

NARA's Cumulative Report Now Available

NARA's second Cumulative Report is now available online. This report describes research efforts and activities conducted between April 2013 through March 2014.

View the [NARA Cumulative Report: April 2013-March 2014](#)

Progress reports are sectioned within the Project's five goals: [Sustainable Biojet](#), [Value Lignin Co-Products](#), [Rural Economic Development](#), [Supply Chain Coalitions](#), and [Bioenergy Literacy](#).

Significant Year-Three findings are summarized in the [Strategic Analysis](#) and [Executive Summary](#).

Future Direction

With a preferred conversion pathway now selected, Year-Four efforts will focus squarely on commercialization. Efforts to lower feedstock costs will continue by building on successes in lowering grinding energy, improving feedstock densification in chip vans and modeling transportation logistics. NARA's pretreatment and conversion teams will continue increasing scale of production, focusing strongly on refining processing parameters so that commercial validation of 1000-gallons of jet fuel in Year-Five can be achieved. The techno-economic analysis team will assess the retrofit of existing facilities operated by NARA's regional

partners. NARA's outreach and education teams will evaluate the entire NARA four-state region for additional retrofit opportunities and evaluate more closely the development of a distributed sugar production model using micronized wood milling.

In addition to the commercialization efforts, models and analyses used to assess the economic, environmental and social sustainability of creating petrochemical substitutes from forest residuals will be further refined. Activities to build bioenergy literacy among students and professionals will continue with improved assessments to measure learning and application success.

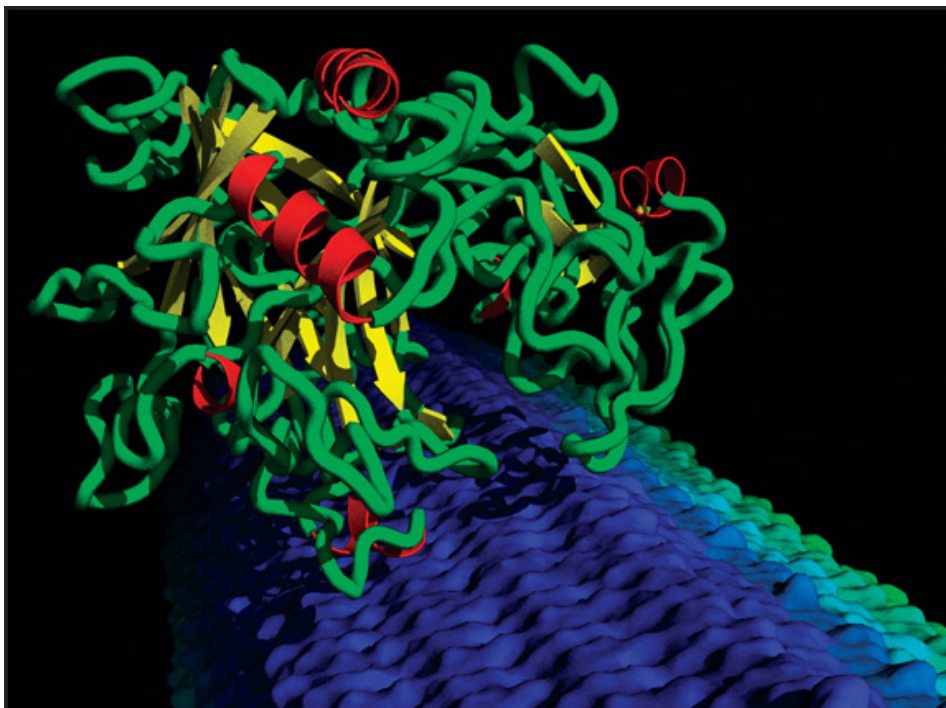


Illustration of cellulase enzyme on cellulose. Courtesy of Oak Ridge National Laboratory

Finding Ways to Improve Cellulase Activity

NARA investigates conversion technologies that rely on enzymes called [cellulases](#). Cellulases break down the [cellulose](#) and hemicellulose polymers found in wood and release simple sugars. The simple sugars can then be used to make isobutanol and other valued chemical products.

Recently, it was observed that cellulases work better when [lignosulfonates](#) are present (Wang et al. 2013; Zhou et al, 2013). These findings are interesting because before the cellulase enzyme can begin cleaving off simple sugars, the lignin around the cellulase needs to be partially removed through a process called pretreatment; however, adding sulfonated lignin to the reaction makes the cellulase enzyme work better.

To better understand this relationship, NARA researcher [J.Y. Zhu](#) and his team investigated the interaction of lignin, cellulose and cellulase and published their results in *Understanding the effects of lignosulfonates on enzyme saccharification of pure cellulose*.

Read [Understanding the effects of lignosulfonates on enzyme saccharification of pure cellulose](#)

Effect on Cellulase Depends on Lignosulfonate Concentration

First, they wanted to know how much lignosulfonate was needed to affect the cellulase activity. Here they discovered that under very dilute concentrations of lignosulfonates, cellulase activity actually decreased. As lignosulfonate concentrations increased, cellulase activity was enhanced.

So what is going on? The authors suggest that lignosulfonates can bind to cellulases and interfere with their ability to perform their cleaving function. This explains how low concentrations of lignosulfonates inhibit cellulase activity. At higher concentrations, however, the authors suggest that lignosulfonates act as a [surfactant](#). They bind to the cellulase to

help stabilize the enzyme and enhance its binding to the cellulose. Adding 5 grams/liter of lignosulfonates increased enzyme efficiency by 20%.

Lignosulfonates Act as a Surfactant

To verify this conclusion, they evaluate how different sized lignosulfonates, number of sulfur groups attached to the lignin, ionic strength and pH affect cellulase activity. The results from these experiments reinforced the surfactant theory and suggest that smaller lignosulfonates with high amounts of sulfonation work best.

Lignosulfonates have traditionally been used as surfactants to bind dust, condition soil, and disperse concrete. Their use to enhance cellulase activity is appealing because lignosulfonates are relatively inexpensive, abundant, and they are a byproduct of the [sulfite-based pretreatment strategy](#) proposed for the conversion of forest residuals to biojet fuel.

References

Wang Z, Zhu JY, Fu Y, Qin M, Shao Z, Jiang J, Yang F (2013) Lignosulfonate-mediated cellulase adsorption: enhanced enzymatic saccharification of lignocellulose through weakening nonproductive binding to lignin. *Biotechnol Biofuels* 6:156

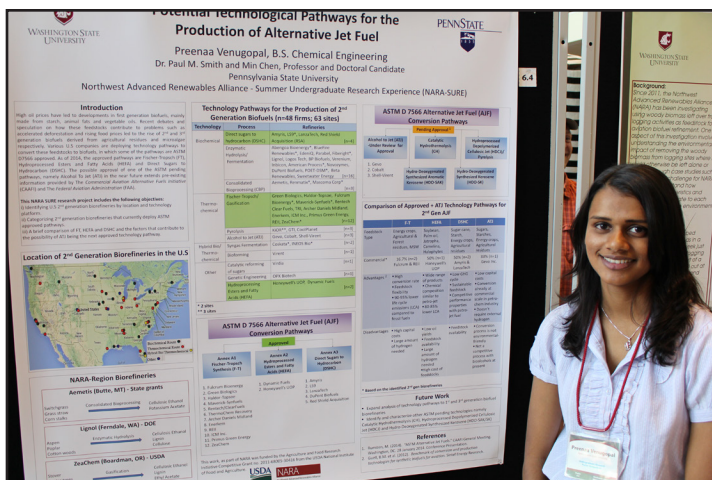
Zhou H, Lou H, Yang D, Zhu JY, Qiu X (2013) Lignosulfonate to enhance enzymatic saccharification of lignocelluloses: Role of molecular weight and substrate lignin. *Ind Eng Chem Res* 52(25):8464–8470

Undergraduate interns contribute to NARA

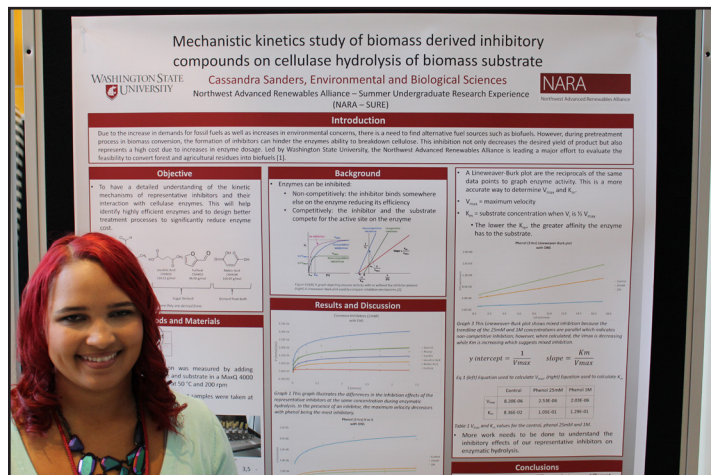
NARA funds educational opportunities for students at all levels — grade school through college graduate. For the past three years, NARA has provided summer research internships to college undergraduates through the NARA SURE program. [SURE](#) (Summer Undergraduate Research Experience) is a program coordinated by Washington State University that provides research internships to undergraduate students throughout the United States and is funded by multiple organizations including NARA.

For the summer of 2014, NARA funded five undergraduate students to conduct research applicable to the NARA project. Listed below are student profiles and a summary of their contribution.

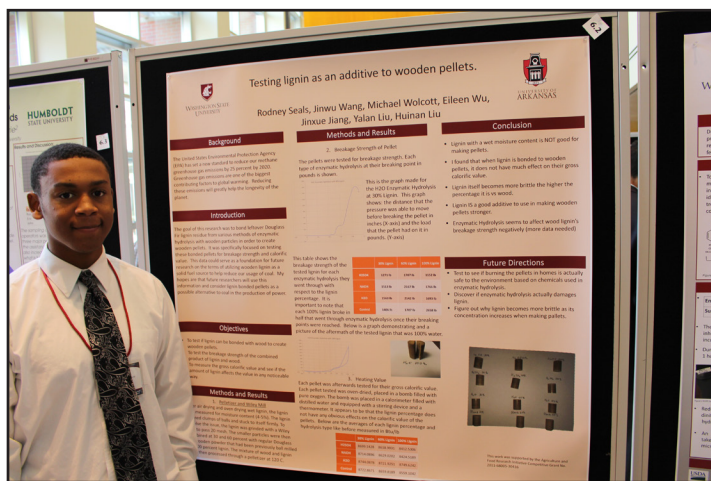
NARA SURE Students



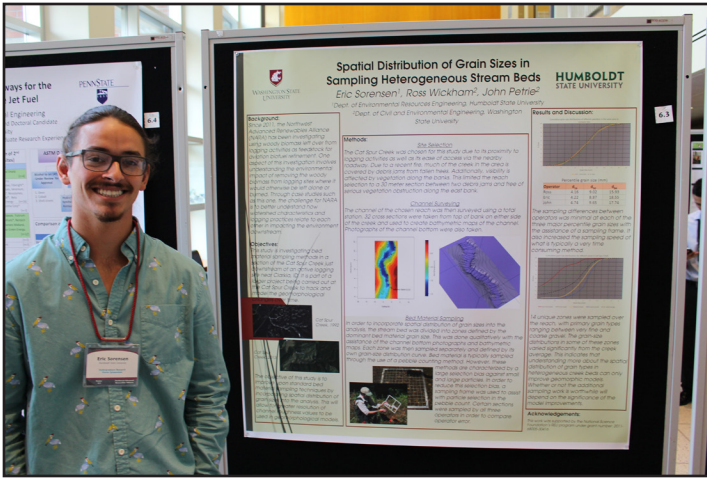
Preenaa Venugopal is a senior at Penn State University majoring in chemical engineering. She collaborated with NARA researcher [Paul Smith](#) to present an analysis that characterized second-generation biofuel refineries in the United States and the conversion technologies employed. Second-generation biofuels are typically produced from agricultural residues like forest residuals. This work builds on NARA's efforts to better understand the supply chain partnerships and value propositions for competitive renewable chemicals. Preenaa will continue working with Dr. Smith during her senior year to expand their analysis to third-generation biofuels.



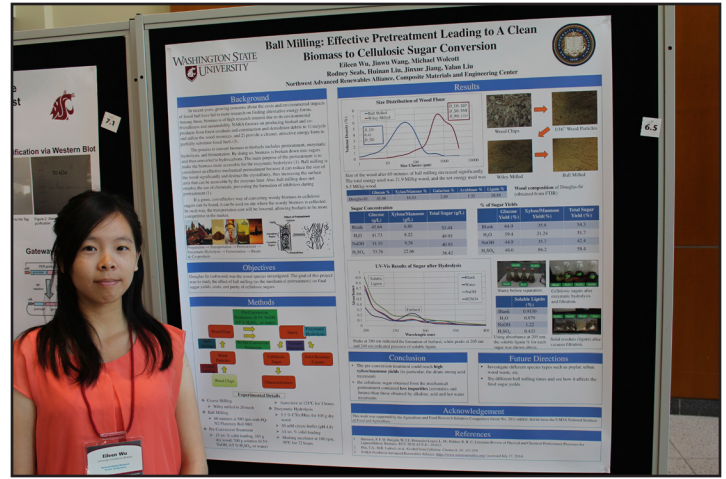
Cassandra Sanders is a senior at Washington State University-Tri Cities finishing a double major in environmental sciences and biology. She joined with NARA researcher [Xiao Zhang](#) to study how certain chemicals inhibit the activity of cellulase: an enzyme responsible for cleaving simple sugars from cellulose. Cellulase inhibition can dramatically decrease the sugar yields from forest residues and her work will support NARA's efforts to improve process design for biomass conversion.



Rodney Seals just began his freshman year at the University of Arkansas at Fayetteville as a chemical engineering student. He worked with NARA researcher [Jinwu Wang](#) to engineer pellets made from the lignin rich residues remaining after simple sugars are removed from forest residuals. Developing valuable products like pellets from the lignin material will contribute significantly to the economic sustainability of a wood residual to bio-jet industry. These pellets can be used to generate heat or electricity, and Rodney tested them for strength and caloric value.



Eric Sorensen is a senior at Humboldt State University majoring in environmental resources engineering. He teamed up with NARA researcher [John Petrie](#) to develop a new and improved method to measure and quantify sediment in streams. His work provides a more comprehensive sampling method used to determine how forest slash removal will affect streambeds.



Eileen Wu is a sophomore at the University of California Berkeley majoring in chemical engineering. She worked in [Michael Wolcott's](#) lab investigating methods used to derive sugar yields from milled wood. Milled wood technology could be a good fit for a distributed sugar model in the Pacific Northwest. Her work contributes towards NARA's efforts to find economical solutions to generating simple sugars from wood slash.

Student Recruitment

Equal number of males and females applied and the ethnicities represented were 37% Caucasian, 31% Asian/Pacific Islander, 12% African American, 6% Hispanic, 6% Native American. This year's recruiting efforts through educational websites and direct mailing to universities was successful. Fifty-two applicants applied for the 2014 NARA-SURE program. Thirty-eight applied in 2013. Selected students work for ten weeks and are provided a \$5000 stipend plus housing assistance.

Although the applicant number was higher compared to previous years, finding qualified applicants for the available tasks was a challenge. Only five students were selected. Increased efforts will be given to find multiple projects and mentors to accommodate the student interest in the NARA SURE program.

View [additional information about the NARA SURE program.](#)

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