diameter at 15 cm above ground (D15) measurements were either directly taken or extrapolated from 2010 measurements.

In March following the year-11 growing season, 26 trees (24 randomly selected and two chosen with mean dimensions) were destructively sampled to create equations for estimating tree biomass. Destructive sampling involved falling the tree, drying and weighing the bole (trunk), branch and foliar segments and determining the carbon and nitrogen content of each segment.

By correlating individual tree measurements with their biomass weight, carbon and nitrogen content, equations were generated that allow total aboveground biomass, carbon and nitrogen estimates on a per-hectare basis for the site.

The effects of vegetation control

Of the 26 trees sampled, half were in an area that received five years of competing vegetative control and half received no vegetative control. Per-hectare biomass was over 20% higher where vegetative control took place. Vegetation control had no significant effect on the relationship between DBH and biomass, however, indicating the robustness of the equation for use on stands with or without vegetative control. Nitrogen and carbon amounts were proportional to total biomass and were not apparently affected by vegetative control treatments.

Comparing published equations with sampling results

Eight published equations that related DBH to total-tree biomass were applied to the study site and the resulting biomass calculations were compared to the biomass results generated in this study. Total-tree estimates generated from the previous reports varied from 8 to 23 percent from the site-specific biomass equation estimates. These results show the error range possible of applying previous equations developed from off-site forests to determine biomass estimates.

Comparing the "mean tree method" with sampling results

The authors then compared their destructive sampling biomass estimates to an estimate obtained using the mean tree method. This comparison relied on destructively sampling a single tree on site that had a mean DBH value to the surrounding trees. The remaining biomass on the site was then calculated using the slope established from a previously published equation. This method over estimated the site biomass by 19.2 %. The authors suggest that the mean tree selected in this study deviated significantly from the DBH-biomass regression line in the published equation and that more than one mean tree should be sampled for more accurate results.

Additional biomass calculation models

This study is part of a coordinated effort to provide superior biomass estimate equations. NARA researcher Doug Maquire and his team at Oregon State University are conducting a more expansive sampling project covering a wide range of trees varying in age and size. The sampling for this study is over 80% complete and results should be communicated soon.

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