NARA
Northwest Advanced Renewables Alliance

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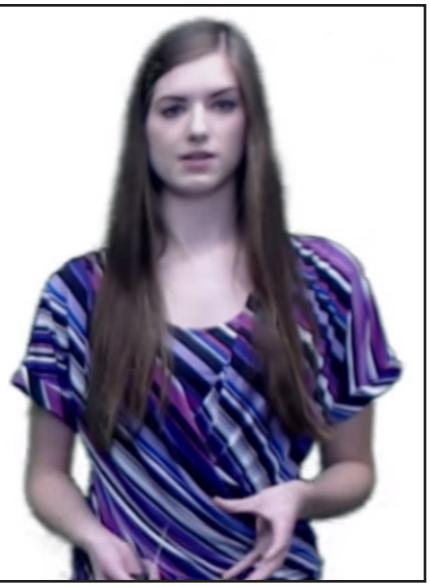
TYPE OF FACILITY SCORE DETERMINATION

Capital Cost ($MM)		Sulfite Mill	Kraft Mill	Ethanol Plant	Oil Refinery	Petroleum Terminal	Chipping Mill	Thermo-Mechanical Pulping	Saw Mill
Feedstock Handling	$70.0	100%	100%	0%	0%	0%	100%	100%	100%
Pretreatment	$200.0	100%	50%	0%	0%	0%	0%	50%	0%
Enzymatic Hydrolysis	$59.0	0%	0%	50%	0%	0%	0%	0%	0%
Fermentation and Separation	$99.0	50%	0%	50%	25%	0%	0%	0%	0%
Alcohol to Jet Refining	$118.0	50%	0%	50%	100%	0%	0%	0%	0%
Blending/Storage/Distribution	$48.0	0%	0%	100%	100%	100%	0%	0%	0%
Boiler	$0.0	0%	0%	0%	0%	0%	0%	0%	0%
Utilities Infrastructure	$11.0	100%	100%	100%	100%	100%	25%	100%	25%
Site Development	$49.0	100%	100%	100%	100%	100%	50%	100%	50%
Land	$5.0	100%	100%	100%	100%	100%	100%	100%	100%
Warehouse	$22.0	100%	100%	100%	100%	100%	100%	100%	100%
Working Capital	$20.0	100%	100%	100%	100%	100%	100%	100%	100%
Additional Piping	$25.0	100%	100%	100%	100%	100%	0%	100%	0%
Total Saved ($MM) IBR	$726.0	$510.50	$302.00	$318.00	$322.75	$180.00	$144.25	$302.00	$144.25
Total Saved ($MM) Solids	$177.0	$177.00	$177.00	$107.00	$107.00	$107.00	$144.25	$177.00	$144.25
Total Saved ($MM) Liquids	$461.0	$402.00	$302.00	$161.50	$132.00	$132.00	$144.25	$302.00	$144.25
Total Saved ($MM) Conversion	$397.0	$240.50	$132.00	$288.50	$322.75	$180.00	$74.25	$132.00	$74.25
Percentage of total (IBR)		70.32%	41.60%	43.80%	44.46%	24.79%	19.87%	41.60%	28.26%
Percentage of total (Solids)		100.00%	100.00%	60.45%	60.45%	60.45%	81.50%	100.00%	81.50%
Percentage of total (Liquids)		87.20%	65.51%	35.03%	28.63%	28.63%	31.29%	65.51%	31.29%
Percentage of total (Depot)		60.58%	33.25%	72.67%	81.30%	45.34%	18.70%	33.25%	18.70%
IBR Score	5	5.00	2.96	3.11	3.16	1.76	1.41	2.96	2.01



Sydnee Dieckman, a graduate student studying civil engineering at Washington State University, was one of nine student presenters in the IDX webinar.

Ranking potential biorefinery and depot sites for a wood to biofuel supply chain

Here is a challenging class room assignment: map out where you would process slash piles from forest harvest into valuable chemical products and justify your answer. Where to begin?

First you would need to know where the slash piles are, the amount available annually, and have an understanding of the technology available to convert them into chemical products. Second, you would have to understand the transportation options available for the region. Finally, in order to "justify" your answer, you would want to include an economically and socially sustainable reasoning for your selection. Oh, and the final classroom requirement is to make your information relevant to the business community and to NARA.

This was the assignment given to the Integrated Design Studio (IDX) course at Washington State University. The IDX course focuses on real projects that require multiple disciplines and involves undergraduate and graduate students from Washington State University and the University of Idaho. They recently presented their findings in a webinar that is available for public viewing.

The Nov. 19th IDX webinar can be viewed here.

Ranking facility types

Students in IDX's 2014 fall semester worked in teams and focused on four facility types: solids depot, liquids depot, conversion facility and integrated biorefinery. The solids, liquid and conversion facilities are envisioned to handle a specific conversion process within the supply chain for converting forest residuals into biojet fuel. For instance, a solids depot is designed to store and process forest residuals for transport to a conversion facility. An integrated biorefinery would accommodate all processes from handling the forest residuals to producing biojet fuel and other products.

In the webinar, the students describe each of these facility types and their requirements. They then illustrate how the facility sites in Oregon and Washington were ranked for each facility type based a variety of weighted factors including biomass availability, existing facilities, transportation access, utility costs, social acceptance and labor costs. The webinar concludes with a listing of recommended facility sites for each facility type.

Regional stakeholders involved with the NARA project were invited to the webinar, and over 40 persons attended. During he webinar, many of the viewers had questions and comments. Some had expertise or information that was offered for the analysis. Others expressed an interest to use the methodology of this analysis for site selection projects in regions outside of the Pacific Northwest. Questions covered environmental permits to facility sites in other states like Idaho and Montana.

The methodology used to rank the facility sites was unique, particularly regarding how siting factors were weighted and the use of social acceptability ranking methods being developed by NARA researchers.

Future work

Most of the students from this past semester will return to the IDX coarse in the Spring 2015 semester. Then the group will extend their analysis to other areas in the WA, OR, ID, and MT region. In addition,

they will provide feasibility analyses and design concepts for high-ranking facility sites that can be modified to contribute to a wood residual to biojet supply chain. Plus, the group will extend their siting analyses to tribal lands that offer unique opportunities for funding and product contracting.

"These students perform critical data gathering and analyses for the NARA project", says Tammi Laninga, one of three IDX course instructors and member of NARA's Education Team. "Their work will be incorporated into a final supply chain analysis that covers Washington, Oregon, Idaho and Montana". Much of this work will be presented on the NARA website that covers the Mid-Cascade to Pacific (MC2P) project.

The 2013-2014 IDX course performed a similar site selection analysis for a region in western Montana, northern Idaho and eastern Washington called the Western Montana Corridor (WMC) project.

Fall 2014 IDX | PNW

Top Sites

Liquid Depot

Site	Location	Score	Rank
Kapstone Craft Paper Corp.	Longview, WA	58.2	1
Weyerhaeuser (NORPAC)	Longview, WA	55.0	2
Cosmo Specialty Fibers	Cosmopolis, WA	50.0	3
Simpson Tacoma Kraft Co., LLC	Tacoma, WA	47.2	4
Anderson Shake and Shingle	Cathlamet, WA	46.6	5

Solid Depot

Site	Location	Score	Rank
Weyerhaeuser (Longview Timber)	Longview, WA	82.2	1
Anderson Shake and Shingle	Cathlamet, WA	81.0	2
Stimson Lumber Co.	Clatskanie, OR	73.9	3
RSG Forest Products	Mist. OR	72.9	4
Kapstone Craft Paper Corp.	Longview, WA	58.2	5
Weyerhaeuser (NORPAC)	Longview, WA	56.4	6

Conversion Facility

Site	Location	Score	Rank
Weyerhaeuser (Longview Timber)	Longview, WA	74.9	1
Stimson Lumber Company	Clatskanie, OR	62.3	2
Kapstone Craft Paper Corp.	Longview, WA	60.9	3
Weyerhaeuser (NORPAC)	Longview, WA	58.7	4
RSG Forest Products	Mist, OR	56.4	5

Integrated Biorefinery

Site	Location	Score	Rank
Weyerhaeuser (Longview Timber)	Longview, WA	66.0	1
Kapstone Craft Paper Corp.	Longview, WA	63.3	2
Weyerhaeuser (NORPAC)	Longview, WA	59.2	3
Stimson Lumber Co.	Clatskanie, OR	55.2	4
Simpson Tacoma Kraft Co., LLC	Tacoma, WA	52.1	5
RSG Forest Products	Mist, OR	50.8	6

Presentation slide from the IDX Nov. 19th webinar ranking recommended sites for four different facility types in the NARA MC2P region.

Information regarding the developing Mid-Cascades to Pacific (MC2P) analysis can be viewed here.

Information regarding the Western Montana Corridor (WMC) analysis can be viewed here.

Cody Sifford (Navajo) (at left) and Clarence Smith (Blackfeet), both 2014 NARA TPP summer interns, placed 2nd and 1st respectively for graduate student posters at the 2014 American Indian Science & Engineering Society (AISES) conference.

NARA and Pacific Northwest Tribes

NARA's Tribal Projects Program (TPP) contributes to multiple NARA project goals. First, it provides relevant research experience to Native American college students. Second, the technical assistance efforts are designed collaboratively with the tribe to assess economic opportunities related to tribally sourced woody biomass. At its core, this program is establishing a national model for collaborative research between university partners and tribal communities so that tribes have the people and information needed to participate in the emerging bioenergy marketplace in a manner that meets their environmental, cultural and economic needs.

Educational opportunities

Thirty-nine percent of Native American students who started college in 2005 graduated. This graduation rate is significantly lower than the 60% of white students who graduated during the same time period (Knapp, Kelly-Reid, and Grinder, 2012). To help make up this deficiency, NARA funds efforts to recruit and retain Native American students at the college level.

NARA's TPP program is a graduate level program that also connects graduate students with undergraduates to ensure a strong pipeline of students for graduate education. The program funds a mix of summer internships and graduate degrees. To date, the TPP program has supported seven undergraduate and seven graduate students. Seven students in the TPP program will have completed their undergraduate or graduate degrees by

December 2014; 6 of them tribal scholars.

"We just came out of a great summer where six interns with tribal affiliation worked on NARA TPP projects, across the Northwest" said Laurel James, program manager for the NARA Tribal Partnership programs. "The number of graduate students with a tribal affiliation is low, across all disciplines and NARA is helping increase those numbers."

Three TPP undergraduate interns attended the Salish Kootenai College (SKC), a NARA affiliate organization, while a fourth student evolved out of Southwest Indian Polytechnic Institute (SIPI). SKC works with NARA to funnel tribal students to opportunities like TPP and the NARA SURE program.

Here is a list of some of the tribal students and a brief description of their work:

Breanna Gervais (Penobscot) attends Portland State University as an undergraduate. Her primary task for the NARA TPP program was to explore the regional tribal assets related to biomass infrastructure and development. Her report formed the basis for a 35-page report that documents biomass interest and operations by region and tribe. She shared her work at the 38th Annual National Indian Timber Symposium in June 2014 at Coeur d'Alene. Breanna also worked with the NARA Life Cycle Assessment (LCA) team to develop a LCA for woody feedstock collected from Tribal forests. "My professional experiences for the past few years have been based around traditional ecological knowledge, biomass and forestry policy", says Breanna, "this project has allowed me to stay connected to the Native American natural resource community in a research capacity." Breanna is a member of the Penobscot Nation.

Burdette Birdinground (Crow) recently completed his bachelor's degree in environmental science at Salish Kootenai College and now attends the University of Washington as a graduate student in the School of Environmental and Forest Sciences. His graduate work is targeted towards improving prediction models for forest growth. He will continue to contribute to NARA by developing models to gage the amount of residual biomass generated from federal lands that are under stewardship agreements with the Confederated Salish Kootenai Tribes. Burdette is a member of the Crow Tribe.

Cody Sifford (Navajo) obtained a bachelor's degree in environmental science from Salish Kootenai College and now attends the University of Washington as a graduate student in the School of Environmental and Forest Sciences. His work investigates air pollution associated with slash pile burning. The results from his work inform forest management departments about the amount of smoke particulates reaching communities. Cody recently attended the 2014 American Indian Science and Engineering Society (AISES) conference in Orlando Florida to present his research co-sponsored by NARA and his USDA National Needs Fellowship and he placed 2nd in the graduate student poster category. Cody is a member of the Navajo Nation.

View Cody's poster *Developing an Impact Assessment of Local Air Quality as a Result of Biomass Burns*

Shawn Defrance (CSKT) completed his bachelor's degree in forest resources at Salish Kootenai College. His work measures the effectiveness of prescribed burn treatments. This data will network with multiple tribal agencies and allow managers to share and analyze the effectiveness of their management practices to reduce catastrophic fire events. Shawn is a member of the Confederated Salish and Kootenai Tribes

Calvin Silas (Navajo) completed his AAS in pre-engineering at Southwest Indian Polytechnic Institute (SIPI), a tribal college in Albuquerque, NM. Calvin joined NARA after graduating from SIPI and after receiving Academic All-American honors from the Governor of the State of New Mexico. That award provided Calvin a fellowship that is allowing him to continue to work towards his bachelor's degree in mechanical engineering at New Mexico State University (NMSU). Initially, Calvin was a NARA SURE intern at Washington State University (WSU). He then received additional training in mechanical engineering as a part of the TPP at the University of Washington (UW). Calvin has been invited to return as a summer intern at either WSU or UW in 2015. Calvin is a member of the Navajo Nation.

View Calvin's Poster *Nanocellulose reinforcement for bio-based phenolic thermo-responsive resins*

Partnerships with tribal landowners
The NARA TPP works to benefit Pacific Northwest tribes by collaborating to define, research, and assess a technical problem that is deemed a tribal priority for ecologic or economic development purposes.

The top tribal timber landowners in the Pacific Northwest are the Colville (660,000 acres), Yakama (449,000 acres), Salish and Kootenai (300,000 acres), Warm Springs (256,000 acres) and Quinault (174,000). The NARA TPP recently completed a project with the Confederated Salish and Kootenai Tribes (CSKT). After a period of review and comment, a final report was completed and sent to the Tribe in June 2014. The TPP's work helped define the total amount of biomass available for bioenergy use based upon the Tribe's 10-year management plan. The CSKT used TPP project work as a basis for the next level of biomass assessment and engineering combined heat and power design work funded through a major DOE Tribal Energy Program grant.

View *Biomass Supply Estimates for the Confederated Salish and Kootenai Tribes Based on Harvest Planning and Management Goals*

A second project has been initiated that will evaluate the forest inventories and management in federal lands that are adjacent to the CSKT reservation. Federal policy authorizes tribes to carry out sound forest management on adjacent federal lands as a way to protect their reservation forestlands (Tribal Forest Protection Act). Stewardship contracting is the financial mechanism used for this program. The Confederated Salish and Kootenai Tribes are one of the few Indian Nations with active stewardship contracts for the adjacent federal forestlands. How these stewardship contracts impact the health of the CSKT lands is unknown. This work will offer a regional assessment of biomass availability within the Tribes' hazardous fuel corridor, and will explore the intersection of competing federal laws on the value of biomass from the reservation vs. biomass from the

adjacent federal lands.

A third project is exploring the potential environmental impact of using distributed sugar depots as intermediate processors for a regional biofuel supply chain. An often overlooked emission source in biofuel processing comes from the extractive compounds, which account for nearly 10% of the dry mass of Douglas-fir. This program evaluates a fairly comprehensive inventory of Douglas-fir extractives and their potential chemical conversion when processed using mild bisulfite pretreatment. An Aspen process simulation model is used to account for extractive-based air emissions, water emissions, and sugar impurities. Results from this project will complement NARA's work to evaluate the role of sugar depots in a developing supply chain, and will inform communities regarding the expected emissions.

> View the poster *Tribal Communities Care About Effluents: Tracking Extractives, Inhibitors & reaction Products in Bisulfite Processing*

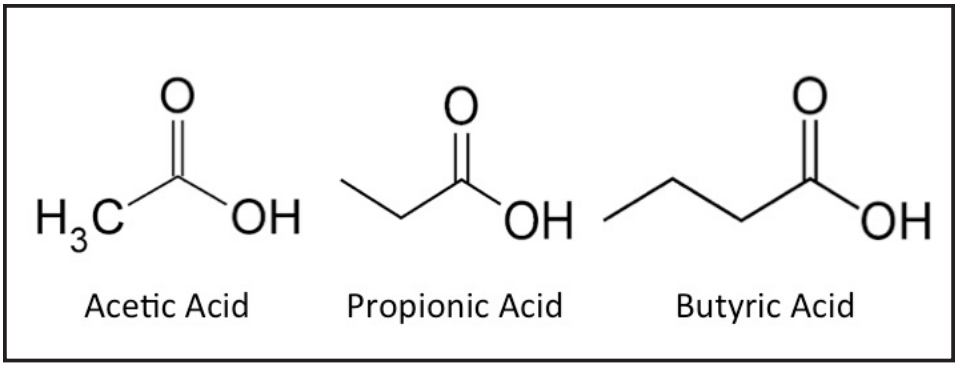
TPP impacts NARA at multiple levels

Laurel James works with tribes to determine where gaps are in their knowledge and how NARA research can fill the void. At every step, NARA TPP provides education and new information to the tribal community, tribal leadership, government officials and tribal scientists. Through this process, NARA TPP also contributes data and outreach activities that supplement NARA's goals on bioenergy literacy, rural economic development and establishing supply chain coalitions. Laurel recently provided an oral presentation about the NARA TPP at the NARA annual meeting in Seattle.

> View Laurel James' presentation *Education and Tribes in the Pacific Northwest*

Reference

Knapp, L.G., Kelly-Reid, J.E., and Ginder, S.A. (2012). Enrollment in Postsecondary Institutions, Fall 2011; Financial Statistics, Fiscal Year 2011; and Graduation Rates, Selected Cohorts, 2003–2008: First Look (Provisional Data) (NCES 2012-174rev). U.S. Department of Education. Washington, DC: National Center for Education Statistics. Retrieved Nov. 5th from http://nces.ed.gov/pubsearch.



Volatile fatty acids identified in this article

Harvesting valuable chemicals from fermented sugars

Fermentation is a biological process that can convert the simple sugars from wood and other cellulosic-based feedstocks into chemical products and represents a key step in the conversion processes evaluated by NARA to convert wood residuals into biojet fuel. Gevo Inc, a NARA member, relies on specialized yeast to ferment simple sugars into isobutanol. The isobutanol is then used as a feedstock in the alcohol-to-jet fuel conversion process.

Alcohols, however, are not the only commercially valuable products generated from the fermentation process. Volatile fatty acids (VFAs) like acetic acid, propionic acid and butyric acid are produced from fermentation in specific bacteria. World demand for acetic acid has steadily increased from 5.4 million tons per year in 1997 to 10.2 million tons per year in 2010. NARA member Birgitte Ahring and her team at Washington State University's Bioproducts, Sciences and Engineering Laboratory (BSEL) are optimizing a process called BioChemCat that uses bacteria to convert cellulosic feedstock into volatile fatty acids.

Creating the optimal conditions for yeast and bacteria fermentation is one challenge taken up by Gevo and Dr. Ahring's group; removing the valuable products from the fermentation broth is another challenge.

In a recent paper published in the Journal of Supercritical Fluids and funded by NARA, researchers at BSEL describe a novel method used to extract volatile fatty acids from the fermentation broth.

> Read *Design and optimization of a semi-continuous high pressure carbon dioxide extraction system for acetic acid* here.

Supercritical carbon dioxide

According to the authors, separation of organic acids, including VFAs, from the fermentation broth represents between 20% to 50% of the total capital and operating costs involved with the fermentation process. Also, these processes generally involve the use of organic solvents that are toxic to human health and hard to clean or dispose. To help reduce these costs, the authors evaluated the use of a "green" solvent such as supercritical carbon dioxide (carbon dioxide under high pressure and low temperature) to carry the VFAs away from the fermentation broth. The advantages of using supercritical carbon dioxide as opposed to other organic solvents are that supercritical carbon dioxide is non-toxic, abundant and its solvent properties can be tuned based on requirements through varying temperature and pressure conditions. A disadvantage to supercritical carbon dioxide is that it usually does not extract VFAs as well as the organic solvents.

To study the effectiveness of supercritical carbon dioxide as a solvent for VFA

extraction, the authors conducted a series of extraction experiments on acetic acid that varied temperature, pressure, flow rate, initial concentration and time. Their first set of experiments tested the effectiveness of supercritical carbon dioxide to extract acetic acid from solution. Depending on the conditions, the amount of acetic acid removed from solution ranged from 10.1% to 85.6%. Higher initial concentrations of acetic acid, faster flow rate and longer time contributed to a high extraction rate.

The researchers then applied the optimized extraction parameters to acetic acid in cow rumen solution. Rumen solution contains many of the ingredients found in a typical bacterial fermentation system. It was found that the extraction rate was lower than with pure acetic acid solution because competing organic acids like propionic and butyric acids were also carried by the supercritical carbon dioxide. Extraction rates in cow rumen were most affected by time. Sixty percent of the acetic acid was extracted in one hour, whereas only 80% was extracted at the end of five hours. It is believed that the additional time allows for the nearly complete extraction of all the organic acids from the fermentation broth.

Future work

Their work expands opportunities to generate valuable bio-based products from wood residuals. The significant output from this paper is an optimized protocol for using supercritical carbon dioxide to extract acetic acid from cow rumen fluids. Additional papers from the Ahring lab that describe the production of VFA's from fermented cellulosic feedstocks have been submitted to journals and will be published soon. In addition, alternative methods are being evaluated to extract larger VFA's from the fermentation broth.

Education and outreach impacts infographic

Want to know how NARA transfers the information it produces to students, teachers, stakeholders and the general public? View our latest Outreach and Education infographic here.

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