NARA
Northwest Advanced Renewables Alliance

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IDX students and mentors touring Weyerhaeuser's Longview facility

Forest residual-to-biofuel facility site analysis available for WA and OR

NARA is tasked with helping U.S. Northwest stakeholders identify depot and biorefinery site locations suitable for a developing industry that uses forest residuals to produce bio-jet fuel and valued co-products. To do this, undergraduate/graduate students in the Integrated Design Experience (IDX) course at Washington State University rank prospective sites based on information generated through NARA research and from open sources.

The approach has been to focus the analysis on sub-regions with NARA's four state region of Idaho, Montana, Oregon and Washington and conclude with a supply chain analysis for the entire region available in 2016. Sub-regional analyses have been completed for the Clearwater Basin and the Western Montana Corridor (which includes portions of eastern Washington and northern Idaho).

The IDX team recently posted a facility site analysis for the Mid-Cascade-to Pacific (MC2P) region that includes northern Oregon and southern Washington.

View Mid-Cascade to Pacific Corridor | Analysis here.

Solids and Liquids Depots

The IDX course considered multiple facility types for the MC2P analysis that could support a centralized integrated biorefinery. These facility types include solids and liquids depots plus distillation and distribution centers. Whereas an integrated biorefinery can be designed to accommodate all of the processing steps from receiving forest residuals through to biojet production, a distributed production model using strategically located depots may prove more economical by lowering overall transportation costs, improving access to feedstocks, and potentially allowing the use of existing yet underutilized facilities.

A solids depot would receive raw slash from logging and thinning operations, and/or construction and demolition waste biomass, and mechanically processes the feedstock for economical transport by rail or highway truck.

A liquids depot receives ground forest residuals directly from nearby forests, or from a solids depot, and processes it to make a sugar-rich syrup. The syrup is then shipped to an integrated biorefinery or distillation and distribution operation for further refining into biojet fuel or other chemicals.

A distillation and distribution facility receives liquid sugars from a liquids depot and produces biojet fuel with fermentation, blending and distribution operations.

Facility sites identified and ranked

The IDX course identified existing facilities in the MC2P region that could potentially accommodate the role of one or more facility type. These existing facilities included active and decommissioned saw and chip mills, pulp and paper mills and surface mines. The facilities were provided a rank score based upon how well they satisfied certain criteria for a specific facility type (solids depot, liquid depot, distillation and distribution, and integrated biorefinery). For instance, the criteria assigned for solids depots included the average distance to forest residuals, rail option, river access and electrical cost. Fourteen active sites and nine non-active sites were ranked for solid depots with Sierra Pacific Industries identified as the best positioned active facility to participate as a solids depot based on the analysis. A more extensive criteria list was applied to potential liquids, distillation and distribution, and integrated biorefinery sites.

Stakeholder and educational benefits

The analysis introduces a method used to rank facilities for various production roles within the wood-residual-to-biojet supply chain. The IDX course is working with some of these high-ranking facilities to provide conceptual master plans and building designs. These results will be posted on the NARA MC2P webpage soon. The IDX students recently shared their work with stakeholders in a webinar format.

The IDX course is composed of graduate and undergraduate students focused on varied academic disciplines ranging form chemical engineering to law.

The work they are doing to provide site analyses and describe the assets with the Northwest U.S provides valuable data to stakeholders and valuable experience to prepare them to contribute to developing a bioenergy economy.

Washington State University graduate student and NARA researcher Ross Wickham measuring streambed particles.

Webinars highlight NARA's environmental sustainability research

NARA's Education Team partners with high school teachers in Idaho, Oregon, Washington and Montana to help them prepare student teams to participate in the Imagine Tomorrow competition. This partnership encourages new high school teams to enter the event and helps transfer NARA research to high school teachers so that the research can be incorporated into the classroom curricula.

Webinars are one method used to transfer NARA research to high school teachers, the Imagine Tomorrow teams, and to a general audience. The University of Idaho's McCall Outdoor Science School (MOSS), a NARA affiliate, coordinates the webinar series and post them on their website. These webinars allow NARA researchers to communicate their findings to a high school audience, and offer an opportunity for the general public to learn about varied aspects of the NARA project.

Visit MOSS's webinar archive here.

Recently, two webinars were recorded that highlight NARA's research to evaluate the environmental sustainability of using forest residuals from logging operations to make bio-based chemical products like biojet fuel.

NARA's long-term soil productivity site

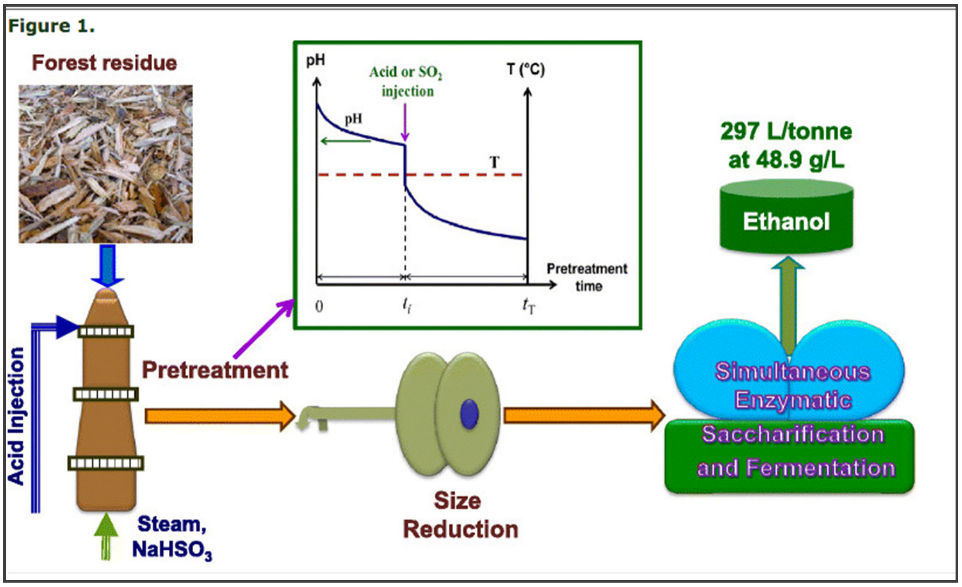
Interested in knowing how removing forest residuals affect forest ecosystems? In the third webinar for the 2014-15 series, NARA researcher Scott Holub describes the work being done at the NARA Long-Term Soil Productivity site (LTSP) in southern Oregon and preliminary data obtained from a 15 year LTSP site at Fall River in Washington. These sites are designed to measure how soil nutrient levels and tree growth productivity are impacted from processing and removing varied amounts of forest residuals from a working forest. The NARA LTSP site also includes experiments to measure the impact to soil moisture levels, soil microbial populations and wildlife.

Forest residual impact on stream channels

In the fourth webinar for the 2014-15 series, NARA researcher John Petrie provides an overview of how forest practices affect streams and describes how his team is measuring the effects of forest residual removal on streamflow and sediment levels. Their work will help establish improved models used to predict how varied forest practices impact streams.

An informative resource for everyone

The webinar site also hosts presentations given last year that cover other NARA research projects such as developing a life cycle assessment that compares the CO_2 emissions generated from producing forest residual-based products to petrochemical-based products. Other webinars explore commercial uses for lignin and establishing a supply chain for producing biojet fuel from wood residuals. These webinars are targeted to a high school level audience and provide an excellent opportunity to learn about the issues and impacts connected to using forest residuals to make chemical products and the research provided by NARA.



Flow diagram of experiment in Cheng et al. Biotechnology for Biofuels 2015 8:22

Improving simple sugar production from forest residuals

Up to 75% of wood is made of simple sugars. For the NARA project, these simple sugars are the molecules used to make biojet fuel. Even though simple sugars are abundant in wood, making them available for further processing into alcohols and biojet fuel is a challenge. The simple sugars are bound together as polymers, and these polymers bind to other molecules to form lignocellulose, which does not break apart easily.

Energy and reactive chemicals are required to break apart lignocellulose in order to expose the simple sugar polymers. This process is called pretreatment, and the more efficient the pretreatment, the higher sugar yield, however, there is a catch. The trick is that as more energy and harsher conditions are applied, simple sugars degrade, and molecules termed "inhibitors" are formed that can interfere with the downstream processes that release the simple sugars (enzymatic hydrolysis) and convert them to alcohols (fermentation).

In order to increase the efficiency of pretreatment, while keeping the level of sugar degradation and inhibitor formation low, researchers at NARA's affiliate USDA Forest Service, Forest Products Laboratory and their colleagues investigated how the timing of pH levels impact sugar degradation, inhibitor formation and pretreatment efficiency. There work, which was partially funded by the USDA-NIFA through NARA, was recently published in the journal Biotechnology for Biofuels.

> View High titer and yield ethanol production from undetoxified whole slurry of Douglas-fir forest residue using pH profiling in SPORL here.

The effects of pH on pretreatment

The authors compared the simple sugar, lignin and inhibitor yields from Douglas-fir residuals using four sulfite-based pretreatment experiments that differed due to the timing of sulfuric acid introduced. Recall from chemistry classes that the pH of a solution is lowered when acid is added. One experiment introduced acid at the beginning of the pretreatment process and provided a baseline condition. The other three experiments had acid introduced at varied times (25, 35 and 45 minutes) during pretreatment.

The experiments show that acid injections made after 25 minutes into the pretreatment process could reduce inhibitor levels by up to 70%. The acid treatment improved lignin removal and decreased hemicellulose removal resulting in enzymatic efficiency (the ability for enzymes to remove simple sugars) that was similar to the pretreatment without acid injection.

The reduced inhibitor levels due to acid injections resulted in more simple sugars available to the fermentation yeast. As they consumed more simple sugars, they produced higher ethanol concentrations. The reduced inhibitor levels also allowed for a higher concentration of pretreated material (over 35%) to be loaded for fermentation without an additional detoxification step. Loading higher concentrations of pretreated material for fermentation provides higher ethanol concentrations and uses less water.

Improving conversion economics

Discovering ways to lower the cost and increase efficiencies of processing forest residuals into chemical products like biojet fuel is a central component to the NARA project. The results published in this paper show how the timing of pH adjustments to sulfite-based pretreatment can reduce inhibitor formation and improve simple sugar yields. These improvements can lead to cost savings as they are relatively inexpensive to implement and allow pretreatment facilities to feed a higher concentration of pretreated material to downstream processes without the need to detoxify the pretreated material.

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