NARA
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2015 Imagine Tomorrow Biofuel Category 1st place winners from Tesla STEM High School, Redmond WA. Student names left to right: Margo Nanneman, Ben Zabback, Maheck Jerez and Zechariah Cheung.

# Northwest high school students present biofuel projects

One of the goals for the NARA project is to enhance the bioenergy literacy of students, educators and the general public. NARA (through the USDA-NIFA) has supported the Imagine Tomorrow competition as a means to promote bioenergy literacy to high school students and educators.

On May 30th, 2015, 425 high school students (44% female; 56% male) attended the Imagine Tomorrow competition at Washington State University. Imagine Tomorrow invites high school students to promote projects and ideas that relate to alternative energy development. It is a fun and rewarding competition, where students and schools receive cash awards for high-ranking projects.

Since 2012, NARA's support allowed the competition to expand its reach to include Oregon, Idaho and Montana high school teams along with the Washington teams that traditionally participated. In addition, a new project category on biofuels was initiated to complement the other three categories of technology, design and behavior.

## The biofuels challenge

Of the 121 teams competing, 19 entered the biofuel challenge category. Listed below are the four highest scoring projects in this category.

**1st place: Recycling Waste Heat for Biohydrogen Generation**
*Tesla STEM High School; Redmond, WA.*

This team measured the amount of hydrogen and ethanol produced from bacterial strains digesting varied feedstocks including wood. They also designed a system that converts the ethanol to hydrogen, which is used to charge fuel cells. The waste heat from the fuel cells is then recycled to enhance the bacteria digestion.

**2nd place: The Biofuture: Aquaponics**
*Tesla STEM High School; Redmond, WA.*

This team created and tested a small-scale aquaponics system used to generate electricity.

**3rd place: Making Biofuels from Algae**
*Skyview High School, Vancouver, WA.*

This team evaluated algae growth with varied fertilizers and compared algae harvesting methods. The algae oil produced from the treatments was evaluated for energy density.

**4th place: Grape Pomace Biodiesel**
*Henry M. Jackson High School, Mill Creek, WA*

This team performed hydrolysis on grape pomace to extract fermentable sugars. Yeast growth rates and oil production were then measured when fed the fermentable sugars.

Tesla STEM High School in Redmond WA made an impressive mark on the competition. Eight teams (the maximum number of teams allowed to compete for a single school) participated. Six of these teams placed within the top four rankings for the four research categories. Although Tesla STEM High School has a modest student population (600 students), they had 23 teams compete for the eight available Imagine Tomorrow slots. At last year's Imagine Tomorrow competition, Tesla STEM High School took home nearly $50,000 worth in cash and prizes.

"We take this event pretty seriously", said Mike Town, a teacher at Tesla STEM High School. "The publicity following our success helped increase the number of students applying to the high school through the lottery and indicates that students and parents take notice".

## Assessing the impact of Imagine Tomorrow

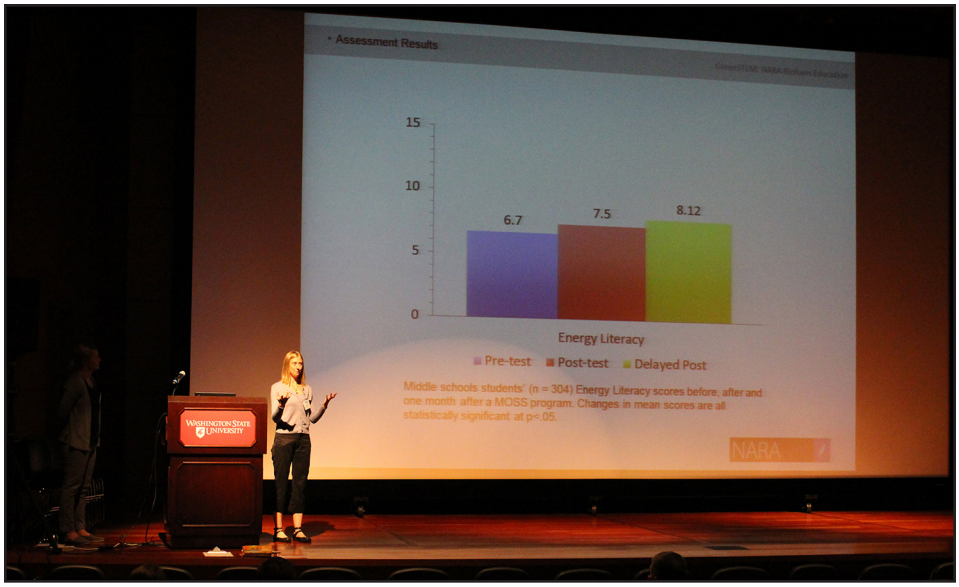
The USDA-NIFA (through NARA) is funding studies to measure the level of bioenergy literacy exhibited at the Imagine Tomorrow competition and whether the event has an impact on students' career choices. To measure bioenergy literacy, NARA researchers developed a rubric to compare the quality of abstracts and poster materials presented at Imagine Tomorrow competitions.

> Read *Refinement of an Energy Literacy Rubric for Artifact Assessment and Application to the Imagine Tomorrow High School Energy Competition* here.

A full understanding to how the Imagine Tomorrow experience affects student career choices will need a few more years of study, however, based on preliminary surveys, the experience has a positive influence.

## NARA provides team mentoring

High school Imagine Tomorrow teams generally complete their science projects after school hours and are assisted by one or more high school educators. For many students and teachers, the time, financial requirements, and learning curve can be daunting. To provide team support, educators and graduate students affiliated with the McCall Outdoor Science School (MOSS) and Facing the Future (both NARA affiliate organizations) provide workshops, webinars and on-going support to the teams. This involvement not only helps to increase the number of teams participating in the competition, but can also help raise the project and experience quality for the participating team. An additional benefit is that the workshops allows NARA scientists to interact directly with high school teachers providing an efficient transfer of primary science information to the classroom.




Danica Hendrickson from Facing the Future reports to teachers at the 2015 Imagine Tomorrow Competition.

> To learn more about how NARA's education team interacts with high school teachers, read *Teacher Professional Development for Energy Literacy: A Comparison of Two Approaches* here.

During the competition, NARA members Karla Eitel and Danica Hendrikson gave a presentation titled "Teaching about Biofuels in the Pacific Northwest" to approximately 30 teachers from throughout ID, MT, OR and WA. This presentation highlighted the resources, like the Bioenergy Literacy Matrix and Fueling our Future, NARA makes available to educators and opportunities to integrate the NARA project into classroom curricula.

Images of graduate students working on NARA projects

# Dissertations and theses from NARA grad students

Since NARA's inception in 2011, over 100 graduate students have conducted research for NARA funded by the USDA-NIFA. Their efforts contribute substantially towards NARA goals and play an important role in preparing a trained workforce for a bioenergy-based industry.

Often a student's dissertation or thesis is their first scholarly presentation in writing and represents a transition from apprentice to professional researcher. These documents are generally well reviewed, represent the most current data and conclusions available, and can be more thorough than traditional journal papers which often have word count or page restrictions. Here is a selection of four dissertations and thesis funded by the USDA-NIFA that contribute to NARA.

Additional theses and dissertations that contribute to the NARA project are available here.

## Douglas–fir (Psuedotsuga menziesii) Biomass and Nutrient Removal under Varying Harvest Scenarios Involving Co-production of Timber and Feedstock for Liquid Biofuels

Kristin Coons presented her thesis in 2014 at Oregon State University for the degree of Master of Science in Sustainable Forest Management. Her work developed an improved model to estimate biomass and nutrient levels for Douglas-fir across a wide range of stand management regimes. This work will help researchers and forest managers gauge how harvesting intensity impacts long-term site productivity.

## The Effects of Increased Supply and Emerging Technologies in the Forest Products Industry on Rural Communities in the Northwest U.S.

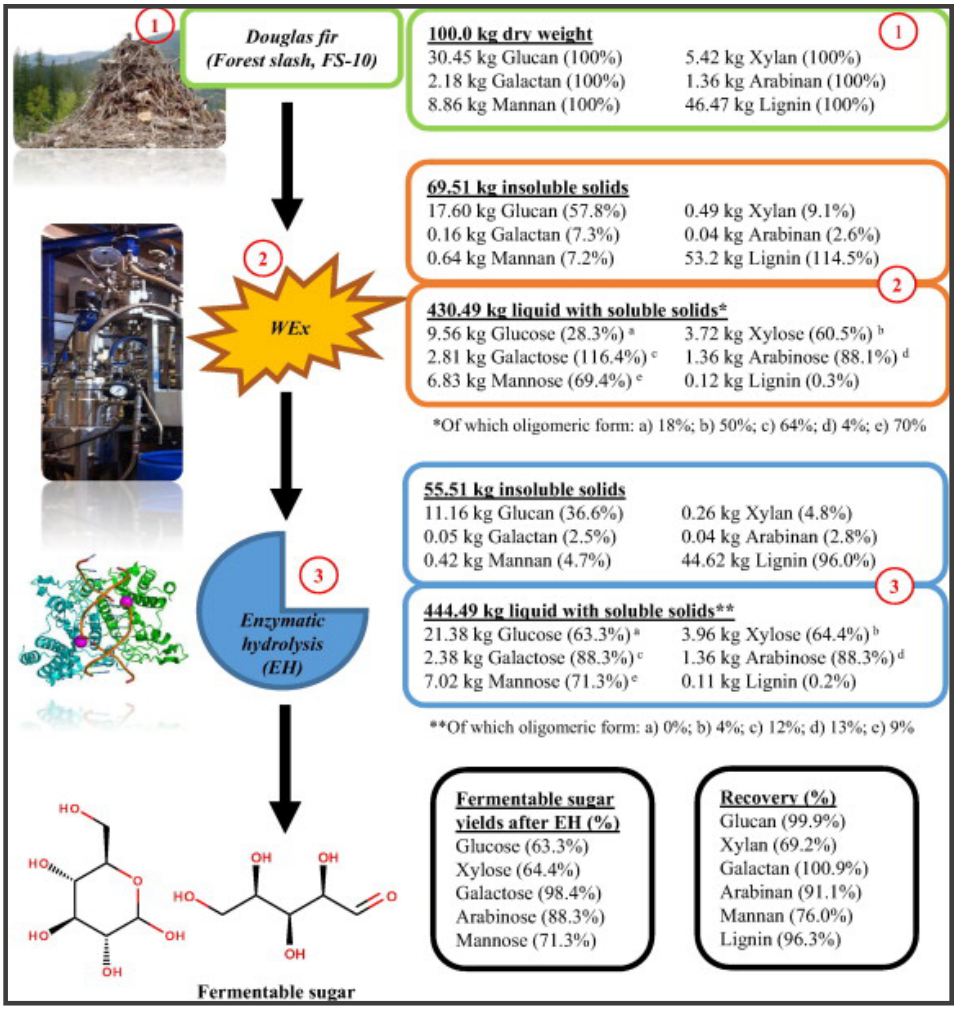
Mindy Crandall presented her dissertation in 2014 at Oregon State University for the degree of Doctor of Philosophy. Her work models multiple scenarios for the commercial use of forest residuals and describes how these scenarios might stimulate rural development in western Oregon communities. This study offers a comprehensive analysis on how non-traditional uses of forest products can stimulate rural development.

## Construction and Demolition Recycled Wood Waste Assessment in the Northwest United States

Gerald Schneider presented his thesis in 2013 at Washington State University for the degree of Master of Science in Civil Engineering. His work provides an inventory assessment of recycled wood waste in the Pacific Northwest and describes factors that can influence the amount of recycled wood waste available. This thesis provides a benchmark assessment to understanding the sustainable amount of recycled wood waste available as feedstock for bio-jet fuel and co-product production.

## Sustainable Biomass Supply from Fuel Reduction Treatments: A Biomass Assessment of Federally Owned Land in Eastern Oregon

Kevin Vogler presented his thesis in 2014 at Oregon State University for the degree of Master of Science in Forest Resources. His work provides a biomass assessment of forest residuals generated from fuel reduction and forest thinning in eastern Oregon. His models predict the effect on forest residual supply and fire hazard levels from various levels of thinning treatments.




Overall mass balance of the optimal wet explosion run at 190 °C, 7.5% O2 loading, and 30 minutes residence time. Figure from Biswas, R., Teller, P.J. & Ahring, B.K. (2015) Pretreatment of forest residues of Douglas fir by wet explosion for enhanced enzymatic saccharification. Bioresource Technology, 192, 46-53.

# Wet explosion pretreatment on Douglas-fir forest residuals

Pretreatment is a process that breaks up wood fibers so that enzymes can access and release the simple sugars found in wood. For the supply chain being evaluated and developed by NARA, pretreatment is a highly critical step. It occurs before the enzymatic hydrolysis and fermentation steps and can therefore influence the success of those downstream events.

The wet explosion pretreatment process has been practiced by the Bioproducts, Sciences and Engineering Laboratory at WSU-Tri-Cities under the direction of NARA member Brigitte Ahring. This process uses steam and oxygen to break up the wood fibers so that the simple sugars can be released by enzymatic hydrolysis. Some attractive features assigned to this pretreatment process are that no hazardous chemicals are used and the pretreatment process can accommodate a wide range of lignocellulosic feedstocks.

Ahring's team recently published the results of a pilot-scale evaluation of the wet explosion pretreatment performed on Douglas-fir forest residuals.

Read *Pretreatment of forest residuals of Douglas-fir by wet explosion for enhanced enzymatic saccharification*

## Pretreatment optimization and mass balance results

The publication, funded by the USDA-NIFA through NARA, describes how the wet explosion pretreatment method was optimized for use on Douglas-fir forest residuals and provides a mass balance for the optimized pretreatment and enzymatic hydrolysis results.

To optimize the pretreatment parameters, 17 experiments were conducted at high solids concentration of 30%. Each experiment differed by either the reaction temperature, amount of oxygen, or reaction time. An optimized wet explosion pretreatment protocol, based on maximum enzyme digestibility, was established at 190°C, oxygen loading at 7.5%, and a reaction time of 30 minutes. The enzymatic hydrolysis reaction was optimized at a pH of 5.5 to produce a glucose yield of 63.3% from the Douglas-fir residuals pretreated under optimal conditions. After enzymatic hydrolysis under optimal pretreatment conditions, the yields of major hemicellulosic sugars in the feedstock such as xylose and mannose were 64.4% and 71.3%, respectively, showing minimal loss of easily degradable sugars. Further, the lignin and cellulose recovery recorded in the mass balance was 96.3% and 99.9 % respectively.

It was also determined that the reaction temperature and time were conditions that affected the amount of degradation products produced; oxygen levels did not affect the amount of degradation products. Degradation products arise when simple sugars are converted into other chemicals (HMF and furfural for instance) due to the pretreatment conditions. They are generally unwanted because they lower the quantity of simple sugars produced and can potentially inhibit the downstream biological conversion processes like fermentation.

View the conversion steps in the NARA supply chain.

## NARA evaluated multiple pretreatment protocols

NARA funded research to evaluate the wet explosion pretreatment process along with other pretreatment processes

using the Douglas-fir residuals mentioned in this study. When comparing pretreatment processes, NARA considered sugar yields and fermentation results, energy and supply costs, environmental impact, effect on lignin and the pretreatment's adaptability to existing pulp mill infrastructure. After a thorough review, the mild bisulfite pretreatment process was selected for use to produce biojet fuel for a demonstration flight and to incorporate in the life cycle assessment (LCA) and techno-economic analysis (TEA) being developed by NARA.

Read NARA selects a single pretreatment method

The results published in this paper provide researchers and industry with a through chemical analysis regarding the use of wet explosion pretreatment technology on forest residuals to produce simple sugars. The protocol allows for pretreatment without introducing harmful chemicals that interfere with downstream processes.

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