NARA EDUCATION

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STEM	Science, Technology, Engineering, and Math
FTF	Facing the Future
FOF	Fueling Our Future: Exploring Sustainable Energy Use (Title of the Elementary, Middle, and High School supplementary curriculum developed by Facing the Future)
MOSS	University of Idaho College of Natural Resources' McCall Outdoor Science School
BF-SURE	Summer Undergraduate Research Experiences - Biofuels
SURE	SKC - Summer Undergraduate Research Experiences - Salish-Kootenai College
TPP	Tribal Partnership Program
UI	University of Idaho
UW-UW	University of Wisconsin Extension- Upham Woods Outdoor Learning Center
WSU	Washington State University
SKC	Salish Kootenai College
WWU	Western Washington University
IDX	Integrated Design Experience
TEA	Techno-economic Analysis
K-12	Kindergarten through 12th Grade
MSW	Municipal Solid Waste
PNW	Pacific Northwest
OP	Olympic Peninsula
MC2P	Mid-Cascades to Pacific
WMC	Western Montana Corridor
LCA	Lifecycle Analysis
EPP	Environmentally Preferred Products
EIA	Energy Information Administration
IGERT	Integrative Graduate Education and Research Traineeship
NREL	National Renewable Energy Laboratory
MBS	Mild Bisulfite
ASTM	American Society for Testing and Materials
SAFN	Sustainable Aviation Fuels Network
CSKT	Confederated Salish and Kootenai Tribes
ITC	Intertribal Timber Council
MIT	Muckleshoot Indian Tribe
NARA TPP	NARA Tribal Partnership Projects

EXECUTIVE SUMMARY

The NARA Education team worked to: 1) meet the workforce needs of the bio-energy/bioproducts economy; 2) develop a broad, integrated view of the biofuels problem among scientists and engineers; 3) enhance the community engagement skills of energy scientists and engineers; 4) improve the capacity of teachers, and; 5) strengthen science literacy of students in areas particular to the biofuels. The NARA Education Team reviewed existing research on energy literacy, conducted new research on energy literacy, and developed energy and bioenergy resources and programming for non-formal and formal audiences. In the process of this work, it became evident that while many quality energy education materials exist, accessing them is a significant challenge for educators. In response, the NARA Education Team Developed the Energy Literacy Matrix (https://energyliteracyprinciples.org/), searchable collection of educational materials related to energy and bioenergy. The Matrix is aligned with the Department of Energy's (DOE's) peer reviewed *Energy Literacy: Essential Principles and Fundamental Concepts for Energy Education* framework (https://energy.gov/eere/education/energy-literacy-essential-principles-and-fundamental-concepts-energy-education), while adding an additional column for bioenergy and bioproducts. The EnergyBadger project will use both the DOE principles and the Matrix to build out the EnergyBadger system.

INTRODUCTION

The NARA project was designed to enable a new and technically complex industry in the Pacific Northwest. Elevating general knowledge around energy literacy serves an important role to ensure biofuels industry sustainability. Focus was on: educating and providing training to a future energy workforce; provision of timely information and resources to stakeholders and professionals in industries connected to the biofuels supply chain, and; enhancing citizen understanding to improve public support and participation in political decision making.

To secure an effective and sustainable workforce and generate future leaders who can move the biofuels industry forward, training and educational opportunities related to Science, Technology, Engineering and Mathematics (STEM) topics, and specific to the biofuels supply chain, need to be created and promoted. For this purpose, NARA provided opportunities tailored to engage students along the education pathway from K-12 students and educators; to undergraduate and graduate students; and finally to practicing professionals.

TASK 1: BIOENERGY AND BIOPRODUCTS GRADUATE EDUCATION AND RESEARCH IN PARTNERSHIP WITH NORTHWEST TRIBES

Introduction

The goal of this task is to educate next-generation scholars with unique skills for devising integrated resource management and technical designs that deliver bioenergy and bioproduct systems tailored to the resources, ecologic, and economic development needs of a community.

Task Objective

The educational outcome objectives of this task were:

1. Create scholars with the integration, teamwork and communication skills needed to be leader in the bioenergy and bioproducts economy.
2. Build multicultural perspectives into the Ph.D.
3. Improve the diversity of STEM graduate programs, especially Native Americans.
4. Disseminate successful program elements locally and nationally.

Methodology

To accomplish this, the team worked with tribes, tribal organizations, and each partner campus to offer up to three grad student tribal research projects. Specifically, student teams worked collaboratively with Northwest Native American tribes to provide integrative research on technical issues tied to feedstocks, their sustainable production and logistics, and conversion to value-added products. System metrics assess the overall performance of the integrated student design. Students benefitted from outstanding training in interdisciplinary communications and research. Tribes benefited by collaborating to define, research, and assess a technical problem that is deemed a tribal priority for ecologic or economic development purposes. Each student team made several trips to the partner tribe's reservation. The project complemented the IDX team corridor-scale activities by incorporating detailed landscape scale information provided by major forested landholding tribes. To have maximum impact and credibility in Indian Country, this task had significant liaison activities with tribes, tribal organizations, and campus offices that coordinate with tribal student recruiting and retention programs.

Results

The project resulted in continued tribal research projects that support tribal interests in forest restoration, resilient forest management, air and water quality-related issues with biorefining, and new technologies to generate economic development from un-merchantable biomass residues. It also resulted in continued direct outreach and support to Tribal Nations within the NARA region

A summer Internship program resulted in the recruitment of students at the American Indian Science & Engineering Society conference. Students participated in research at Western Washington University's Huxley School, Facing the Future, and on the University of Washington's campus and at two field sites. In total, 12 Native Scholars earned higher degrees:

- 1 AAS degree from a Tribal College
- 7 BS degrees (Mostly in Environmental Sciences)
- 1 BA degree
- 2 MS Forest Resources
- 1 MECHE Ph.D.

Douglas-fir biomass residues were acquired from the Muckleshoot Tribe and the Confederated Salish Kootenai Tribes to participate in the production of the 1,000 gallons of biojet fuel that NARA produces. Product were delivered to Lane Forest Products in Eugene, OR.

Finally, the projected resulted in deepened collaboration with Tribal Nations via the Intertribal Timber Council.

TASK 2: GREENSTEM K-12 INITIATIVES

Introduction

The NARA Education Initiative, or GreenSTEM, includes an imaginative suite of programs that seamlessly link an array of educational and training programs with our university and commercial partners in order to meet the region's most compelling energy development needs. The overarching goal of GreenSTEM is to increase the capacity of the region for a transition to biofuels. This will be accomplished through four interrelated objectives:

1. Meet the workforce needs of the bio-energy/bioproducts economy;
2. Develop the next generation of energy leaders for industry, government, and the civic sector;
3. Improve the biofuels literacy of teachers educating our future citizens; and
4. Strengthen overall science literacy of these same young citizens in areas particular to the biofuels debate.

The program developed energy and biofuel curricula, which was field-tested at UI's award winning McCall Outdoor Science School (MOSS), annually reaching 2,500 K-12 students and 150 teachers. This curricula was delivered via the web and social networking approach pioneered by Facing the Future (FtF), an independent program of Western Washington University renowned for its web-based global sustainability curricula. K-12 teacher training was also achieved through MOSS teacher institutes and FtF webinars and professional development workshops.

Task Objectives

Teachers and students will be impacted through this work, and outcomes- through assessment and evaluation - will show that:

1. K-12 students are more knowledgeable about biofuels, biofuels research, and energy.
2. K12 students apply knowledge in energy literacy to successfully develop an approach to answering a problem-based energy issue.
3. K-12 teachers are more knowledgeable about biofuels, biofuels research, and energy.
4. K12 teachers apply knowledge in energy literacy to help their students successfully develop an approach to answering a problem-based energy issue.
5. Teachers participating in professional development programs will integrate problem-based learning and energy content in their home classrooms with increased confidence.

Methodology

K12 Students (MOSS)

The McCall Outdoor Science School delivers biofuel education programs to 2,500 middle and high school students annually both during the school year and during the summer. New biofuel lesson plans were created and field-tested in partnership with FtF. Select students participated in conjunction with their teacher and MOSS graduate students as they prepare a problem-based project to compete in the Washington State University (WSU) Imagine Tomorrow (IT) Competition.

MOSS staff and graduate students focused on both energy lesson creation and assessment of energy literacy. Over 40 energy-related lessons have been created, taught and refined at MOSS (Table NE-2.1). Several of these lessons are also designed or come with adaptations to be taught in a classroom setting. All MOSS lessons are loaded to the Energy Literacy Matrix.

Table NE-2.1. Lessons developed by MOSS and funded through NARA

	Topic	Title	General Description	Grade Level(s)
1	All stages	Biomass Adventure Race	Students follow clues to make pine tea following the process of making biofuel	Any
2	Biojet & Co-products		Students will explore the various uses for activated carbon	High School
3	Biojet & Co-products	Biofuel (evening program) (Adapted from FtF)	Students learn about various sources of biofuel and evaluate their sustainability.	5th-12th
4	Biojet & Co-products	Fuel Debate (evening program) (Adapted from FtF)	Students debate about the more sustainable fuel option for our region.	5th-12th
5	Biojet & Co-products	Lifecycle of a Fuel (evening program) (Adapted from FtF)	Students use a lifecycle assessment framework to evaluate the impacts of producing various types of fuel.	5th-12th
6	Biojet & Co-products	Planes in Flight (evening program) (Adapted from FtF)	Students evaluate the sustainability of jet fuel from the perspective of various government agencies.	5th-12th

7	Biojet & Co-products	Value of a Tree	Students determine how many miles of biojet fuel a Ponderosa Pine tree can convert to from the leftover slash.	6th-12th
8	Forest Management	Trees, Water and the Landscape	Students will understand the relationship plants have and how they affect their watershed and landscape formations. They will examine how vegetation affects ground runoff and soil discharge. Discuss the effects of removing these plants to be used as energy.	5th – 6th grade students
9	Forest Residues Preparation	CSKT Forest Management History & Biomass in Your Own Backyard	The goal of this first lesson is to have students understand the rich history of forest management practices among the tribes of the Northern Rockies. Students should be able to give a brief overview of these practices, their ecological and cultural significances and how they are or are not being used in European- style forestry today. The goal of “finding biofuel potential in Your own Backyard” is to have students begin to understand how changes in ecosystems, from less densely vegetated to more densely vegetated, provides different biofuel potential.	8th-10th
10	Forest Residues Preparation	Matchbox Forests Pre & Post European Simulated Forests	The goal of lesson two is for students to gain an appreciation for the ecological benefits of tribal fire management. Students should also be able to articulate the different factors that allow a forest to bounce back after a wildfire (legacy trees, minimal damage to canopy etc…)	8th-10th
11	Forest Residues Preparation	Mechanical Thinning and Biofuel Production	To have students think critically about the plausibility of mass biofuel production using dry, woody biomass that has been mechanically thinned from the forest. The objective of this lesson is creating connections between the student’s lives and the impact biofuel production could have on them. By having students calculate realistic biofuel potentials and converting that number into an actual amount of useable fuel, students see the real world potential of biofuel production.	8th-10th
12	Forest Residues Preparation	Posters & Holistic Forest Management Plans (summative of previous 3)	The goal of this lesson is to simply reiterate the information learned earlier in the week and check for understanding among the students. Students should be able to articulate the ecological benefits of prescribed fires and mechanical thinning. Students should have a deeper understanding of native forest management practices and how they can be used today to create healthier forests.	8th-10th
13	Forest Residues Preparation & Transportation	From Forest to Fuel	In this lesson, students will calculate and measure the amount of woody biomass in forest residual slash piles, to determine efficacy of processing and transporting methods for biomass energy production.	High School
14	General Energy Literacy	Classifying Energy	Students learn about different types of energy from a physics perspective (e.g. kinetic, potential, thermal, nuclear, etc.)	Middle School
15	General Energy Literacy	Energy Audit	Students will engage in an energy scavenger hunt to determine what items on campus use the most electricity.	5th-8th
16	General Energy Literacy	Energy Ethics	Students will explore the ethics behind energy choices.	High School Environmental Science
17	General Energy Literacy	Greenhouse Gases	Students will understand the greenhouse effect and the role of greenhouse gases in Earth's atmosphere.	5th-6th
18	General Energy Literacy	Local Sustainable Energy	Students should understand how biofuels can help create energy independence for a local community. Students will also see how alternative energy sources serve as an economically stable and sustainable product for a community	6th-8th
19	General Energy Literacy	MOSS Energy Day	Students will explore how energy moves through trophic levels, learn about various sources of energies and their advantages and disadvantages.	5th-12th
20	General Energy Literacy	Reducing Your Carbon Footprint, One Step at A Time	During this lesson, students will understand that carbon dioxide (CO_2) is one of the largest contributors to climate change and learn how they can reduce CO_2 emissions at home and within their state. Students will also examine how biofuels and other renewable resources can be used as an alternative to nonrenewable resources.	7th-12th
21	General Energy Literacy	Renewable Energy (evening program) (Adapted from FtF)	Students learn about various types of energy sources and evaluate the pros and cons of each.	5th-12th
22	General Energy Literacy	The Great Debate	This lesson is designed to help students understand the differences in stakeholder perspectives and the collaboration required to overcome the complex problem of creating a bioenergy infrastructure.	6th-12th
23	General Energy Literacy	Toil for Oil (Adapted from FtF)	Learn about renewable and nonrenewable resources while “drilling for oil” with beans.	5th-8th
24	General Energy Literacy	Toil for Oil Beans - revised	Learn about renewable and nonrenewable resources and identify issues related to the environment from using them.	5th-6th
25	General Energy Literacy	Toil for Oil Tag	Learn about renewable and nonrenewable resources and identify issues related to the environment from using them.	5th-6th
26	General Energy Literacy	Vacation Carbon Footprint	Students will examine the carbon used on a vacation involving a flight.	5th-12th

23	General Energy Literacy	Toil for Oil (Adapted from FtF)	Learn about renewable and nonrenewable resources while “drilling for oil” with beans.	5th-8th
24	General Energy Literacy	Toil for Oil Beans - revised	Learn about renewable and nonrenewable resources and identify issues related to the environment from using them.	5th-6th
25	General Energy Literacy	Toil for Oil Tag	Learn about renewable and nonrenewable resources and identify issues related to the environment from using them.	5th-6th
26	General Energy Literacy	Vacation Carbon Footprint	Students will examine the carbon used on a vacation involving a flight.	5th-12th
27	General Energy Literacy	What's a Watt Worth	Students will engage in an energy scavenger hunt to determine what household items use the most electricity while exploring the effort that is involved in generating electricity.	5th-6th
28	General Energy Literacy	Wind &/or Solar Hunt	Students will explore renewable sources of energy and which would provide the most energy on the MOSS campus	5th-12th
29	General Energy Literacy	Winter Photosynthesis	Students understand the flow of energy in an ecosystem.	5th-6th
30	General Energy Literacy & Fermentation	Energy Values	A demonstration of how different fuels have different energy densities.	5th-6th
31	General Energy Literacy / Ecosystem Energy	Life in a Food Chain	Students understand the flow of energy in an ecosystem	5th – 6th grade students
32	General Energy Literacy & Forest Residues Preparation	Forest Management	Student will be able to evaluate the benefits and drawbacks of forest management strategies.	5th-6th
33	LCA	LCA over a cup of coffee	Following the lesson, students will have an understanding of the creation and uses of life cycle assessments.	High School
34	LCA	Life Cycle Assessment		
35	NARA project as case study	MOSS Teacher Institute	Teachers work through the forest residuals biofuel supply chain while answering the following questions: Is this a good idea? How do we know? Activities not specifically listed out in this table that need to be developed into lessons include: making root beer (fermentation), comparing auto miles to jet miles, impact on nutrient cycling and soil productivity, transportation logistics, town hall meeting of environmental, economic and social considerations of using biofuel	Secondary Teachers
36	NIFA	Beetle Kill to Bioenergy	This lesson explores bioenergy as a clean and alternative energy resource for powering communities. Students will use nonfiction narrative that tells the story of Eagle Valley Clean Energy (EVCE) in Colorado as well as the Bioenergy Alliance Network of the Rockies (BANR). These projects are examples used to assess the social, environmental, and economic impacts of bioenergy and biofuels. A magazine article is used to familiarize the students with bioenergy, the players involved in the process, and the impacts on the community. A video about EVCE will then be used to spur discussion from students based on different stakeholder perspectives. A more detailed explanation of the EVCE and BANR projects is found in the background and can also be used to familiarize students with the project.	High School
37	Pre-treatment	Making Chemistry Visible	The objective is to explain and demonstrate the chemical process of turning woody biomass into biofuel.	10th-12th
38	Pre-treatment	Plant Cell Walls to Alcohol	Students are challenged with separating the usable cellulose and hemicellulose from the lignin co-product.	7th-12th
39	Residuals prep	Value of Slash	Students learn about the value of slash and potential fire mitigation reasons for removing slash from a forest.	High school
40	Sustainability / Wildlife	Value of a Dead Tree	Students will learn about the value of standing dead trees for wildlife habitat	High school
41	Transportation	Cleaning up our Air	This lesson introduces students to the environmental impacts or air pollution caused by trucks and compares the impacts left from diesel and biodiesel. It helps students to identify ways they can reduce air pollution during their daily lives.	1st
42	Transportation	CO2 & Biofuel Adventure Race	In this lesson, students will be tasked with determining the best method of transporting slash from the environment to a pretreatment facility. Students will be given a choice of one of three transportation methods and then will go on their own “adventure race” that models their respective process.	6th-8th

Energy Literacy Assessment

Several NARA Education team members were involved in the creation of an energy assessment tool for middle and high school students. The middle school version of the test was tested extensively to check for validity and reliability.

A preliminary pilot study was conducted to check for reliability and construct validity. A think-aloud method was employed to validate flow and reliability from a student's perspective. During the trial period four groups of five – eight students per group were asked to participate in a think-aloud when reading the assessment to determine areas of confusion or define any limitations, as suggested by the National Quality Council (2009). Talk-alouds (or think-alouds) are used to determine the quality and clarity of the questions used to test students. Talk-aloud protocol includes asking the participants to "talk-aloud constantly from the time the problem was presented until they had given their final answer". The use of a talk-aloud, or think-aloud, is to capture "what is held in the short-term memory", which "results in a sequence of thought that reflect what occurs cognitively during completion of a given activity". The use of a talk-aloud with assessment questions helped to determine if the questions made sense and/or are appropriate for the associated age population (middle or high school) as well as point out any gaps in the development of the constructs. Results were compiled from the think-alouds, feedback from teachers, and comments from industry experts to validate the content of the questions. The incorporation of the results and feedback led to the next round of edits for the questions and answer choices. Following final question edits, the tool was tested to determine change in energy literacy for a middle school age population.

Pilot testing and further sampling was conducted at the University of Idaho College of Natural Resources McCall Outdoor Science School (MOSS). MOSS is a residential program offering four or five-day programs for K12 students. MOSS programs offer place-based, inquiry-based science education that utilizes the surrounding state park as the outdoor classroom. Teachers bring their students to MOSS for the opportunity to use various technologies and field research practices, develop team-building skills, and to learn in an outdoor setting often not available near their schools.

About 2500 students participate in the MOSS residential program a year. A sampling of the fall population of students (n= 304) participated in pretest, posttest, one-month delayed posttest assessment. Students completed the pretest the first day of the program and the posttest the final day of the program. The one-month posttest was mailed to schools following their visit to MOSS. All three tests are identical with each other. Analysis on the pre, post, one-month post data aimed to examine change in energy literacy throughout the testing periods.

In the spring of the same school year an additional 508 students completed the energy literacy test to collect data for further validation of the instrument. These students only took the test once, as the purpose of this secondary research was not to examine change in energy literacy but to further understand the extent to which the test is a valuable instrument. The spring data from the 508 students was used to conduct a confirmatory factor analysis, item analysis including difficulty, discrimination and reliability and differentiate item analysis. On average, items were answered correctly by the students 52% of the time. Individual item-correct percentages ranged from 13% to 82%. Ten items were answered correctly by 40-60% of the students. Another 10 items were answered correctly by 30% to just above 70% of the students. So the vast majority of items were centered around that ideal moderate level of difficulty. Among those outside that range, one was moderately easy (82%) and one was difficult (13%). An inspection of the content and response patterns (i.e., how many students selected each answer option) of the difficult item found it addressed a fundamental nuance representing a high level of energy literacy. The moderately easy item addressed the topic of photosynthesis at a basic level, which is covered in early grade levels (K-4). Both items were judged to be necessary for adequately representing the energy literacy construct. For these reasons, no item was flagged for revision or deletion based on item difficulty analyses. These outcomes suggest the instrument is well positioned to serve a research or program assessment context. The lack of item difficulties very close to 0 or 100% means student change over time (e.g., before and after an educational intervention) can be assessed without much concern that some level of growth has been [3]missed[2]. In other words, performance of the pilot sample suggests most students will be able to demonstrate an accurate baseline level of energy literacy and will have room to grow on the instrument. Further, correlational analyses that investigate the energy literacy instrument in relation to other variables (e.g., broad educational outcomes) will likely not suffer from a restriction of range influence.

MOSS graduate students taught K-12 energy literacy education with an emphasis on biofuels to students from 2011-2016. All students that attend MOSS (about 2,500 annually) did two energy literacy lessons, the Value of a Tree, energy related morning activities (chores), and an energy related evening program if selected by teachers, as well as a multi-day demonstration in the spring and fall. MOSS offered an Energy Day to the list of content days for schools to select, which about five schools selected a year. MOSS graduate students created and refined energy related lesson both for classroom use and use at MOSS. Completed lessons were uploaded to the Energy Literacy Matrix. MOSS staff meet every other week with NARA funded graduate students to help in the development of curriculum, progress towards their graduate research, and share NARA related research.

MOSS conducted a comparison study fall 2015. All students that attended fall MOSS programs have taken a pretest upon arriving at MOSS, a posttest before leaving and a one-month posttest after returning to their schools. Various members of the Education and Outreach team continue to meet to further develop the middle school energy literacy assessment tool. Spring 2015 includes collecting data on at least 500 K-12 students to further examine the validity of the instrument. A continuation study was conducted fall 2016 using a pre and post test model to measure continued energy literacy as a result of MOSS energy related curriculum.

Results from 2013-14 testing:
The mean Energy Attitude pretest was 23.98 (sd = 4.70), and the mean Energy Attitude posttest was 24.37 (sd = 4.64). There was not a significant increase from pretest to final found (t(311) = -1.653, p>.05). The mean Energy Behavior pretest was 9.34(sd = 2.83), and the mean Energy Behavior posttest was 9.56 (sd = 2.91). There was not a significant increase from pretest to final was found (t(311) = -1.406, p>.05). There was not a significant increase in their energy behavior or attitudes about energy in general. There was an increase in these two categories, but not a statistically significant one. This can be explained by several contributing factors: MOSS curriculum, at that point in time, did not address these construct specifically, the questions in the energy attitude category are too broad and range from attitudes about energy education and beliefs about current energy choices, which can be at odds to each other and not explicitly harmonious in student's opinions, and the behavior construct only contains three questions which isn't enough to account for reliability.

Results from the fall 2014 testing:
The mean Energy Literacy pretest was 6.70 (sd = 2.72); the mean Energy Literacy posttest was 7.50 (sd = 2.71); the mean Energy Literacy one-month posttest was 8.12 (sd = 2.98). A significant increase from pretest to posttest was found (t(304) = 5.19, p<.000); a significant decrease from posttest to one-month posttest was found (t(304) = 3.75, p<.000); a significant increase from pretest to final was found (t(304) = 8.25, p<.000).

The results from fall 2014 assessment indicates that students that attending a four or five-day MOSS residential program demonstrated a positive increase in their energy literacy, overall. Energy literacy increased between each testing time, even after having participated in the MOSS programing one-month prior. MOSS programing resulted in students' increase in energy literacy content knowledge. The MOSS program is a positive influence on students' development of their competence in energy literacy.

Results from spring 2015 testing:
In the spring of the same school year students attending the MOSS residential program completed the middle school NARA Energy Literacy tool (n=508). Cronbach's alpha was used to determine internal consistency reliability for the test. The Cronbach's alpha was 0.473, which is fairly low. This can be explained due to the large range in sub-topics within energy literacy as the test included questions pertaining to many areas within science.

Item difficulty analysis was also conducted to determine if questions were too challenging to too easy for the students. The average percent correct is 52.24% indicating about half of the students answered the questions correctly. Individual question analysis indicates most questions were not too easy, with percentages over 80% or too difficult with percentages below 30%.

Analysis was conducted to examine percentage of students answering correctly for males and females and if certain questions resulted in one gender answering higher than another. Only three questions resulted in boys answering statistically significantly higher than girls. Next all students were lumped into high, medium and low categories based on their total score. A bivariate correlation was ran to compare the groupings to total score to examine if those that were in the high category, for example, tend to answer each question correctly. Statistical significance was found for each question indicating that there is a link between groupings of high, medium and low score and percentage correct. The analysis summarized here indicates the test is adequately difficult for this age range and questions are not easier or more difficult for one gender versus the other.

Another analysis was conducted to look at the answer choices. Frequency of each answer choice per question was conducted to determine if one answer choice was either a non-distractor, not chosen by any student due to the answer being too obviously incorrect. No answer choice for any of the questions was never selected by students, indicating the answer choices were adequate for each question.

Results from fall 2015 testing:
The mean Energy literacy pretest was 6.88 (sd = 2.86); the mean Energy Literacy posttest was 7.68 (sd = 2.61). A significant increase from pretest to posttest was found (t(304) = -5.48, p<.000). The results from fall 2015 assessment indicates that students that attending a four or five-day MOSS residential program demonstrated a positive increase in their energy literacy.

Conclusions/Discussion
Lessons created and taught at MOSS resulted in increased energy literacy for attending students, as seen from the results of the energy literacy assessment tool. Pre, post test and one-month post test results show that students energy literacy increased from students' time at MOSS and continued to increase one month later. Follow up assessment in 2015 indicates MOSS lessons are still effective for increasing energy literacy.

K12 Teachers (MOSS)
The McCall Outdoor Science School delivered a summer workshop and an annual biofuel webinar series for 15 - 30 middle school to high school teachers from 2012-2015. Teachers participating in the webinar series were supported as coaches for the Imagine Tomorrow competition while developing their own energy literacy through a series of lectures and discussions with NARA research scientists. An additional 40—50 teachers followed the IT competition preparation process via the web. Fifty teachers that accompany their 6th grade students to MOSS residential school programs participated by observing their students as they participate in biofuel focused education lessons. Teachers were also supported through a web-based "Energy Literacy Principle Matrix" (ELPM), designed to house and effectively organize educational materials covering a broad spectrum of subjects related to

biofuels. Its design is flexible and adapts well to NARA activities while providing a single site where teachers or community members can effectively find information about biofuels.

MOSS Imagines Tomorrow: online webinar series delivered monthly for seven months

In the first workshop format, we used a series of webinars to support teachers who are engaged as coaches for a problem-solving competition called Imagine Tomorrow, sponsored by Washington State University. The participants were teachers who were committed to serving as coaches for student teams who would ultimately develop projects for the Imagine Tomorrow problem-solving competition. The participants included 31 teachers from Idaho, Montana and Washington.

The purpose of our workshop series was to give teachers content, facilitation and financial support with the goal of increasing the overall quality of support given to student groups as they work on problem-solving projects for the competition. In connecting to this ongoing work we were able to build on many place-based projects already taking place within teachers' communities.

Additionally, we wanted to provide an easy opportunity for scientists to engage with these teachers. We provided the overall curriculum structure and asked scientists to plug in to support the overall content goals. This work is situated within the larger context of problem-based learning and building energy literacy amongst citizens of the Pacific Northwest, the region where this bioenergy development work is taking place.

The guiding questions for the webinar series included:

- What resources exist for teaching bioenergy literacy?
- What is the NARA project doing to advance bioenergy in the Pacific Northwest?
- How can these ideas contribute to my students' projects for the Imagine Tomorrow Competition?

All webinars were delivered using the GoToMeeting platform. Participants were asked to record video responses to pre-workshop questions through the online platform Flipgrid. Pre-workshop interviews with presenters were recorded using a Skype audio recording feature. Every month a different professional was asked to give a presentation during a webinar broadcast to teachers from across three of the four states in the region. Relevant content material was supplied in advance of the webinar.

During the webinar, we started with an introduction to the presenter and a review of the project goals. The presenters then gave an approximately 20 minute lecture during which participants could type questions into a chat window within the webinar "environment". Questions were answered by workshop facilitators as much as possible, or were saved to ask the presenters following the lecture. After the lecture, participants had an additional 20 – 30 minutes in which they could ask questions of the presenter. Following the formal presentation and questions we had an informal "check in" with teachers about how their project work was coming. Teachers reported that participation in these webinars raised their awareness of energy issues, provided them examples to bring into their curriculum and increased their confidence in working with their student teams on projects for the Imagine Tomorrow competition.

Adventures in Bioenergy: Intensive four-day workshop delivered onsite with an online cohort "following along"

In the second workshop format, we invited a cohort of teachers to come to our field campus in McCall for a hands-on problem-based workshop exploring questions around bioenergy (Table NE-2.2).

Within this context, we explored two overarching essential questions:

- Is this a good idea? How do we define "good" when we ask if this is a good idea? By what criteria should we evaluate if this is a "good" idea?
- How do we know? By what measures do we know if something is "good"? What data do we have to use in our evaluation? How are these data generated?

And these additional guiding questions:

- How much wood waste is out there? (and how do we know?) (measurement)
- How does wood become jet fuel? (conversion)
- What do we do with the other stuff that doesn't turn into fuel? (co-products)
- What are the potential social, economic, and environmental considerations in these processes? (LCA and techno-economic analysis)
- What are some of the unintended consequences of this choice?

Teachers reported that this workshop helped them to think more critically about energy and the benefits and tradeoffs of various approaches to providing energy to meet societal demand. Additionally, they said that the format allowed them to really understand the problem-based learning model and to think of ways that they could apply it in their classroom.

Table NE-2.2. “Adventures in Bioenergy” teacher workshops.

Workshop Date	Workshop Title	# of participants	# of scientists involved	Funding Source
2015-16	*NARA E-book development*	6 online	n/a	USDA-NARA
June 2015	*Adventures in Bioenergy*	15 onsite 18 online	None onsite but materials (newsletters, videos, recorded webinars and scholarly papers) from across the NARA project were used in curriculum.	USDA-NARA
2014-15	*MOSS Imagines Tomorrow Webinars*	15 online	5	USDA-NARA
June 2014	*Adventures in Bioenergy*	17 onsite 19 online	4	USDA - NARA
2013-14	*MOSS Imagines Tomorrow Webinars*	30 online	5	USDA – NARA
June 2013	*Adventure Learning through biofuels, water and MOSS*	14 onsite 61 online	3	USDA – NARA NSF - EPSCoR
Fall 2012	*MOSS Imagines Tomorrow*	12 onsite	-	USDA – NARA
July 2012	*Adventure Learning through biofuels, water and MOSS*	13 onsite 49 online	3	USDA – NARA NSF - EPSCoR
June 2012	*Adventure Learning through biofuels, water and MOSS*	19 onsite 60 online	3	USDA – NARA NSF – EPSCoR

MOSS recruited six teachers from Washington and Idaho to participate in the 2015-16 MOSS NARA Teacher Professional Development. Teachers meet once a month with MOSS staff and MOSS NARA graduate students to explore topics associated with the supply chain. Teachers reviewed lessons and pilot tested these lessons with their students.

Finalized lessons are included in a NARA e-book that MOSS graduate students are creating and should be available in Fall, 2017. Background information, links and various resources are included in the e-book. Eight MOSS graduate students were funded through NARA to work on this e-book and the lesson creation for the Teacher Professional Development.

Teachers had their students take the high school Energy Assessment Tool created by the NARA Education Assessment team. In the spring students took the posttest to track changes in Energy Literacy. Teachers took the pre and posttest in addition. Teachers presented their experience at the Northwest Wood-based Biofuel and Co-products Conference in Seattle, May 2016. Teachers presented lessons they adapted, their experience with biofuels lessons, and their incorporation of the lessons within STEM curriculum. The NARA MOSS Teachers provided a rich context to the Education Strand at the conference. Several teachers commented on the valuable experience the conference gave them and how the year-long NARA MOSS Teacher Professional Development has enriched their teaching.

Results of the Pre/Post Workshop Evaluation indicate that as a result of the workshop, teachers gained confidence in teaching about biofuels and bioenergy and intend to include bioenergy topics in the classroom. Statistically significant differences were found between Pre-workshop and Post-workshop scores on answers to the statements “I am comfortable teaching about bioenergy in the classroom” (Mean Pre score = 4.32, Slightly Disagree; Mean Post score = 7.04, Agree); “I am knowledgeable about bioenergy issues (Mean Pre score = 4.44, Slightly Disagree; Mean Post score = 6.76, Slightly Agree) and “I include bioenergy as a topic in my classroom (Mean Pre score = 3.24, Disagree; Mean Post score = 5.28, Slightly Agree) (Tables NE-2.3 and NE-2.4).

Table NE-2.3. Paired samples statistics from workshop evaluation.

	Evaluation Questions	Mean	N	Std. Deviation	Std. Error Mean
Pair 1	I include bioenergy as a topic in my classroom (Pre)	3.24	25	2.314	.463
	I include bioenergy as a topic in my classroom (Post)	5.28	25	2.542	.508
Pair 2	I engage students in critical thinking about global issues (Pre)	6.69	26	1.784	.350
	I engage students in critical thinking about global issues (Post)	7.04	26	1.685	.330
Pair 3	Energy education is important (Pre)	7.62	26	2.858	.560
	Energy education is important (Post)	8.81	26	1.625	.319
Pair 4	Energy is relevant to and connected to the subject(s) I teach (Pre)	7.38	26	2.334	.458
	Energy is relevant to and connected to the subject(s) I teach (Post)	7.85	26	2.292	.450
Pair 5	I am knowledgeable about bioenergy issues (Pre)	4.44	25	1.917	.383
	I am knowledgeable about bioenergy issues (Post)	6.76	25	2.223	.445
Pair 6	I am comfortable teaching about bioenergy in my classroom (Pre)	4.32	25	2.719	.544
	I am comfortable teaching about bioenergy in my classroom (Post)	7.04	25	2.031	.406

Table NE-2.4. Paired Samples Test for teacher workshop

		Paired Differences							
					95% Confidence Interval of the Difference				
	Questions	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	I include bioenergy as a topic in my classroom	-2.040	3.116	.623	-3.326	-.754	-3.274	24	.003*
Pair 2	I engage students in critical thinking about global issues	-.346	1.325	.260	-.881	.189	-1.332	25	.195
Pair 3	Energy education is important	-1.192	3.099	.608	-2.444	.059	-1.962	25	.061
Pair 4	Energy is relevant to and connected to the subject(s) I teach	-.462	2.353	.462	-1.412	.489	-1.000	25	.327
Pair 5	I am knowledgeable about bioenergy issues	-2.320	2.610	.522	-3.397	-1.243	-4.445	24	.000*
Pair 6	I am comfortable teaching about bioenergy in my classroom	-2.720	2.441	.488	-3.728	-1.712	-5.571	24	.000*

* Indicates statistical significance at p<.05

When asked "What was your most important learning outcome of the week", teachers responded:

- A broadened range of knowledge of biofuel development/research.
- My most significant learning outcome is that I learned we could reduce the waste from logging sites, and actually have a purpose for them instead of burning the slash piles.
- Thinking about biofuels, the pros and cons that affect us socially, economically, and environmentally. There is a lot to think about when considering what should be used and getting it to be usable when creating biofuels.
- That technology exists to turn bio-materials into a product that can make planes fly!
- An awareness of another alternative source for fuel and the socioeconomic influences as well. These really were not something I had considered prior to this class.
- My most significant learning outcome is the networking, which takes place at these educational events. It is so helpful to talk with other teachers about curriculum and how teachers deliver that curriculum.

- Progress being made toward biofuel efficiency and research to alternates to petroleum based fuels.
- Life cycle assessment and the existence, uses of and burning of slash piles.
- I love this discussion that this created. It made me think about all those slash piles that I have hiked past and given very little thought about. My dad is the occasional logger and it started a conversation that was thoughtful and full of information that I had very little knowledge about. I look forward to discussing this with my 4th graders. We study Idaho history, biomes, ecosystems, etc...I can't wait to include this in my instruction.
- My most significant learning outcome from this experience is there are unique places to look for our fuel needs to help offset our dependence on fossil fuel. Also, I can see that there are companies willing to seek out these alternatives
- Often there are more unanswered questions than answered ones when looking into current topics in science research.
- Being educated on biofuel, what is, how it's used and also the pros and cons of using it as an alternative source of energy.
- I learned what biofuels are and how we can use them. It made me think about the products we use on a daily basis, and think about what the next 10 to 15 years might look like.
- How many "ifs" there still are.
- I didn't know this process was available. It has made me want to investigate what other possible biofuels there are.
- That there are ways to change existing structures to process the biomass.
- My perspective on the topic is extremely broadened. I knew very little about the potential and possibilities from biofuels and bioenergy. I feel excited to share the information with my colleagues and students and I hope to inspire students to come up with future solutions to energy problems.
- Learning how many parts of an interconnected web apply to all the decisions.
- I furthered my knowledge in Biofuel and Bioenergy, which before was non-existent!
- I have a better grasp of the energy value in organic matter. It has made me think about other sources of energy. Sagebrush?
- A better idea of all the variables in creating fuel from feedstock. Also, the impact of transportation costs.

A word cloud of teacher discussion on the class blog shows that the discussion was oriented around energy, waste, slash piles, ethics and thinking (Figure NE-2.1).

Figure NE-2.1. Word cloud from teacher discussion regarding the NARA project.

Energy Curriculum Web Delivery (FtF)

Facing the Future (FTF) is an independent program of Western Washington University that creates interdisciplinary K–12 curriculum resources that equip and motivate students to develop critical thinking skills, build global awareness, and engage in positive solutions for a sustainable future. These resources use global sustainability as a framework to present engaging, real-world issues such as energy to K-12 students. Our resources are used in all 50 states and over 140 countries through web-based delivery. FTF provides K-12 educators with high quality, low-cost curriculum resources through the web that engage students in learning math, science, language arts and social studies through the context of real-world social, environmental, and economic issues such as energy. FTF's professional development services equip educators with sustainability and global education frameworks and content, instructional strategies, and curriculum resources to help students excel academically. FTF works with peer educators from around the country who provide professional development to other educators based on FTF resources.

FTF contributed to the objectives of the GreenSTEM K-12 initiatives through the:

- development, dissemination, and promotion of K-12 curricular units called *Fueling Our Future (FOF)*;
- development and delivery of teacher training materials tailored to *FOF* and energy literacy; and,
- promotion of educational resources related to energy and bioenergy to our extensive network via social marketing campaigns and marketing collateral.

Curriculum Development, Dissemination, and Marketing

Facing the Future developed and published elementary, middle, and high school supplementary curricular units called *Fueling Our Future: Exploring Sustainable Energy Use (FOF)*. The purpose of these units is to provide classroom teachers with accessible, interdisciplinary lessons that will expose students to foundational energy concepts and provide students the opportunity to critically think about the sustainability of alternative energy sources such as woody biomass. Each unit is aligned to the principles outlined in the U.S. Department of Energy's peer-reviewed Energy Literacy Framework and is available for purchase via Facing the Future's website: www.facingthefuture.org. Additionally, FTF offers 1 free lesson from each unit that teachers can download from the landing page: www.edu/FOF. MOSS staff and graduate students provided extensive reviews and field-testing of these lessons, and several other NARA members reviewed lessons such as Tait Bower, Nathan Meehan, Daniel Schwartz, and Laurel James. Teachers from around the country and world were recruited to pilot these lessons and feedback was used to develop the final product.

The middle and high school versions of *FOF* are 9-lesson interdisciplinary energy curricular units that were developed, reviewed, and piloted during Years 1-3 of the NARA project. In addition to 9 lessons, each unit includes 4 student readings, a pre and post assessment to measure student growth in energy literacy, and a performance-based assessment (PBA). This PBA closely mirrors the NARA project - students conduct research on different biofuel supply chains, learn about stakeholders related to this project, and participate in a "regional council meeting" in order to determine which biofuel is most sustainable for the Pacific Northwest. *Lesson 8: The Life of a Fuel* focuses on the supply chains of different fuels including woody biomass.

The elementary school version (grades 3 through 5) of *FOF* is a 6-lesson interdisciplinary energy curricular unit that was developed, reviewed, and piloted during Years 3-5 of the NARA project. This unit includes 6 lessons and a pre and post assessment to measure student growth in energy literacy. The lessons were developed to be vertically aligned to the middle and high school versions of *FOF* and cover topics from basic energy science, to the supply chain of fuel, to case studies that feature youth conserving energy.

FTF has promoted the elementary, middle, and high school versions of *FOF* to our extensive network via the development of marketing collateral and social marketing campaigns. The units have been promoted to our network through a fall social media marketing campaign, eNewsletters, blogs and by strategic partners such as the Snohomish County PUD, and an Albert Einstein Fellow at the Department of Energy. Promotional efforts also included two marketing emails to our network of 30,000 educators and an email highlighting *FOF* to a new network of 5,000 teachers.

In addition, FTF has promoted the educational resources and tools developed by other members of the NARA Education team as well as other educational resources related to energy or bioenergy literacy through social media, flyers, and presentations. FTF has supported the U.S. DOE's energy education efforts by sharing their messages with our teacher network. In the last 2 years of the NARA project, we have conducted a presentation and shared NARA Educational resources with teachers at the Imagine Tomorrow competition. We also hosted Charmayne Smith, a participant in the UW Tribal Partnerships Project Summer Internship Program, who helped with our July teacher workshop and performed market research on curricula related to the carbon cycle.

As of June 30, 2016, 508 copies of *FOF* (53 elementary, 253 middle school, and 202 high school) have been distributed and 272 free individual lessons have been downloaded from FTF's website, reaching 23,400 students. The number of resources reaching the NARA states is shown in Table NE-2.5.

Table NE-2.5. Distribution of Fueling Our Future in the Pacific Northwest

STATE	Idaho	Montana	Oregon	Washington
Number of Teacher's Guides and Free Lessons	24	2	47	140
Potential Student Reach*	720	60	1,410	4,200

*FTF conservatively estimates that 50% of teachers who order the resource use the resource, and each teacher serves 60 students.

Teacher Training—Development and Delivery

FTF developed teacher training materials tailored to *FOF* and energy literacy that have been used for webinars, workshops, presentations, and FTF's Peer Educator Program. In particular, a 6-hour workshop was developed in partnership with the Snohomish County PUD's education program that has been conducted 2 more times than anticipated due to educator feedback and interest. Plans are underway to use content and video footage from this workshop in the development of an online course for WWU-FTF.

Additionally, the 2015-2016 Peer Educator Program featured energy and the curriculum developed during Years 1 through 4 of NARA, *Fueling Our Future (FOF).* FTF Peer Educators are experienced teachers who regularly use FTF materials to meet the needs of diverse learners in K-12 settings. Peer Educators facilitate workshops in their own school or district, at regional professional development meetings and at national conferences. This past year, 6 peer educators received training on the *FOF* curriculum through Canvas' online conferencing tool. These educators also received FTF resources they can use to conduct teacher workshops such as the FOF units, teacher training materials, and marketing flyers. Though some peer educators are still waiting to hear back about acceptance of workshop proposals, 3 events related to energy have been conducted in 2016 reaching about 47 teachers. After facilitating a workshop, one peer educator wrote:

"I was quite surprised at the participants that I worked with and how ill at ease they were with their knowledge around Energy. The resources that were shared are fantastic and this was an incredible help and I have had contact with participants since the workshops I conducted."

As of June 30, 25 FTF professional development events related to energy and/or *FOF* have been conducted reaching over 750 educators/participants. These 25 events included:

- 2 webinars,
- 1 YouTube video (a recorded webinar),
- 1 virtual meeting with Peer Educators, and
- 21 in-person workshops (3 facilitated by Peer Educators and 18 facilitated by FTF staff).

Other outreach efforts included:

- A presentation at the CleanTech Alliance™ Washington's Workforce Breakfast Series "Not Just for Kids: Educating Tomorrow's Cleantech Workforce" in October 2014.
- A presentation of *Fueling Our Future: Lesson 6* at the WA Corrections Center for Women through the Sustainability in Prisons Project Guest Lecture Program in 2014. (43 attendees)
- Attendance at both the 2015 and 2016 National Energy Education Summit.
- A presentation during Session 13: Bioenergy Education at the 2016 National Energy Education Summit and contributions on behalf of this session to the Summit report.
- An article about FTF's global sustainability approach to energy education published in the Journal of Sustainability Education.

Middle and High School Curriculum

FTF received feedback on the *FOF* curriculum from teacher pilots of initial drafts of *FOF* lessons, a small study that FTF conducted with MS and HS teachers who used *FOF lessons*, and from a study that University of Idaho's MOSS conducted on their energy programs in which a few modified *FOF* lessons were used.

The FTF study that was conducted began with the recruitment of middle and high school teachers to administer a coded Energy Literacy Survey to students before and after they were exposed to lessons (at least 2) from Facing the Future's *Fueling Our Future* in order to gather 2 sets of data for each individual. The Energy Literacy Survey included 4 sections. Section 1 included questions that had students self-assess their energy knowledge and behavior. Sections 2 and 3 included questions that addressed the affective (attitude) and behavioral aspects of energy literacy, and a few questions related to sustainability; most of the questions in sections 1 through 3 came from the *Energy Literacy Survey: A Broad Assessment of Energy-related Knowledge, Attitudes, and Behaviors*, High School Version 3[1]. However, questions 12-15 were written by FTF to address sustainability and to help inform FTF programming. In the end, question 12 was not included in the data because the content was seen as an outlier. Finally, questions in Section 4 addressed the cognitive dimension of energy literacy and came from the NARA Energy Literacy Assessment. These questions were designed to assess bioenergy- and energy-related content knowledge and to align with the US Department of Energy's peer-reviewed Energy Literacy Framework [2].

The total number of participants that completed both the pre-survey and post-survey was 50; this included 42 middle schoolers and 8 high schoolers. While 83 students (70 middle school; 13 high school) completed the pre-survey, only 50 students (43 middle school; 8 high school) completed the post-survey. For the surveys that were counted, the pre and post scores for each construct were entered into SPSS and a paired t-test was conducted. Dr. Jennifer Schon from MOSS helped to analyze results, which are shown and discussed below (Table NE-2.6)

Table NE-2.6. Middle School Results from FTF's Study

Construct	Mean Pretest Score	Standard Deviation Pretest	Mean Posttest Score	Standard Deviation Posttest	Significance* Pretest vs. Posttest
Self-Assessment (15 points possible)	8.57	1.73	8.90	1.87	.255
Affective (35 points possible)	26.62	4.85	27.54	4.18	.127
Behavior (20 points possible)	11.88	2.73	12.79	2.21	.044
Cognitive (22 points possible)	11.60	3.04	13.33	3.00	.000
Total (92 points possible)	58.67	7.73	62.57	6.78	.000

* These numbers indicate a positive increase from one test to the next. Any value less than .05 is considered to be statistically significant.

[1] Questions in Sections 1, 2, and 3 (except for questions 12-15) are used with permission from Jan DeWaters and Researchers at Clarkson University's *Energy Literacy Survey: A Broad Assessment of Energy-related Knowledge, Attitudes, and Behaviors*, High School Version 3, (Potsdam, NY: Jan DeWaters, 2009), http://www.clarkson.edu/cses/research/energylitproj.html.

[2] U.S. Department of Energy, Energy Literacy: *Essential Principles and Fundamental Concepts for Energy Education*, (Washington, DC: July 2013), www.energy.gov/energyliteracy.

Middle School Results – statistically stated:
The mean self-assessment pretest was 8.57 (*sd* = 1.73); the mean self-assessment posttest was 8.90 (*sd* = 1.87). A significant increase from pretest to posttest was not found for self-assessment (t (41) = -1.16, p=.255). The mean affective pretest was 26.62 (*sd* = 4.85); the mean affective posttest was 27.54 (*sd* = 4.18). A significant increase from pretest to posttest was not found for affective (t (41) = -1.56, p=.127). The mean behavior pretest was 11.88 (*sd* = 2.73); the mean behavior posttest was 12.79 (*sd* = 2.21). A significant increase from pretest to posttest was found for behavior (t (41) = -2.07, p<.05). The mean cognitive pretest was 11.60 (*sd* = 3.04); the mean cognitive posttest was 13.33 (*sd* = 3.00). A significant increase from pretest to posttest was found for cognitive (t (41) = -4.19, p<.000). The mean total pretest was 58.67 (*sd* = 7.73); the mean total posttest was 62.57 (*sd* = 6.78). A significant increase from pretest to posttest was found overall (t (41) = -3.90, p<.000) (Table NE-2.7).

Table NE-2.7. High School Results from FTF's study

Construct	Mean Pretest Score	Standard Deviation Pretest	Mean Posttest Score	Standard Deviation Posttest	Significance* Pretest vs. Posttest
Self-Assessment (15 points possible)	8.75	1.67	9.12	0.99	.528
Affective (40 points possible)	33.50	5.48	34.50	5.42	.104
Behavior (20 points possible)	12.38	2.39	13.38	2.97	.200
Cognitive (22 points possible)	15.38	2.39	16.00	3.02	.588
Total (92 points possible)	70.00	9.12	73.00	10.31	.106
* These numbers indicate a positive increase from one test to the next. Any value less than .05 is considered to be statistically significant.					

High School Results – statistically stated
The mean self-assessment pretest was 8.75 (*sd* = 1.67); the mean self-assessment posttest was 9.12 (*sd* = 0.99). A significant increase from pretest to posttest was not found for self-assessment (t (7) = -0.664 p=.528). The mean affective pretest was 33.50 (*sd* = 5.48); the mean affective posttest was 34.50 (*sd* = 5.42). A significant increase from pretest to posttest was not found for affective (t (7) = -1.87, p=.104). The mean behavior pretest was 12.38 (*sd* = 2.39); the mean behavior posttest was 13.38 (*sd* = 2.97). A significant increase from pretest to posttest was not found for behavior (t (7) = -1.41, p=.200). The mean cognitive pretest was 15.38 (*sd* = 2.39); the mean cognitive posttest was 16.00 (*sd* = 3.02). A significant increase from pretest to posttest was not found for cognitive (t (7) = -0.57, p=.588). The mean total pretest was 70.00 (*sd* = 9.12); the mean total posttest was 73.00 (*sd* = 10.31). A significant increase from pretest to posttest was not found overall (t (7) = -1.86, p=.106).

Teachers and Trainings
In Years 4 and 5 of the NARA grant, Danica Hendrickson collected pre- and post-surveys from teachers at 7 out of the 8 FTF-led and FTF-facilitated workshops in order to evaluate FTF's energy-related professional development programming. The pre-survey included background questions about the educational environment teachers are involved with and 7 statements (see Table 4 below) that participants rated from strongly agree to strongly disagree. The post-survey included the 7 statements from the pre-survey, 2 statements asking about the likelihood of participants integrating sustainability and energy into their curriculum (see Table NE-2.8), and open-ended questions about the workshop suggestions and take-aways. Seventy-six people completed the pre-survey and 67 people completed the post-survey. Answer choices for each statement and the corresponding score are as follows:

- Strongly Agree – 5
- Agree – 4
- Neutral – 3
- Disagree – 2
- Strongly Disagree – 1

Table NE-2.8. Data from FTF's Teacher Workshop Post Survey Questions 8 and 9

	After taking this workshop, I am more likely to integrate sustainability into my curriculum.	After taking this workshop, I am more likely to integrate energy into my curriculum.
Question	Question 8	Question 9
Test	POST	POST
Average	4.43	4.55
Std. Dev.	0.60	0.76

Results from these pre and post surveys show that:

- The greatest positive change between the pre and post survey was in questions 6 and 7 which asked teachers to state how knowledgeable they were about biofuels and biofuels research, respectively.
- 97% of respondents agreed (63% strongly agreed; 23% agreed) with this statement: *After taking this workshop, I am more likely to integrate energy into my curriculum.*

- 94% of respondents agreed (49% strongly agreed; 45% agreed) with this statement: *After taking this workshop, I am more likely to integrate sustainability into my curriculum.*

A few of the open-ended questions on the post-survey and responses listed below:

What's one action you could take in your classroom/work life to implement what you have learned today?
- "Integrate energy instruction with other disciplines (not just science)."
- "I already teach a unit on energy but I will integrate throughout the year and have kids make more personal connections"
- "Incorporate parts of this curriculum next year and share with team members to hopefully have some cross curricular collaboration."
- "Integrate an energy-based lesson into sustainability unit"

What is one action you could take in your personal life to implement what you have learned today?
- "Continue awareness/learning about biofuels esp. the project with Alaska Airlines."
- "Support biofuel research"
- "awareness on how my choices of energy use impact local and global community"
- "Continue learning about energy so can better teach it."
- "Reflective thinking of multiple perspectives in energy for our world. As a science teacher one tends to think only of the environmentalist view."

What is one of the most useful or interesting takeaways from this workshop and why?
- "Appreciation for various energy types. Eager to follow biofuel news now that I understand it more."
- "The most useful takeaway is the Facing the Future the curriculum. Thank you!"
- "That biofuels are being explored for aviation fuels"
- "I found the NARA project very interesting - a very real world use of STEM to share with my students."
- "Ozone is recovering, positive changes re: environment; NARA renewables website; Fueling our Future"
- "That biofuels are being explored for aviation fuels"
- "Understand concepts more - big plus.; Familiarity with book/lessons.; Appreciate the book and lunch!"

Conclusions/Discussion - FTF
FTF has completed the development of elementary, middle, and high school curriculum units called *Fueling Our Future* and continues to disseminate this curriculum through their website www.facingthefuture.org. As of June 30, 2016, 508 copies of *FOF* (53 elementary, 253 middle school, and 202 high school) have been distributed and 272 free individual lessons have been downloaded from FTF's website, reaching 23,400 students (FTF conservatively estimates that 50% of teachers who order the resource use the resource, and each teacher serves 60 students). Results from a small study conducted by FTF and a study conducted by University of Idaho's MOSS on their energy programming (which incorporates some lessons from *FOF)* suggest that these lessons can positively impact the energy literacy of students, though, more data would be beneficial. The study that FTF conducted showed a significant increase in energy literacy from pretest to posttest in the middle school students that participated (42 total), but not the 8 high school students (8 total).

FTF has completed the development of teacher training materials related to the *FOF* curricula and trained 6 peer educators to train teachers using the *FOF* curricula. As of June 30, 2016, has conducted 25 events reaching over 750 educators/participants. Teachers who attended an FTF-facilitated workshop about energy showed that professional development events that highlighted biofuels and the NARA project can positively impact how knowledgeable teachers feel about biofuels and biofuels research and their willingness to integrate energy and sustainability into their curriculum.

FTF uses the lens of global issues and sustainability to frame and develop interdisciplinary curricula and teacher workshops. We've found this global sustainability framework is an authentic context for helping teachers and students learn about the NARA project and critically think about the social, economic, and environmental issues associated with energy and biofuels. This interdisciplinary approach to energy education can also help teachers who teach non-science subjects identify ways to integrate energy into their classrooms. Finally, we've found that leveraging existing energy education research and resources can lead to strategic partnerships that can encourage a more collaborative and coherent approach to advance bioenergy education.

TASK 3: BIOREGIONAL INTEGRATED DESIGN EXPERIENCE (IDX)

Introduction

IDX is an integrated design studio experience for students in engineering, design (architecture and landscape architecture), natural resources, and planning disciplines, focusing on technical assistance to communities interested in participating in the emerging biofuel economy. IDX involves a year long integrated design course delivered jointly through Washington State University (WSU) and the University of Idaho (UI). The course is a trans-disciplinary planning and design studio that addresses the planning and infrastructure needs of communities exploring their role in biofuel supply chain. Aimed at upper-level BS and MS students, the course is organized around service-learning experiences that link teams of students with communities. PhD students from around NARA with special expertise in required areas consultant to the design teams, improving the level of analysis. The IDX team was tasked with evaluating pilot supply chains in the NARA fours state region. IDX student teams assess and analyze regional assets to develop wood-to-biofuels pilot supply chain scenarios in Washington, Oregon, Idaho and Montana. Five different pilot supply chain regions were served, one each year of the project, with a focus on identifying regional supply chain assets, optimizing sub regional biofuels supply chains, and designing interventions at specific locations within the supply chain (e.g., depot sites, conversion facilities, multi-modal transportation hubs, etc.).

Task Objective

The goals for IDX studio are to:

1. Ensure that every student exits with strong collaborative research, questioning, and design methods to utilize in their academic and professional work within their discipline.
2. Provide technical assistance to communities interested in participating in the emerging biofuel economy. We will assist these communities begin the process of transformation necessary for them to be engaged in the biofuels supply chain.
3. Envision how regions and specific sites can play a role in the biofuels supply chain by collecting regional supply chain assets, analyzing optimal supply chains scenario, and designing depot and conversion site interventions (e.g., site programming, engineering and planning).

Methodology

During the 5 years of the NARA project the IDX team collected assets for the entire 4 state region and analyzed 5 pilot supply chains:

- Year 1: Clearwater Basin in North Central Idaho, 2011-2012
- Year 2: the Western Montana Corridor (WMC), 2012-2013
- Year 3: the Mid-Cascade to Pacific (MC2P), 2013-2014
- Year 4: the Pacific Northwest Region (PNW), 2014-2015
- Year 5: the Olympic Peninsula (OP), 2015-2016

The IDX method examined the NARA supply chain, identifying specific regions, nodes, and linkages where key activities in the supply chain could be sited. The NARA supply chain is shown in Figure NE-3.1. A supply chain can be analyzed for regions, nodes and linkages. A biofuels supply chain initially requires a **region** rich in biomass. For NARA, the biomass of interest is forest residuals, as well as construction and demolition debris (C&D waste). Feedstock materials are refined from this raw biomass, at specific **nodes** termed 'depots' and 'conversion' sites. These nodes may exist at a landing of a forest harvest operation or at a nearby facility such as a sawmill or chipping yard. At depot sites, the forest residuals are sorted, ground, and loaded for transport to other nodes, that is conversion facilities where the chips undergo mechanical, chemical, and biological treatments to produce isobutanol. Finally, **linkages** are transport systems that enable the transfer of materials between nodes (e.g., forest roadside pickup from slash piles, highway, rail and pipelines).

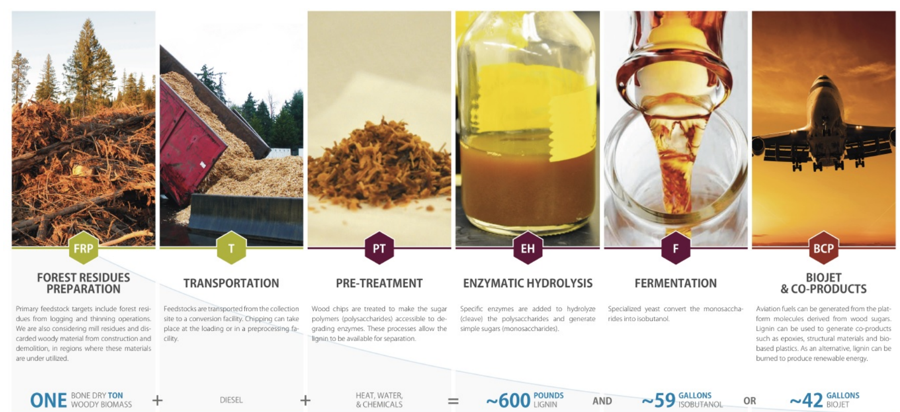

Figure NE-3.1. NARA Supply Chain

To analyze the supply chains and identify locations for particular biofuels facilities, a number of methods were developed including biomass estimation for feedstock supply curves, site selection, and site design.

Biomass Estimation for Feedstock Supply Curves

IDX developed a biomass estimation process utilizing the Total Product Output (TPO) dataset from past harvest data. The TPO data includes forest residual volumes per class (federal, state, tribal, etc.) in each county. To provide an accurate GIS dataset with a high level of detail a three step his process was established. In the first step the area of forest coverage in each TPO class for each county in the four-state region was calculated after excluding all non-forested areas and other areas with minimal residual harvesting. Next the volume of forest residuals of each TPO class for each county in the four-state region was calculated for each area in the first step, and finally the density for each area is calculated and added the GIS file to provide a detailed forest residual density dataset for the four state region.

Site Selection

IDX developed a site selection methodology to identify potential sites for pre-conversion depots (Solid or Liquid), conversion plants, and integrated biorefineries (IBR). Site selection compares the programming needs (e.g., activities that occur on site and required equipment) of a new facility with geographic and site specific assets in a given region. GIS analysis and decision matrices were used to identify, assess and rank potential sites based on their assets. GIS was used to analyze potential sites by geospatial evaluation of pertinent assets at a given site. Decision matrices were used to rank the potential sites based on providing a valuation of multiple applicable assets. The matrices provide a mechanism for ranking/ weighting asset data based on their level of importance for selecting a depot or conversion facility site. The weighted algorithm evaluates the value of each asset on a site and provides a ranking of each site. Key assets, organized by the community capitals framework[3], for wood-based biofuels facilities are listed in Table NE-3.1.

[3] Flora, C. Emery, M. Fey, S. and Bregendahl, C. 2005. Community capitals: A tool for evaluating strategic interventions and projects. http://oklahoma4h.okstate.edu/ edu/docs/7-capitalshandout.pdf.

Table NE-3.1. Biofuels Facility Assets, Organized by Community Capital Framework.

Capital	Asset
Natural	Biomass Availability
Physical	Road Access
	Port Access
	Rail Access
	Facility Size
	Facility Status (active, decommissioned)
	Facility Type (Sawmill, Paper Mill, Refinery)
	IBR Proximity to Airport
	Onsite Assets (boiler, wastewater treatment)
Social	Social Capital
	Creative Vitality Index
	Poverty
Financial	Natural Gas Rates
	Electricity Rates
	Labor Costs

Site Design

Once sites were identified, IDX examined them for the addition of a biofuels facility. A number of steps were taken including site analysis, schematic design, and design development. Site analysis examines site opportunities and constraints for development of the site as a depot or IBR. The primary objective of the schematic design is to arrive at a clearly defined, feasible concept. The schematic drawings demonstrate basic spaces, scale and relationship of components. The secondary objective is to clarify the project program, explore the most promising alternative design solutions, and provide a reliable basis for analyzing the cost of the project. The design development phase focuses on the technical aspects of materials and infrastructure systems. Although this phase allows the designer to further refine space and function, the primary goal is to illustrate how the project will function as well as give more detail about what the design will look like.

Results

NARA considered two models to facilitate a complete wood-based biojet fuel supply chain. One model is built around a large centralized IBR, a high-capacity plant that receives direct haul feedstock and converts the biomass from raw slash all the way to biojet fuel. The second model is a distributed production approach, where multiple remote depots could produce intermediate products (i.e. refined and sorted biomass, wood-based sugar-rich liquids, isobutanol), which could supply conversion plants. These distributed operations could help maintain economies of scale for other core processes, such as fermentation and conversion of alcohol to biojet fuel. Three main facility types, depots, conversion plants and IBRs, were analyzed. Figure NE-3.2 illustrates the model options.

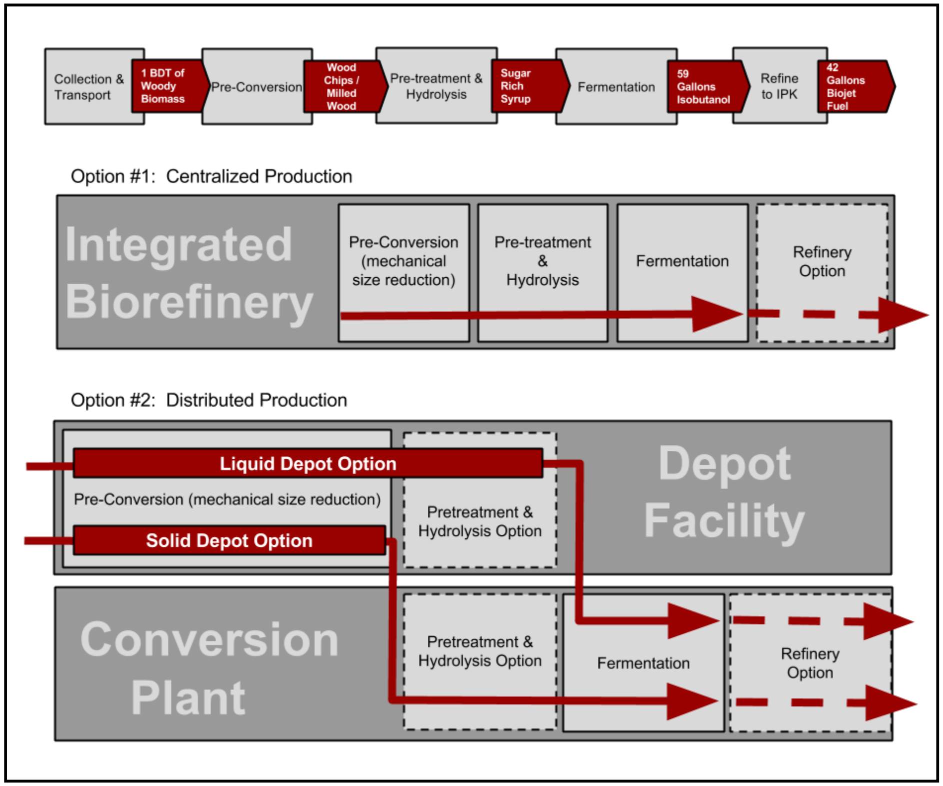

Figure NE-3.2. Wood to Biofuels Supply Chain Pathway Options

Depot facility: A pretreatment facility that prepares the biomass for processing in a conversion facility. IDX assumed that a depot facility would process 100,000 to 250,000 BDT/year. Three depot options were investigated:

- *Solids Depot:* a pre-conversion facility that receives post-harvest forest residuals, forest thinnings, and/or C&D waste biomass. Mechanically processed materials, in the form of chips, could be shipped by rail or highway truck to a receiving liquids depot, conversion plant, IBR or other potential end user (e.g., fuel pellet manufacturer).
- *Micronized Wood Depot:* a pre-conversion facility that receives post-harvest forest residuals, forest thinnings, and/or C&D waste biomass. Mechanically processed material, in the form of finely ground wood flour, could be shipped by rail or highway truck to a receiving liquids depot, conversion plant, or IBR. Due to the particle size of the wood flour (0.01mm), the mild-bisulfite pretreatment step is bypassed; wood flour can go directly to enzymatic hydrolysis.
- *Liquids Depot:* a pre-treatment facility that receives raw and mechanically processed woody residuals directly from nearby forests, chips from a solids depot, or wood flour from a micronized wood depot. A liquids depot produces a concentrated sugar-rich syrup that would be transported for con version to isobutanol at an IBR for further refining into biojet fuel or other chemical conversion facilities.

Conversion plant: A high-capacity plant that takes in chips from a solids depot, wood flour from a micronized wood depot, or liquid sugars from a liquids depot and produces isobutanol. IDX assumed that a conversion plant would process 250,000 to over 700,000 BDT/year.

Integrated Biorefinery (IBR): A high-capacity plant that converts biomass from raw slash or other woody residuals all the way to biojet fuel. Based on the NARA techno-economic analysis (TEA), it was assumed the IBR would process upwards of 770,000 BDT/year.

The centralized and distributed production models each aim to produce biojet fuel as the final product. The NARA four state region has diversified supply chain assets across a vast geography. IDX evaluated both supply chain models based on existing assets in the region, evaluating best sites for locating particular facilities.

Results, including analysis of each region, potential pilot supply chains, and site design work for pilot supply chain studies have been compiled for the Clearwater Basin, the WMC, the MC2P, and PNW, and the OP. Reports for each of these supplies chain studies are available under "Supply Chain Analysis" on the NARA website. Furthermore, an interactive storymap has been developed through ESRI, and is available at the following link: https://wsuniv.maps.arcgis.com/apps/MapJournal/index.html?appid=3a748d4e64604b83b4f07e6e9fb40bec

Conclusions/Discussion

A number of conclusions can be reached based on the work performed by IDX. First, IDX developed two supply chain production pathways based on the realities of regional feedstock availabilities and other regional and site-specific assets: a centralized production model for an IBR with direct haul of feedstock, and a distributed production model where a conversion plant receives feedstock from multiple remote depots. Second, IDX realized that there was a need to identify specific locations for siting solids and liquids depots, conversion plants, and IBRs. Thus, IDX developed a site selection method that identified hotspots for biofuels facility siting. Third, IDX found that it is important to have strong community engagement and support when making siting decisions for proposed biofuels facilities. Each of these conclusions is discussed in greater detail below.

1. Supply Chain Production Pathways
Feedstock quantities vary geographically across the 4-state region. Working with the NARA TEA assumption that an IBR requires 770,000 BDT/year of feedstock, IDX found that not all regions in the 4-state area could independently support an IBR with direct haul of biomass to the plant gate. For example, there is ample feedstock on the west side of the Cascade Range, in the MC2P, to support more than 1 IBR. However, on the east side, particularly in the WMC and the Clearwater Basin, the dryer, less dense and more dispersed forests require a distributed model, where remote sites, which collect and densify forest residuals, supply a conversion/IBR facility.

IDX also examined intermediate steps in the biofuels supply chain, in particular looking at liquids depots. This intermediate option produces a wood-based sugary syrup, which could be marketed to a biorefinery, or to other consumers interested in wood-based sugars (e.g., chemical manufacturer, polymer manufactures, and/or the bioplastics industry [PHB [polyhydroxybutyrate & polylactic acids], such as Blue Marble Biomaterials in Missoula, MT or Renmatix in Philadelphia, PA). For potential investors interested in entering the wood-based biofuels market starting with a liquids depot that produces a versatile product could be less risky and more affordable than building an IBR.

2. Facility Siting Criteria
IDX, working closely with PhD candidate Natalie Martinkus, identified locations for siting biofuels facilities. Both geographic and site specific assets that fed into site selection included: availability of forest residuals, transportation infrastructure (rail, road, barge, pipeline), facility size, facility status (e.g., active, decommissioned), electric costs, natural gas, pretreatment capability, boiler/energy plant, onsite wastewater treatment, cost of living, and unemployment. The factors were weighted based on their relative importance, as outlined in the scientific literature. Using GIS to map the facilities and their assets, a hotspot map was produced, which showed key locations for biofuels facilities. Figure NE-3.3 shows a hotspots map, where blue squares represent paper mills, red dots saw mills, and organ dots refineries or ethanol plants. IDX found that the counties just north and south of the Columbia River in Washington and Oregon contain a significant number of assets to support solids and liquids depots, conversion plants, and IBRs. Other hotspots include southern Oregon, northeastern Washington, north central Idaho, and western Montana. These locations are more likely able to support solids and liquids depots than an IBR.

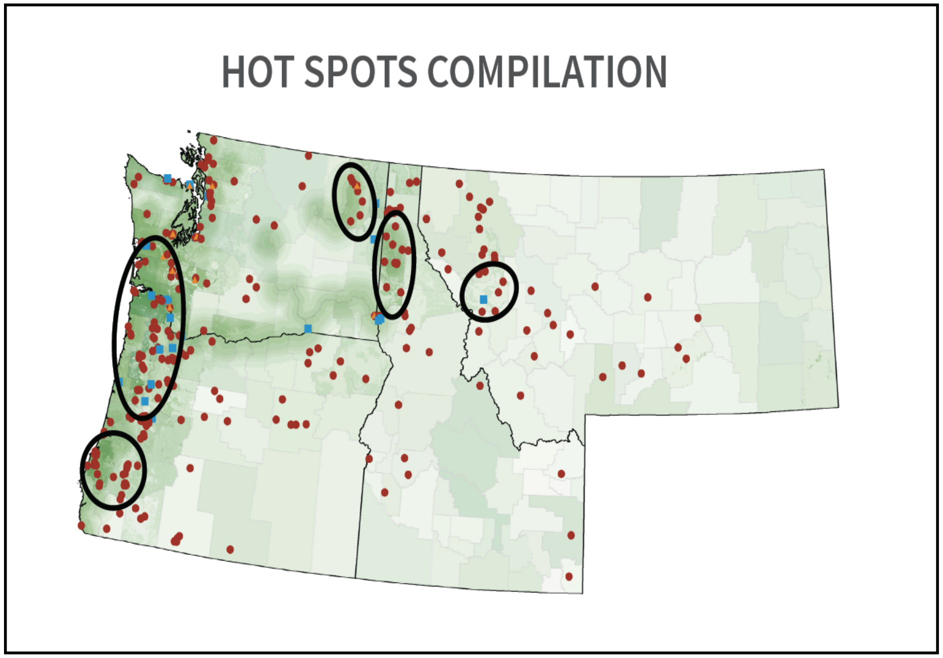

Figure NE-3.3. Biofuels Facility Siting Opportunities based on Geographic & Site Specific Assets

3. Community Engagement and Support for Wood-based Biofuels
Working closely with interested industries and communities makes a significant difference in the success of student research, analysis, and designs. We had extensive engagement from stakeholders in the Western Montana Corridor, in Grays Harbor County, WA, Longview, WA, and on the Olympic Peninsula. People in these locations gave facility tours, provided data, and gave feedback on student work; all of which improved student deliverables.

During year 5, when IDX worked on the Olympic Peninsula, Drs Laninga and Moroney conducted a survey of stakeholders in Clallam and Jefferson counties. Results of the survey showed that community members in Clallam County, where Port Angeles is located, are significantly more supportive of a wide range of options for utilizing woody biomass from forest management activities, including a bioenergy power plant, a wood pellet production plant, a sawmill, a wood products manufacturer, or a liquids biorefinery, than their counterparts in Jefferson County, where Port Townsend is located. The findings from this survey show the importance of identifying not only regional and site specific assets, but also community support in the success of siting biofuels facilities.

TASK 4: IMAGINE TOMORROW WITH BIOFUELS

Introduction

The NARA Imagine Tomorrow program is designed to engage high school students in developing creative solutions to society's energy challenges. This project built upon the Imagine Tomorrow high school science competition at Washington State University. NARA supported the competition from its fifth through ninth year. In the ninth year it was renamed the Alaska Airlines Imagine Tomorrow Competition. The goal of Imagine Tomorrow is to unite educators, scholars, and industry leaders to teach students of all backgrounds and high school grade levels how to translate ideas into results. With the NARA support, this energy-based competition program was expanded to include a biofuel track and welcome students from the four state region of Washington, Idaho, Oregon and Montana. The objectives of Imagine Tomorrow are to:

1. Engage future energy innovators. Students find ways to shift the public mindset, reshape governance and policy, reengineer technologies, and redesign communities toward a new energy future.
2. Foster collaboration. The competition shows students how collaborative actions make a difference in meeting the challenge of energy production and use in the 21st century.
3. Support educators. High school teachers inspire students to think bigger, gather information from diverse resources, and jointly develop new ideas.
4. Strengthen our community. Imagine Tomorrow creates connections among students, research faculty, and industry leaders. Students build confidence in their ability to make a positive difference in their communities.
5. Raise energy literacy. Imagine Tomorrow builds awareness of energy issues among students, educators, and the general population.

Task Objective

This task had five main objectives, which are contained in the Table NE-4.1.

Table NE-4.1. NARA Imagine Tomorrow task objectives.

No.	Task Objectives	Years Completed
4	Assessment and survey collection and analysis	2013-2016 (Survey only 2012)
11	School and Student Recruitment	2012-2016
17	Recruit and Select Judges	2012-2016
23	Program Delivery - Imagine Tomorrow Competition	2012-2016
24	Final Report	Underway 2016

Methodology

The NARA representatives worked on the Imagine Tomorrow Steering and Executive Committees over the five years of the NARA participation with typically monthly meetings of the Steering Committee and annual meetings of the Executive Committee. Over the last three years of the project, the NARA liaison was also director of judging for the competition and aided in the development of the re-arrangement of the competition in the last year as explained in the Results Section. The Steering Committee oversaw school, student and judge recruitment, marketing for the competition and the implementation of the competition each May under the direction of a Director with supporting staff.

In the first year, standard surveys on the general view of the competition were sent to the participants, under the direction of the Director. In subsequent years, the NARA representatives participated in an assessment subcommittee that focused on both the STEM impacts of the competition and energy literacy aspects. The STEM impacts were evaluated as part of the survey instrument under the direction of Dr.s Brian French and Chad Gotch, and were compiled into a report to the Steering Committee post the competitions in 2013, 2014, 2015 and 2016. The energy literacy assessment was led by the NARA liaison, Dr. Liv Haselbach and resulted in reports to the Steering Committee and various publications as listed in the outputs. These were based on reviewing abstracts from all competitions from 2009 onward in 2012, and photos of the posters in the 2013, 2014, 2015 and 2016 competitions. Due to the rearrangement of the competition in 2016, the energy literacy assessment also included a review of other sustainability topics in the competition.

Results

The competition was held successfully each May for the five years of NARA participation and the number and types of attendees are listed in the Outputs section (Physical). The addition of the Biofuels challenge attracted the attention of the Department of Energy, which then provided additional awards to one team in 2014 and another team 2015. The DOE funded a team to the Biofuels conference in Washington DC in 2014 and a team to visit DOE laboratories in 2015.

The funding also partially provided for the development of an energy literacy rubric, which has been vetted over several of the competitions, with subsequent peer-reviewed publications, proceedings and presentations, also listed in the Outputs section. This energy literacy rubric is based on the Department of Energy, Energy Literacy Principles, and could be used in evaluating deliverables such as posters or papers. The analysis of the rubric provided some insight into the efficacy of the competition related to energy literacy and some variables of consideration for most of the years. Of note was the gender neutrality of the competition, with respect to energy literacy scoring. In addition, there was no significant difference between the scoring for teams advised by STEM versus non-STEM focused advisors. Energy literacy scores tended to be higher for those in the biofuels challenge and also for those teams who competed as part of a classroom activity. Some representative data from the energy literacy assessment for the 2015 competition on the posters are provided in Figures NE-4.1 through NE-4.6.

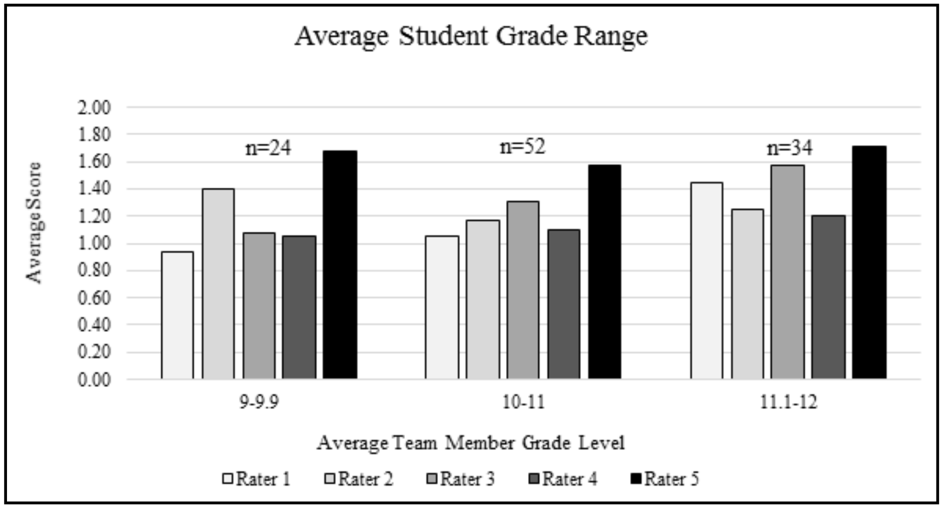

Figure NE-4.1. Average team member grade range average scoring trend for 2015 posters. (n is the sample size)

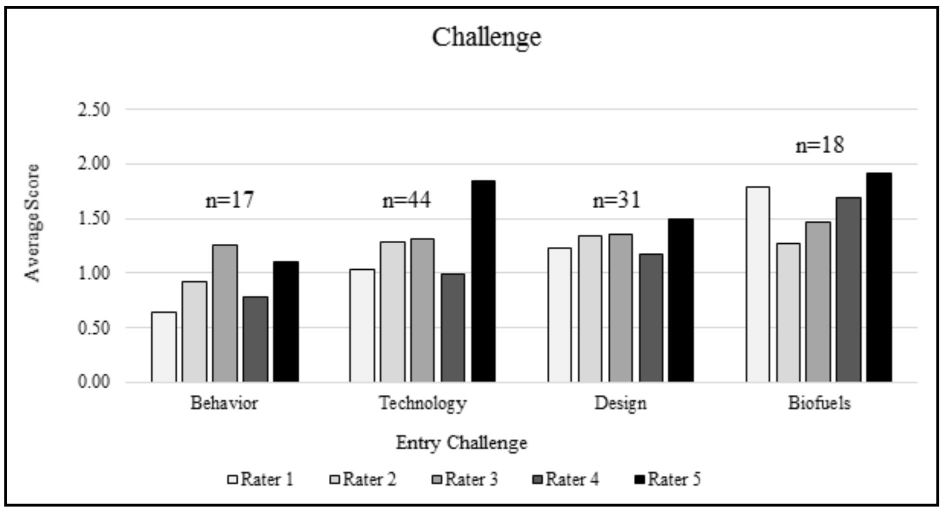

Figure NE-4.2. Scoring trends by challenge entered for 2015 posters. (n is the sample size)

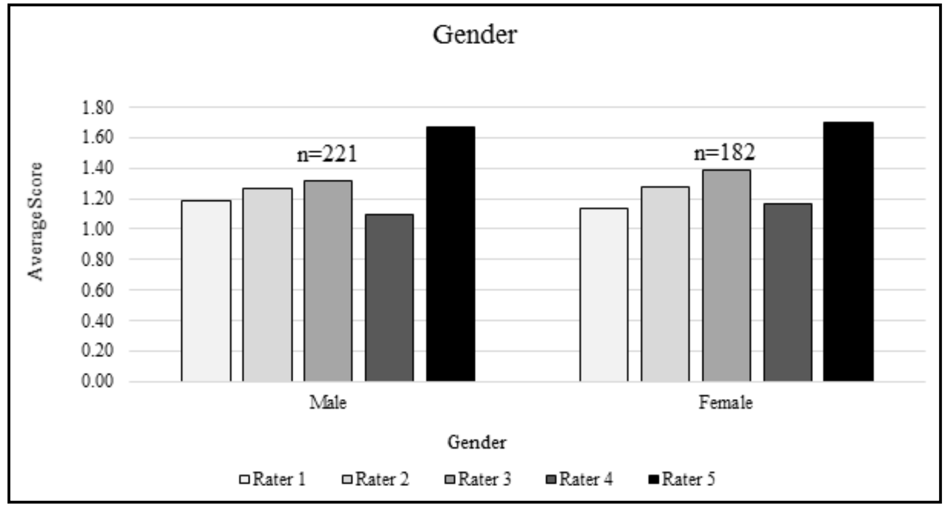

Figure NE-4.3. Gender average scoring trend for 2015 posters. (n is the sample size)

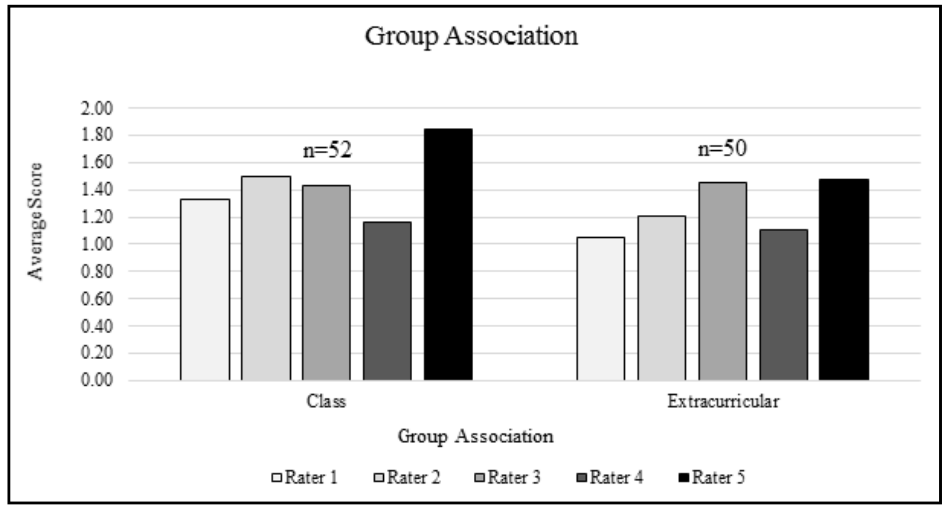

Figure NE-4.4. Group association (class or extracurricular) average scoring trend, 2015 posters. (n is the sample size)

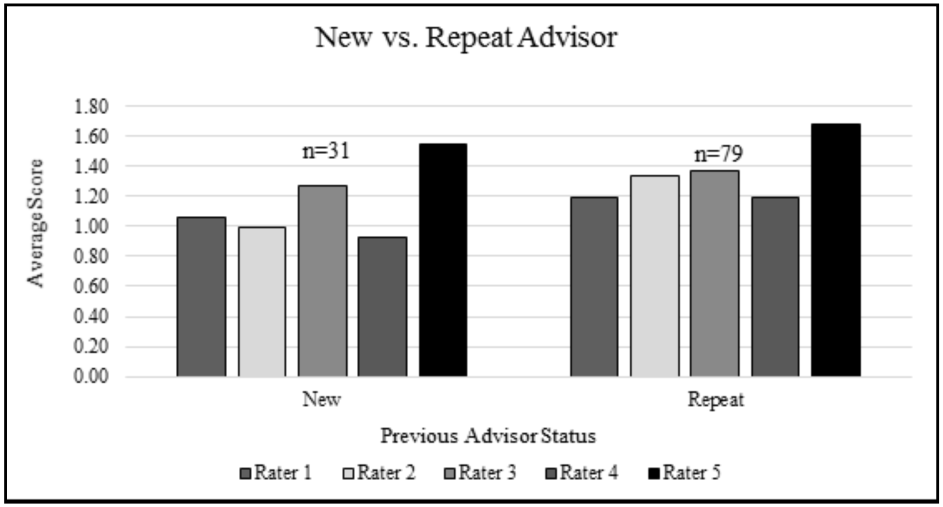

Figure NE-4.5. New versus repeat advisors average scoring trend for 2015 posters. (n is the sample size)

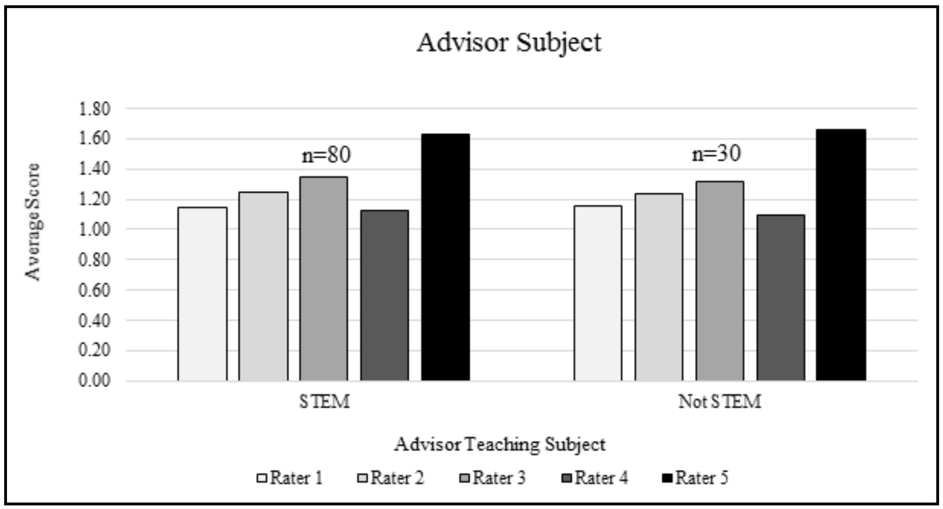

Figure NE-4.6. Advisor subject average scoring trend for 2015 posters. (n is the sample size)

The ancillary assessment for other sustainability topics in the modified competition in 2016 resulted in the following word clouds of keywords for those posters that were not energy centric. The Figure NE-4.7 word cloud is for posters with no energy content, while the Figure NE-4.8 is for those with some energy content. As can be seen in the word clouds; money, water and pollution were frequent themes.

Figure NE-4.7. Word cloud of keywords for 2016 posters that were not energy centric and had no energy content.

Figure NE-4.8. Word cloud of keywords for 2016 posters that were not energy centric but had some energy content

Specific to biofuels, the competition has had an impact on this topic being used for the competition by the students. Figure NE-4.9 is from 2013 when abstracts from 2009 through 2012 were evaluated with respect to biofuels word content. As can be seen, this increased with the NARA involvement.

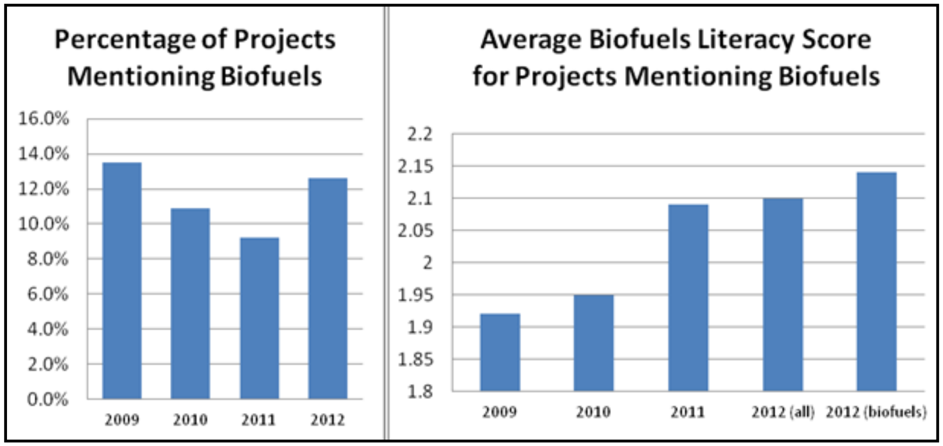

Figure NE-4.9. Preliminary biofuels ranking on the abstracts: Percentage mentioning biofuels and score.

Figures NE-4.10 through NE-4.12 provide some insight into the STEM impacts of the Imagine Tomorrow Energy Competition in 2013. Note that the students thought the judges were one of their favorite aspects of the competition, showing how Imagine Tomorrow is truly connecting industry with the future generation.

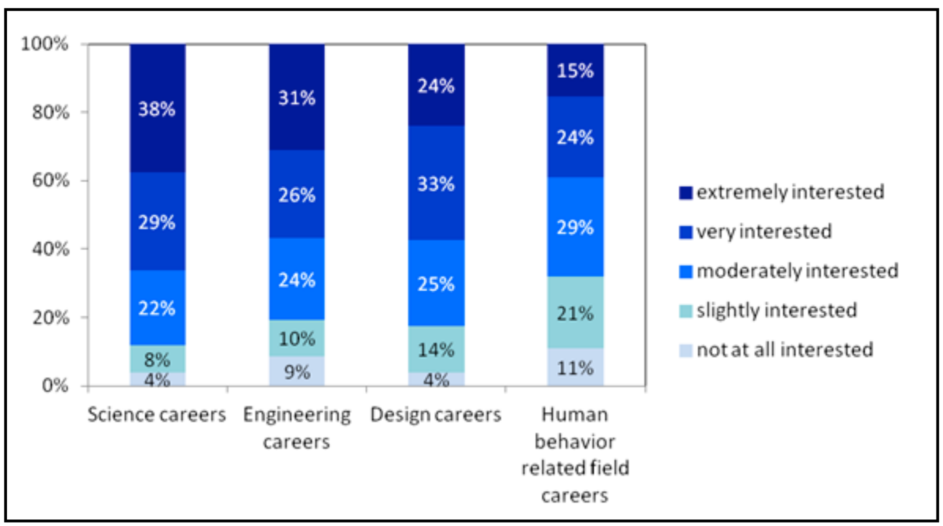

Figure NE-4.10. Students' interests in pursuing a career in science, engineering, design, or human-behavior after the 2013 competition.

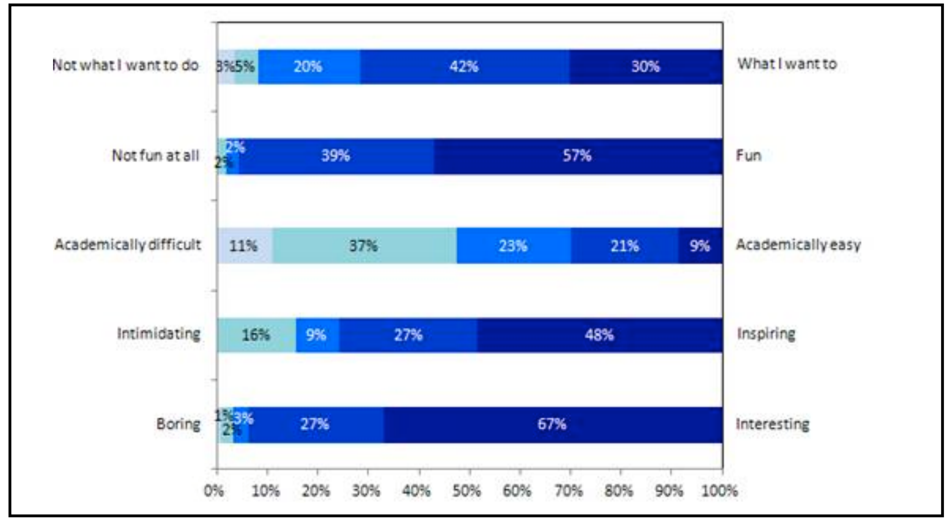

Figure NE-4.11. Students' opinions about pursuing a career in STEM fields after the 2013 competition.

Figure NE-4.12. Words used by students to describe the best part of Imagine Tomorrow 2013.

Based on the experience with Biofuels as a topical area for the first four years that NARA was part of the competition, the Imagine Tomorrow High School energy competition has been re-arranged, mainly based on the interest in different topical areas such as biofuels. This is intended to expand the technical reach by providing directional topics for exploration, and to expand the breadth by embracing technical and social sciences more broadly. The competition as of 2016 is the Alaska Airlines Imagine Tomorrow Competition and there are now four challenge topics:

- Aerospace
- Built Environment
- Food/Energy/Water
- Biofuels

Which can be addressed in any of three ways:

- Design
- Behavior
- Technology

Conclusions/Discussion

The expansion of the competition to other states in the Pacific Northwest resulted in several teams from both Montana and Idaho competing in several of the years. No teams competed from Oregon. It is assumed that reasons for this are mainly due to the distances involved and conflicts with other activities near the end of the school year in May. Some teams from Oregon registered, but were not able to make it in the end.

The addition of the Biofuels challenge was seen to be a major success, with numerous teams involved each year. In addition, in 2016, with the rearrangement of the competition, there were teams competing using all three pathways; design, technology and behavior.

NARA support for the competition has been a major player in establishing the sustainability of this event, and its far reaching impacts on energy literacy and outreach to high school students, members of industry, teachers and many others. Recent efforts have aided in directing the arrangement of the competition to have a better foundation for the future, with the addition of other funding groups and the more official adoption of the competition by Alaska Airlines and the Voilland College of Engineering and Architecture at WSU. In addition, the competition had impacts on students beyond those attending. Schools were limited to eight teams and some had internal competitions prior to the event each May. Also, there were many teams, which registered but were unable to attend due to other conflicts such as state athletic meets, etc.

TASK 5: SUMMER UNDERGRADUATE RESEARCH EXPERIENCES (BF-SURE)

Introduction

BF-SURE is a summer immersion research experience for undergraduates aimed at giving them hands on skills in biofuels and bioproducts research, feeding the pipeline into energy research careers. The overall goal of this program is to train competent, confident undergraduates in the area of biofuels and bio-products research with an understanding of the importance of bioenergy literacy education. By exciting undergraduate students (in particular underrepresented minorities) about cutting edge research, they will be more likely to remain in Science, Technology, Engineering and Mathematics (STEM) fields. SURE participants participate in full time research experiences for a summer (10 week) program that provides laboratory, fieldwork, and research skills in the broad area of biofuels and bioproducts research.

Task Objective

The SURE program goals are:

1. To excite undergraduate students about cutting edge research in the area of biofuels and bioproducts.
2. To develop skills needed for future biofuels and bioproducts research careers
3. To increase the number of students participating in biofuels and bioproducts research in the northwest, including those from schools that do not have strong research efforts.
4. To integrate mentoring experiences for graduate students and post docs into a formalized training program.

Methodology

Students were recruited via a multiple pronged approach including website postings to the following: 1) NARA website, 2) Pathways to Science, Institute for Broadening Participation, 3) American Indian Science and Engineering Society (AISES), 4) the-nucleus.org, 5) Society for Advancement of Chicanos and Native Americans in Science (SACNAS), 6) Guide for undergraduate research (webGURU), and 7) the Earth Science Women's Network (ESWN). In addition, visits were made to community colleges by NARA staff to present undergraduate research opportunities to STEM students. All of these efforts were to ensure a diverse application pool which resulted in a very diverse group of participants. Figure NE-5.1 and Table NE-5.1 present the total number of applications to the program as well as the diversity of applications.

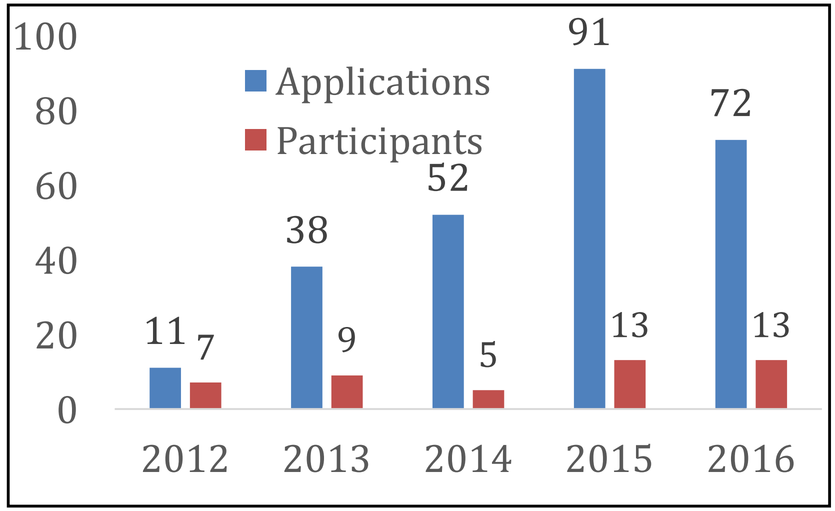

Figure NE-5.1. Number of applications and participants for 2012-2016.

Table NE-5.1. Demographics of applications for 2012-2016.

	2012	2013	2014	2015	2016
Female	36%	61%	48%	49%	54%
Male	64%	39%	52%	51%	46%
Hispanic	18%	11%	6%	12%	14%
Native American/ African American	9%	11%	18%	12%	4%
Multi-cultural	NA	5%	NA	3%	3%
Asian/ Pacific Islander	9%	34%	31%	19%	36%
Caucasion	64%	39%	37%	45%	39%

Applications, reviewed by NARA faculty and students, were selected to participate in the summer program. Students were matched with a research project mentored by a faculty member in one of the following areas:

- **Feedstock development**: To identify and select improved phenotypes of regionally important Douglas-fir/poplar feedstock for energy crops via advanced genomic sequencing, comprehensive phenomics characterization, and pretreatment.
- **Sustainable feedstock production**: To assess availability and cost of forest/energy crop biomass to support a sustainable regional biofuel industry with minimal environmental impact.
- **Feedstock logistics**: To assess the harvesting and transportation methods needed to support a woody biomass supply chain, in part, dedicated to fuels and chemical production.
- **Biomass conversion/refining**: To provide facile, economic and technological means for biomass-derived replacement of aviation fuel and various petrochemicals.
- **System Metrics**: To provide state of the art factors needed to assess the economic viability, social perceptions, and environmental burdens for a fuels and chemical industry based on woody biomass.
- **Outreach and extension**: Develop supply chain coalitions that benefit a biofuels and bioproducts industry in our region.
- **Education**: To comprehensively broaden biofuel and bioproduct literacy at all levels.

Prior to the start of the summer program, a faculty-training workshop for research mentors (including graduate students and post docs) was facilitated. Information provided during this training session included best practices for mentoring students and how to handle difficult situations (i.e. Significant Opportunities in Atmospheric Research and Science (SOARS) website; Haacker, 2015; Jolly et al., 2004). Formal mentoring of the students was complemented by informal mentoring opportunities during workshops, working meetings and social events throughout the summer.

After the summer of research with a faculty mentor, the students prepare a poster and present it during the final Summer Undergraduate Research Poster symposium. This event is attended by many WSU faculty as well as Pullman community members. Students have the opportunity to explain their research, field questions from a wide variety of people, as well as visit and view posters of their colleagues. It's a very rewarding capstone experience for the students.

Results

A total of 47 students have been trained through the NARA BF-SURE program during the 5-year period. Each of the students completed a 9.5-week research experience and presented a poster at the end of the summer during the Summer Research Poster Symposium.

A diverse group of students were selected to participate in the program. Diversity includes gender, underrepresented minorities as well as diversity in terms of "young" undergraduates (i.e. freshman or sophomores) and undergraduates that come from an institution that does not have research opportunities available. The demographic information for each year is shown in Table NE-5.2.

Table NE-5.2. Demographic information for all NARA BF-SURE students.

	male	female	hispanic	NA/ AA	Cauca sion	Asian	non research Institution	freshman/ sophomore	Total
2012	3	4	2	1	4	0	2		7
2013	6	3	1	1	3	4	1		9
2014	2	3	0	2	1	2	2	1	5
2015	5	8	2	2	8	1	2	6	13
2016	4	9	1	1	9	2	5	5	13
All year s	20	27	6	7	25	9	12	12	47
	43%	57%	13%	15%	53%	19%	26%	26%	100%

Individual research project results are summarized in the posters that are available to view here: https://nararenewables.org/posters/#toc-summer-undergraduate-research-experience-sure-. Table NE-5.3 lists each student and the title of their research project.

Table NE-5.3. NARA BF-SURE students and research project title.

2016	
John Barth	Comminution of Unmerchantable Forest Residuals to Determine Power and Energy Consumption as a Function of Moisture Content and Size Reduction Range
Muhui Chen	Development of Epoxy Coating Technology on Lignosulfonate Hydrogel
Jessica Curry	The Value of Slash Trees and Snags in Forest Ecosystems
William Daniels	Characterization of Molecular Structure and Interlinkage Network for Seven Representative Biorefinery Lignin
Allie Davis	Regional equations for streams in forested watersheds in the Pacific Northwest
McKayla Drozd	Biofuel Concept Learning Assessment of Middle School and Elementary School Youth through the Value of a Tree Lesson Plan
Abigail Flowers	Types of Energy with Biofuels Applications
Sarah Knue	Lesson Plan Design: Life Cycle Assessment of NARA Jet Biofuel
Sarah Pate	Energy Literacy and Sustainability Topics in a High School Problem-Solving Competition
Thomas Potolicchio	DES for the Extraction of Lignin from Biomass
Shalonda Robinson	Educating Youth on the Carbon Cycle within Biofuel Production
Guadalupe Salazara	Water-based Acrylic Polymer Incorporating Cellulose Nanocrystal for Coating of Food Packaging Films
Emily Sun	Application Development for Kraft Lignin and Waste Cooking Oil-Based Epoxy Asphalt
2015	
John Barth	Comminution of Unmerchantable Forest Residuals to Determine Power and Energy Consumption as a Function of Moisture Content and Size Reduction Range
Kyle Thompson	Characterization and Modification of Asphalt With Epoxy Resins Synthesized From Pyrolysis Oil, a Derivative of Lignocellulosic Biomass
Oshauna Morgan	Characterization of Biorefinery Lignins and Comparison of Reactivity for Value-added Chemical Production
Adriana Guzman	Making the Chemistry of the NARA Project Visible
Shakema Haynes	Activated Carbon by Chemical Activation of Lignin with Potassium Hydroxide
Kasey Markland	Modifying Lignin and its Model Compounds to Enhance Oxidative Ring Cleavage to Dicarboxylic Acids
Jennifer Murphy	Educating Youth on Air Pollution Caused by Transportation
Emily Schwartz	Forest Ecology and Biofuel Production Potential for Tribally-Managed Forests in the Northern Rockies
Maika Bui	Synthesis of Lignosulfonate Hydrogels cross-linked with PEGDGE
Aleksandr Kirpach	Preventing Nitrogen Depletion in Forests Undergoing Forest Residual Removal
Mark Wohlpart	Screening of Value-Added Market Opportunities for Lignin
Sarah Wilkins	Biofuel Transportation and CO_2 Emission Adventure Race
Bailey Tebou	Air Quality Impact of the NARA Aviation Biofuel Refinery
2014	
Eileen Wu	Ball Milling: Effective pretreatment leading to a clean biomass to cellulosic sugar conversion
Cassandra Sanders	Mechanistic kinetics study of biomass derived inhibitory compounds on cellulase hydrolysis of biomass substrate
Preenaa Venugopal	Potential technological pathways for the production of alternative jet fuel
Eric Sorensen	Spatial distribution of grain sizes in sampling heterogeneous stream beds
Rodney Seals	Testing lignin as an additive to wooden pellets
2013	
Andrea Laguna	Determining the effect of densification of pretreated harvested forest residue on enzymatic monosaccharide production
Steve Cline	Isolation of high purity lignin from bio-jet biorefinery hydrolysis residue
Calvin Silas	Nanocellulose reinforcement for bio-based thermo-responsive resins
Karissa Garcia	Not all Douglas Fir trees are created equally for conversion to biofuels
Daniel Leong	Partical depolymerization of lignin using hydrogenolysis over raney nickel
Kane Norton	Physical methods for breakdown of cellulose crystallinity
Chanel Casayuran	Preparation and characterization of porous carbon adsorbent materials from lignocellulosic residuals
Jing-Li	Surface characterization of lignocellulosic biomass for understanding the enzymatic hydrolysis
2012	
Lucy Cheadle	Analysis of bioproducts from ultra-low cost biomass processing
Maggie Buffum	Assessing moisture content in biomass piles
Brady Do	Assessing risks of arson in biomass piles
Ellen Simonsen	Biobased curing agent for epoxy
Pedro Guajardo Jr.	Diluted acid and peroxide pretreatments of Douglas Fir
Anthony Lathrop	Evaluation at nano-scale of hot water extracted Ponderosa Pine chips
Madeline Fuchs	NARA biofuels production emissions
Burdette Birdinground	Scale up of an ultra-low cost in forest thermal processing of biomass

Conclusions/Discussion

To conclude, the BF-SURE has successfully met the goals and objectives of the program. A total of 47 students spent the summer engaged in research full time in the area of biofuels and bioproducts, with 26% of these students coming from schools that do not have research opportunities available to them (objectives 1 and 3). Formal assessment was not conducted on this project, but informal assessment indicates that the students were engaged and excited about their research experience. Many of them have continued on to graduate school in STEM disciplines. Results presented on the posters and communication with the faculty mentors indicate that the students developed skills needed for future biofuels and bioproducts research careers (objective 2). Lastly, through the program, many graduate students and faculty were involved in a pre-summer training program to discuss best practices with respect to mentoring undergraduates (objective 4).

Overall the BF-SURE program was very successful, and it has led to continued funding through the USDA Agriculture and Food Research Initiative (AFRI) Competitive Grants Research and Extension Experiential Learning for Undergraduate (REEU) Fellowships Program. Four years of funding to support 8 students per year have been secured to continue this program. Students will be split between the WSU Pullman campus and the McCall Outdoor Science School (MOSS) where they will engage in biofuels and bioproducts research or energy literacy and energy education research, respectively.

TASK 6: NARA SALISH KOOTENAI COLLEGE SUMMER UNDERGRADUATE RESEARCH EXPERIENCES (SURE)

Introduction

Biofuels and bioproducts offer a high value use for woody biomass. Tribal forestry operations generate substantial quantities of woody biomass during fuels reduction aimed at forest health, timber harvest, and other activities. These forestry operations are keen to realize the environmental, economic, and social benefits of developing high value products from the forest. In order to help accelerate the development of high value-added uses of woody biomass among Northwest tribal communities, NARA is partnering with the forestry program at Salish Kootenai College (SKC), a tribal university, to provide research opportunities tied to biofuels and bioproducts from woody biomass. Annual summer internship awards will be made to SKC Forestry students so they can join a NARA research university for a summer research experience.

Task Objective

SURE participants participate in full time research experiences for a summer (10 week) program that provides laboratory, fieldwork, and research skills in the broad area of biofuels and bioproducts research. The SURE program goals are:

5. To excite undergraduate students about cutting edge research in the area of biofuels and bioproducts.
6. To develop skills needed for future biofuels and bioproducts research careers.
7. To increase the number of students participating in biofuels and bioproducts research in the northwest, including those from schools that do not have strong research efforts.
8. To integrate mentoring experiences for graduate students and post docs into a formalized training program.

Results

In the 2015-2016 grant year, work has focused on wrapping up student research on climate change impacts on the hydrology of tribal woods roads. Initial findings were reported by one student in his Senior Thesis in June 2015. A second year of research was performed by two students during the summer of 2015. Analysis and interpretation of this second year of data has been completed and the second student is preparing his Senior Thesis, to be delivered in July 2016

In the past year, two undergraduates have completed senior projects related to NARA. One has gone on to get a job with the USFS utilizing skills that he gained as a NARA intern.

Additionally, two SKC alumni received Masters degrees at UW this year, in both cases, NARA was a crucial bridge that provided funding at both institutions and developed relationships with faculty.

Conclusions/Discussion

The NARA project has had a strong impact on students through engagement in undergraduate research. This experience has bolstered the academic confidence of undergraduates, relating in higher job success and greater interest in graduate school

Task 1: Bioenergy and Bioproducts Graduate Education and Research in Partnership with Northwest Tribes

Refereed Publications

Katie E. Moore-Drougas, Daniel T. Schwartz, Laurel James and Jim Durglo. 2016. *Redefining renewables biomass: A policy change with cascading outcomes.* Washington D.C. Brookings Institution Press. http://www.brookings.edu/blogs/planetpolicy/posts/2016/03/28-redefining-renewable-biomass. (March 29, 2016).

Blake R. Hough, Tom Richards, Jim Durglo, Laurel James, Cody Sifford, Daniel T. Schwartz. ***Submitted*** June, 2016. Implications of holistic management of biomass residues from the forestlands of the Confederated Salish and Kootenai Tribes. *Proceedings of the National Academy of Sciences*.

Hougham, J., Hollenhorst, S., Schon, J., Eitel, K.B., Hendrickson, D., Gotch, C., Laninga, T., James, L., Hough, B., Schwartz, D., Pressley, S., Olsen, K., Haselbach, L., Langfitt, Q., and Moslemi, J. (2015). From the forest to the classroom: Energy literacy as a co-product of biofuels research. *Journal of Sustainability Education*.

Research Presentations

Hendrickson, D., Schon, J., Eitel, K., Laninga, T., Hougham, R.J., Hollenhorst, S., Haselbach, L., James, L., Olsen, K., Pressley, S., Schwartz, D., Gotch, C. *Education at the Speed of Research: An Overview of the NARA Approach to BioEnergy Literacy*. Presented at the 2016 National Energy Education Summit. Washington, DC, June 7, 2016. https://energyedsummit.files.wordpress.com/2016/05/education-at-the-speed-of-research-an-overview-of-the-nara-approach-to-bioenergy-literacy2.pdf

Alex Nussbaum, R. Justin Hougham, Taylor Riedl, Marc Nutter, Sarah Burgess, and Brant Schroeder. *Energy Literacy Matrix: An Online Repository of Energy Education Resources.* The 2nd Northwest Wood-Based Biofuels and Co-products Conference, Seattle, WA, May 3, 2016.

Hougham, R. Justin, Marc Nutter, Peter Schumann, and McKayla Drozd. Utilizing digital learning technologies in your classroom and beyond. 2016 Annual Wisconsin Association of Agricultural Educators. Appleton, Wisconsin. June 29, 2016.

Hougham, R. Justin. *Education at the Speed of Research: Communicating the science of biofuels.* The 2nd Northwest Wood-Based Biofuels and Co-products Conference, Seattle, WA, May 3, 2016.

Marc Nutter, R. Justin Hougham, Alex Nussbaum, Taylor Riedl, Sarah Burgess, and Kevin O' Brien. *Value of a Tree: Comparing Carbon Sequestration to Forest Products.* The 2nd Northwest Wood-Based Biofuels and Co-products Conference, Seattle, WA, May 3, 2016.

Riedl, Taylor, R. Justin Hougham, Alex Nussbaum, Marc Nutter, and Sarah Burgess. Energy Literacy Principles: Bioenergy Education at the Speed of Research. Poster Abstract. The 2nd Northwest Wood-Based Biofuels and Co-products Conference, Seattle, WA, May 3, 2016.

Karl R. Oleson and Daniel T. Schwartz. Extractives in Douglas-fir: Tracking Extractives through Biofuel Production and Assessing their Effects on Saccharification. Poster presented at 2015 NARA Annual Meeting, Spokane, WA, September 2015.

Cody Natoni Sifford, Indroneil Ganguly, Ernesto Alvarado, Ivan Eastin. Developing an Impact Assessment of Local Air Quality as a Result of Biomass Burns. Poster presented at 2015 NARA Annual Meeting, Spokane, WA, September 2015.

Katie Moore-Drougas, Laurel James and Daniel Schwartz. Redefining Renewable Biomass: A policy Change with Cascading Benefits. Poster presented at 2015 NARA Annual Meeting, Spokane, WA, September 2015.

Laurel James and Daniel T.Schwartz. Education and Tribes in the Pacific Northwest. Oral Presentation at the 2014 NARA Annual Meeting, Seattle, WA. September 15-17, 2014.

Ikechukwu Nwaneshiudu, Francesca Pierobon, Indroneil Ganguly, Ivan Eastin. Environmental Assessment of Wet Oxidation and Mild Bisulfate Pretreatments for Converting Forest Slash Residues to Sugar. Poster Presented at the 2014 NARA Annual Meeting, Seattle, WA. September 15-17, 2014.

Cody Natoni Sifford, Indroneil Ganguly, Ernesto Alvarado, Ivan Eastin. Developing an Impact Assessment of Local Air Quality as a Result of Biomass Burns. Poster Presented at the 2014 NARA Annual Meeting, Seattle, WA. September 15-17, 2014.

Blake R. Hough, Cody Sifford, Laurel James, Tom Richards, Jim Durglo, Daniel T. Schwartz. Biomass supply estimates for the Confederated Salish and Kootenai Tribes based on harvest planning and management goals. Poster Presented at the 2014 NARA Annual Meeting, Seattle, WA. September 15-17, 2014.

Karl R. Oleson and Daniel T. Schwartz. Tribal Communities Care about Effluents: Tracking Extractives, Inhibitors & Reaction Products in Bisulfite Processing. Poster Presented at the 2014 NARA Annual Meeting, Seattle, WA. September 15-17, 2014.

Laurel James and Daniel T. Schwartz. NARA Tribal Partnership Projects Overview. Poster Presented at the 2014 NARA Annual Meeting, Seattle, WA. September 15-17, 2014.

Dan Schwartz, Laurel James, Greg Fizzel, Karla Eitel, Jenny Schon, Justin Hougham, et.al. Energy Literacy. Oral Presentation at the 2013 NARA Annual Meeting, Corvallis, OR. September 10, 2013.

Ikechukwu Nwaneshiudu, Zheng Zhou, Daniel T. Schwartz. Process Simulation for Conversion of Woody Biomass to Sugar Concentrate. Poster presented at the 2013 NARA Annual Meeting, Corvallis, OR, September 10, 2013.

Blake R. Hough, Daniel T. Schwartz, Laurel James, Cody Sifford, Jim Durglo, Tom Richards. Biomass supply estimates for the Confederated Salish & Kootenai Tribe based on harvest planning and management goals. Poster presented at the 2013 NARA Annual Meeting, Corvallis, OR, September 10, 2013.

Daniel T. Schwatz and Laurel L James. NARA Tribal Partnership Projects. Poster presented at 2012 NARA Annual Meeting, Missoula, MT, Sept 13-14, 2012.

Task 2: GreenSTEM K-12 Initiatives

Refereed Publications

Hougham, R.J., Gotch, C., Schon, J., Hendrickson, D. Development of an Energy Literacy Measure for Middle School Students (in preparation).

DeWaters, Jan, Justin Hougham, Clare Hintz and Larry Frolich. Beyond Conservation: Reimagining the Purpose of Energy Education. Journal of Sustainability Education (8) 2015.

Eitel Karla, Justin Hougham, Tammi Laninga, Greg Fizzell, Jenny Schon, and Danica Hendrickson. Teacher Professional Development for Energy Literacy: A Comparison of Two Approaches. Journal of Sustainability Education (8) 2015.

Eitel, Karla, R. Justin Hougham, Jenny Schon, Aaron Boyles, and Ashlee Fliney. Professional Development for Energy Literacy. Poster Abstract. National Extension Energy Summit, Seattle WA, April 7 2015.

Hendrickson, Danica, Kimberly Corrigan, Alicia Keefe, Danielle Shaw, Sheeba Jacob, Laura Skelton, Jennifer Schon, Karla Bradley Eitel and Justin Hougham. Global Sustainability: An Authentic Context for Energy Education. Journal of Sustainability Education (8) 2015.

Hougham, R. Justin, Steve Hollenhorst, Jennifer A Schon, Karla B Eitel, Danica Hendrickson, Chad Gotch, Tammi Laninga, Laurel James, Blake Hough, Dan Schwartz, Shelley Preslley, Karl Olsen, Liv Haselbach, Quinn Langfitt, and Jennifer Moslemi. From the forest to the classroom: Energy literacy as a co-product of biofuels research. Journal of Sustainability Education (8) 2015.

Hougham, R. Justin (2015) Exploring Energy Literacy: Wood based biofuels and co-products. Midwest Renewable Energy Association, Stevens Point, WI.

Hougham, R. Justin (2015). Exploring Energy Literacy: Wood based biofuels and co-products. Midwest Renewable Energy Association, Stevens Point, WI.

Hougham, R. Justin (2015) Education at the Speed of Research: An Overview of the NARA Approach to BioEnergy Literacy. 2015 National Extension Educator Summit, Seattle, WA, April 7th.

Hougham, R. Justin, Jenny Schon, Karla Eitel, William Stubblefield, and Justin St. Onge. Assessing Energy Literacy in an Outdoor Learning Center. Poster Abstract. National Extension Energy Summit, Seattle WA, April 7 2015.

Langfitt, Q., Haselbach, L., & Hougham, R.J. (2014). Artifact Based Energy Literacy Assessment Utilizing Rubric Scoring. Journal of Professional Issues in Engineering Education and Practice (2014).

Langfitt, Quinn, Liv Hasselbach, and Justin R Hougham. (2015) Refinement of an Energy Literacy Rubric for Artifact Assessment and Application to the Imagine Tomorrow High School Energy Competition. Journal of Sustainability Education (8) 2015.

Schon, J., Hougham, R.J., Eitel, K.B., & Hollenhost, S. (2014). *The Value of a Tree: Comparing Carbon Sequestration to Forest Products.* Science Scope, Vol. 37 No. 7.

Schon, A. Jennifer, Karla B Eitel, R Justin Hougham, and Danica Hendrickson. Creating a research to classroom pipeline: closing the gap between science research and educators. Journal of Sustainability Education (8) 2015.

Eitel, K.B., Hougham, R.H., Miller, B.G., Schon,J., & LaPaglia, K. (2013). Upload/download: Empowering students through technology-enabled problem-based learning. *Science Scope*. 36(7).

Hougham, R. J., Bradley Eitel, K., & Miller, B. G. 2013. “Technology-enriched STEM Investigations of Place: Using Technology to Extend the Senses and Build Connections to and between Places in Science Education.” Manuscript in review at the *Journal of Geoscience Education*.

Conference Proceedings and Abstracts from Professional Meetings

Hendrickson, D., Schon, J., Eitel, K., Laninga, T., Hougham, R.J. 2016. *Education at the Speed of Research: An Overview of the NARA Approach to BioEnergy Literacy*. In Proceedings of the 2016 National Energy Education Summit. Washington, DC.

Hendrickson, D., Ivancic, J., Murphy, P., Well, J., Zobrist, Z, Field, K., Burrows, E. "Session 13: Bioenergy Education Outcomes." National Council for Science and the Environment (NCSE), Council of Energy Research and Education Leaders (CEREL). Report from the Second National Energy Education Summit's Session 13: Bioenergy Education Outcomes Second National Energy Education Summit. Washington, DC. June 7, 2016.

O'Brien, Kevin and Hougham, R.J. (2015) Value of a Tree. 2015 Wisconsin Society of Science Teachers Annual Meeting, Wisconsin Dells, WI March 6th.

Hougham, R.J., J.A. Schon, K.B. Eitel, and S.A. Hollenhorst. 2012. *Education at the Speed of Research: Communicating the Science of Biofuels.* In Proceedings of the Sun Grant Initiative. New Orleans, LA.

Veletsianos, G., B. Miller, K.B. Eitel, J.U.H. Eitel, and R.J. Hougham. 2012. *Localizing Adventure Learning: Teachers and Students as Expedition Leaders and Members.* In Proceedings of Society for Information Technology & Teacher Education International Conference 2012 (pp. 2164-2169). Chesapeake, VA.

Research Presentations

Hendrickson, D., Schon, J., Eitel, K., Laninga, T., Hougham, R.J., Hollenhorst, S., Haselbach, L., James, L., Olsen, K., Pressley, S., Schwartz, D., Gotch, C. *Education at the Speed of Research: An Overview of the NARA Approach to BioEnergy Literacy*. Presented at the 2016 National Energy Education Summit. Washington, DC, June 7, 2016. https://energyedsummit.files.wordpress.com/2016/05/education-at-the-speed-of-research-an-overview-of-the-nara-approach-to-bioenergy-literacy2.pdf

Schon, J. Energy Literacy: The creation of the assessment tool and results. Northwest Wood-based Biofuels and Coproducts Conference, Seattle, WA May 4, 2016

Hendrickson, D. Energy Education and Bioenergy Literacy: Starting Now. Northwest Wood-based Biofuels and Coproducts Conference, Seattle, WA. May 3, 2016.

Perrin, S., Faulkner, H., Schon, J., Eitel, K., Wolfenden, M., Stufflefield, W. From Forest to Fuel: A lesson on woody biomass feedstocks. Poster presented at Northwest Wood-based Biofuels and Coproducts Conference, Seattle, WA May 4, 2016

Morrone, P., Waksman, L., Wolfenden, M., Schon, J. Eitel, K. Biofuel Production Co-Products Lesson. Poster presented at Northwest Wood-based Biofuels and Coproducts Conference, Seattle, WA May 4, 2016

Daniels, J.M., Hughes, C., Eitel, K., Wolfenden, M., Schon, J. Designing the NARA ebook. Poster presented at Northwest Wood-based Biofuels and Coproducts Conference, Seattle, WA May 4, 2016

Alex Nussbaum, R. Justin Hougham, Taylor Riedl, Marc Nutter, Sarah Burgess, and Brant Schroeder. *Energy Literacy Matrix: An Online Repository of Energy Education Resources.* The 2nd Northwest Wood-Based Biofuels and Co-products Conference, Seattle, WA, May 3, 2016.

Hougham, R. Justin, Marc Nutter, Peter Schumann, and McKayla Drozd. Utilizing digital learning technologies in your classroom and beyond. 2016 Annual Wisconsin Association of Agricultural Educators. Appleton, Wisconsin. June 29, 2016.

Hougham, R. Justin. *Education at the Speed of Research: Communicating the science of biofuels.* The 2nd Northwest Wood-Based Biofuels and Co-products Conference, Seattle, WA, May 3, 2016.

Marc Nutter, R. Justin Hougham, Alex Nussbaum, Taylor Riedl, Sarah Burgess, and Kevin O' Brien. *Value of a Tree: Comparing Carbon Sequestration to Forest Products.* The 2nd Northwest Wood-Based Biofuels and Co-products Conference, Seattle, WA, May 3, 2016.

Riedl, Taylor, R. Justin Hougham, Alex Nussbaum, Marc Nutter, and Sarah Burgess. Energy Literacy Principles: Bioenergy Education at the Speed of Research. Poster Abstract. The 2nd Northwest Wood-Based Biofuels and Co-products Conference, Seattle, WA, May 3, 2016.

Schon, J., Hougham,R.J., Eitel, K., St. Onge, J., Stubbelfield, W., Hendrickson, D., Laninga, T., Hollenhorst, S. Assessment of Energy Literacy at an Outdoor Science School. Poster presented at 2015 NARA Annual Meeting, Spokane, WA, September 2015.

Hendrickson, D., Corrigan, K., Keefe, A., Shaw, D., Jacob, S., Skelton, L., Schon, J., Eitel, K.B., Hougham, R.J. *Global Sustainability: An Authentic Context for Energy Education.* Poster presented at 2015 NARA Annual Meeting, Spokane, WA, September 15-17, 2015.

Eitel, K., Schon, J., Vierling, L. and Fizzell, G. Developing STEM Identity through Place-based Field Science Inquiry. Idaho Conference on STEM Education Challenges and Innovative Solutions: Overcoming STEM Education Barriers in Rural States, Boise, ID, 28 May 2014

Hendrickson, D. *Global Sustainability: An Authentic Context for the Classroom.* Presented at CleanTech Alliance™ Washington's Workforce Breakfast Series "Not Just for Kids: Educating Tomorrow's Cleantech Workforce," October 8, 2014.

Hendrickson, D., D. Shaw, S. Jacob, A. Keefe and L. Skelton. *Fueling our Future: Exploring Sustainable Energy Use – Middle and High School Interdisciplinary Energy Curricula.* Poster presented at 2014 NARA Annual Meeting, Seattle, WA, September 15-17, 2014.

Schon, J., R.J. Hougham, K. Eitel, D. Hendrickson, T. Laninga, C. Gotch, S. Pressley, L. Haselbach and S. Hollenhorst. The Energy Literacy Feedstock. Poster presented at 2014 NARA Annual Meeting, Seattle, WA, September 15-17, 2014.

Eitel, K., T. Laninga, J. Schon, R.J. Hougham, D. Hendrickson and S. Hollenhorst. Teacher Professional Development: An Energy Literacy Supply Chain. Poster presented at 2014 NARA Annual Meeting, Seattle, WA, September 15-17, 2014.

Eitel, Karla, R. Justin Hougham, Jenny Schon, Jyoti Jennewein, Jan Eitel, Gary Thompson, and Steven Hollenhorst. 2013. "Teacher Professional Development: An Energy Literacy Supply Chain" (Poster). NARA Annual Meeting. Corvallis, OR, September 10.

Hendrickson, D., D. Shaw, S. Jacob, A. Keefe, and L. Skelton. 2013. *Fueling Our Future: Exploring Sustainable Energy Use; An Interdisciplinary Curriculum for Middle and High School.* Poster presented at 2013 NARA Annual Meeting. Corvallis, OR, September 10-12, 2013.

Hougham, R. Justin, Jenny Schon, Karla Eitel, Danica Hendrickson and Steven Hollenhorst. 2013. "Education at the Speed of Research: Communicating the Science of Biofuels" (Poster). NARA Annual Meeting. Corvallis, OR, September 10.

Hougham, R. Justin, Jenny Schon, Brant Schroeder, Karla Eitel and Steven Hollenhorst. 2013. NARA Energy Literacy Matrix: http://energyliteracyprinciples.org" (Poster). NARA Annual Meeting. Corvallis, OR, September 10.

Hougham, R.J., J.A. Schon, K.C.B. Eitel, D. Hendrickson and S.A. Hollenhorst. 2012. *Education at the Speed of Research: Communicating the Science of Biofuels*. Poster presentation at NARA 2012 Annual Meeting, Missoula, MT, Sept 13-14, 2012.

Hougham, R.J., J.A. Schon, B. Schroeder, K.C.B. Eitel, and S.A. Hollenhorst. 2012. NARA energy literacy matrix: http://energyliteracyprinciples.org. Poster presentation at NARA 2012 Annual Meeting, Missoula, MT, Sept 13-14, 2012.

Hendrickson, D. 2012. *Facing the Future: Energy Unit Overview*. Poster presented at 2012 NARA Annual Meeting, Missoula, MT, Sept 13-14, 2012.

Hendrickson, D. 2012. *Life Cycle Assessment Lesson: Feedback on a Working Draft*. Poster presentation at 2012 NARA Annual Meeting, Missoula, MT, Sept 13-14, 2012.

Schon, J., R.J. Hougham, K. Eitel and S. Hollenhorst. 2012. Value of a Tree. Poster presentation at NARA 2012 Annual Meeting, Missoula, MT, Sept 13-14, 2012.

Videos and Webinars

Wilton, Dave. (2013, November 15). Fueling Our Future: Exploring Sustainable Energy Use. [Webinar/YouTube]. In *Global Sustainability Webinar Series*. https://www.youtube.com/watch?v=NwHUDdntGCE.

Trainings, Education and Outreach Materials

Eitel, K., Wolfenden, M., Schon, J. MOSS NARA Teacher Professional Development. Online meetings once a month November, 2015- April 2016.

Hendrickson, D., and, Keefe, A. (2015). *Fueling Our Future: Exploring Sustainable Energy Use*. (Elementary School ed.). Bellingham, WA: Western Washington University. DOI: www.facingthefuture.org

D. Hendrickson, D. Shaw, S. Jacob, A. Keefe, & L. Skelton. (2015). *Fueling Our Future: Exploring Sustainable Energy Use*. (Middle School ed.). Bellingham, WA: Western Washington University. DOI: www.facingthefuture.org

D. Hendrickson, D. Shaw, S. Jacob, A. Keefe, & L. Skelton. (2015). *Fueling Our Future: Exploring Sustainable Energy Use*. (High School ed.). Bellingham, WA: Western Washington University. DOI: www.facingthefuture.org

D. Hendrickson, D. Shaw, S. Jacob, A. Keefe, & L. Skelton, *Fueling our Future: Exploring Sustainable Energy Use*, Middle School ed., (Seattle: Facing the Future, 2014), www.facingthefuture.org.

D . Hendrickson, D. Shaw, S. Jacob, A. Keefe, & L. Skelton, *Fueling our Future: Exploring Sustainable Energy Use*, High School ed., (Seattle: Facing the Future, 2014), www.facingthefuture.org.

D. Hendrickson, D. Shaw, S. Jacob, A. Keefe, & L. Skelton, *Fueling our Future: Exploring Sustainable Energy Use*, High School SMART Board ed., (Seattle: Facing the Future, 2014), www.facingthefuture.org.

Hendrickson, D. 2016. *Biofuels in the PNW.* (PowerPoint.) Presentation developed for 1-hour workshops used by FTF staff and shared with Facing the Future's 2015-2016 Peer Educators. Storming the Sound conference for environmental educators 2016. La Conner, WA, January 28.

Hendrickson, D. 2015. *Fueling Our Future: Exploring Sustainable Energy Use.* (Power Point.) Presentation developed for full day workshops used by FTF staff and shared with Facing the Future's 2015-2016 Peer Educators. Snohomish County PUD Fueling Our Future Workshop 2015. Everett, WA, April 18.

Hendrickson, D. 2015. *Interdisciplinary & Interconnected: Social Studies Takes on Energy.* (PowerPoint.) Presentation developed for social studies conferences used by FTF staff and shared with Facing the Future's 2015-2016 Peer Educators. WSCSS Spring Chelan Conference 2015. Chelan, WA, March 6.

Wilton, D. & Hendrickson, D. 2014. *Fueling Our Future: Exploring Sustainable Energy Use.* (PowerPoint.) OSU SMILE Winter Teacher's Workshop 2014. Corvallis, OR, January 24. https://dl.dropboxusercontent.com/u/59697507/Fueling%20Our%20Future%20for%20OSU%20SMILE%20workshop.pdf

Table NE-output.1. Facing the Future Professional Development and Outreach Events Featuring Fueling Our Future and/or Energy

Date	Workshop/Training	Venue	City, State	Participants	Facilitator
6/4/2016	Fueling Our Future: Exploring Stainable Energy Use	Snohomish County PUD	Everett, WA	8	Danica Hendrickson
6/17/2016	Fueling the Future: Full STEM Ahead	MREA: The Energy Fair	Custer, WI	12	Peer Educator
6/7/2016	Energy at the Speed of Research: An Overview of the NARA Approach to Bioeenergy Education	2016 National Energy Education Summit	Washington, DC	5	Danica
6/7/2016	Teaching Energy with a Global Approach: Interdisciplinary Learning in a Middle School Classroom	2016 National Energy Education Summit	Washington, DC	12	Peer Educator
5/21/2016	Biofuels in the Pacific Northwest	Imagine Tomorrow	Pullman, WA	17	Danica Hendrickson
5/3/2016 - 5/4/2016	Energy Education and Bioenergy Literacy: Starting Now And How can sustainability be used as a context for energy education?	NW Wood-Based Biofuels + CoProducts Conference	Seatac, WA	~25	Danica Hendrickson
4/1/2016	Fueling Our Future	Montana Environmental Education Association Annual Conference	Bozeman, WA	6	Danica Hendrickson
3/11/2016	A Turning Point for Alternative Energy?	WA State Council for the Social Studies Spring Chelan Conference	Chelan, WA	5	Danica Hendrickson
Spring 2016	Open Lab for K-5 Teachers - How can FOF be used to meet NYS Draft Standards?	SUNY- Fredonia	Fredonia, NY	23	Peer Educator
3/1/2016	Peer Educator Online Meeting: Energy	Canvas: Big Blue Button	Online	5	Danica Hendrickson
2/27/2016	Fueling Our Future: Exploring Sustainable Energy Use	Snohomish County PUD	Everett, WA	20	Danica Hendrickson
1/28/2016	Biofuels in the Pacific Northwest	Storming the Sound	La Conner, WA	14	Danica Hendrickson
7/29/2015	Fueling Our Future	Facing the Future	Seattle, WA	18	Danica Hendrickson
6/22 to 6/26/15	FOF Lessons 8 and 9	MOSS Summer Institute	McCall, ID	16	Danica Hendrickson
5/30/2015	Biofuels in the Pacific Northwest	Imagine Tomorrow	Pullman, WA	13	Danica Hendrickson; Karla Eitel
4/18/2015	Fueling Our Future: Exploring Sustainable Energy Use	Snohomish County PUD	Everett, WA	11	Danica Hendrickson
3/6/2015	Interdisciplinary and Interconnected: Social Studies Takes on Energy	WA State Council for the Social Studies Spring Chelan Conference	Chelan, WA	7	Danica Hendrickson; Alicia Keefe
11/8 to 11/9/2014	FOF Lessons 2, 8, and 9	U of Wisconsin KEEP and Upham Woods Outdoor Learning Center	Wisconsin Dells, WI	8	Danica Hendrickson
6/20/2014	Classroom Lessons to Teach About Sustainability	MREA: The Energy Fair	Custer, WI	35	Peer Educator
6/16 to 6/20/2014	FOF Lessons	MOSS Summer Institute	McCall, ID	17	Danica Hendrickson
1/24/2014	FOF - Middle School	OSU SMILE Winter Workshop	Corvallis, OR	19	Danica Hendrickson
1/24/2014	FOF - High School	OSU SMILE Winter Workshop	Corvallis, OR	13	Danica Hendrickson
Fall 2013	Fueling Our Future Imagine Tomorrow MOSS-NARA Webinar	MOSS Imagine Tomorrow Webinar Series	Online	30	Dave Wilton
Fall 2013	Fueling the Future: Energy Interconnections and Sustainable Choices	National Science Teachers Association	Portland, OR	78	Dave Wilton
11/15/13	Fueling Our Future: Exploring Sustainable Energy Use	Global Sustainability Webinar Series. Archived as YouTube video.	Online	278 views	Dave Wilton; Danica Hendrickson
June 2013	Workshop featuring FOF Lessons	Webster University's Summer Sustainability PK-12 Institute	St. Louis, MO	52	Dave Wilton
April 2013	FTF Webinar featuring FOF	FTF Webinar	Online	11	Dave Wilton

Task 3: IDX

Refereed Publications

Laninga, T., S. Millman and K. Payne. 2014/2015. "From Wood to Wing: Opportunities to Build an Advanced Biofuels Industry in the Pacific Northwest Utilizing its Timber-based Assets." *Western Planner*. December/January. 35(5): 12-19. http://westernplanner.org/wp-content/uploads/2012/03/2014_vol35_05_WesternPlanner_cover.jpg

Martinkus, N., W. Shi, N. Lovrich, J. Pierce, P. Smith and M. Wolcott. 2014. Integrating biogeophysical and social assets into biomass-to-biofuel supply chain siting decisions. *Biomass and Bioenergy*. 66: 410-418. doi:10.1016/j.biombioe.2014.04.014

Research Presentations

IDX. 2016. Micronized Wood Depot and Conversion Facility Site Designs in Port Angeles, WA. Northwest Wood-Based Biofuels + Co-Products Conference. May 4. Seattle, WA.

Laninga, T. 2016**.** Integrated Design Experience (IDX):Wood-based Aviation Biofuels Supply Chains in the Pacific Northwest. Education Panel. Northwest Wood-based Biofuels + Co-Products Conference. Seattle, WA. May 4.

Olsen, K., T. Beyreuther, M. Wolcott, T. Laninga. 2015. "Interdisciplinary Design Course Structure: Lessons for Engineering Instructors from a Capstone Design Course." American Society for Engineering Education, Seattle, WA. June 14-17. Available online: http://www.asee.org/public/conferences/56/papers/13673/view.

Laninga, T. and J. Moroney. 2014. Wood to Wing: Stakeholder Perspectives on a Wood-based Biofuels

Industry in the Northwest United States. Associated Collegiate Schools of Planning. Philadelphia, PA. November 1.

Laninga, T. 2014. NARA's Approach to Social Sustainability. Moderator. NARA Annual Meeting. Seattle, WA. September 16.

Martinkus, N. and M. Wolcott. Assessing Existing Plant Assets for Biorefinery Siting. NARA Annual Meeting. Seattle, WA. September 16.

Moroney, J. and T. Laninga. 2014. The Informed Stakeholder Assessment. NARA Annual Meeting. Seattle, WA. September 16.

Laninga, T. and K. Olsen. 2014. Identifying Suitable Sites for Wood-based Biofuels Facilities in Western Oregon and Washington. Northwest Wood-based Biofuels and Co-Products Conference. Seattle, WA. April 29. https://www.youtube.com/watch?v=vxlgjQDBB8M

Austin, G. and T. Laninga. 2014. Jet Bio-Fuel: Environmental Implications of Woody Biomass Harvest. 56th Annual Idaho Academy of Science Meeting and Symposium. Moscow, ID. March 21.

Laninga, T. Wood-based Biofuels Supply Chains in the Pacific Northwest. Washington Contract Loggers Association Annual Meeting. Spokane, WA. March 14.

Laninga, T., M. Vachon and M. Payne. 2013. "Asset-based Assessment of Regional Wood-based Biofuels Industry Potential." Idaho Chapter, American Planning Association. Idaho Falls, ID, October 10.

Laninga, T. and M. Wolcott. 2013. "Western Montana Corridor—Pilot Supply Chain Case Study." NARA Annual Meeting. Corvallis, OR. September 10.

NARA Outreach and Education Teams. 2013. "NARA Outreach and Education – An Integrated Approach." NARA Annual Meeting. Corvallis, OR. September 10.

Beyreuther, T. 2013. *Northwest Advanced Renewables Alliance (NARA): Resource Assessment & Supply Chain Analysis*. Panel Presentation at the Small Log Conference. Coeur d'Alene, ID. March 14. http://nararenewables.org/templates/hubbasic/docs/small-log/beyreuther.pdf

Martinkus, N. 2013. *GIS as a Decision Support Tool for Supply Chain Analysis in the Western Montana Corridor.* Panel Presentation at the Small Logs Conference. Coeur d'Alene, ID. March 14. http://nararenewables.org/templates/hubbasic/docs/small-log/martinkus.pdf

Beyreuther, T. 2012. *Sustainable Community Design*. Center for Environmental Research, Education, and Outreach (CEREO) Advisory Board Annual Meeting. Washington State University: Pullman, WA. October 14.

Beyreuther, T. 2012. *Crafting an Integrated Model for Architectural Education*. AIA Western Mountain Region / Northwest and Pacific Region Joint Conference. Tucson, AZ. October 10-13.

Laninga, T., and M. Vachon. 2012. *From Wood to Wing: Wood-based Energy Options*. Idaho Chapter, American Planning Association Annual Conference. Boise, ID. October 10-12.

Poor, C., and T. Beyreuther. 2012. *Integrate Site Redevelopment*. Panel Presentation at NARA Annual Meeting. Missoula, MT. September 14.

Gray, P. 2012. *Supply Chain Economics: A Modeling and Research Plan*. Panel Presentation at NARA Annual Meeting. Missoula, MT. September 14.

Laninga, T., and M. Vachon. 2012. *Pilot Supply Chain Coalitions: The Role of Asset Mapping and Community Capitals Framework*. Panel Presentation at NARA Annual Meeting. Missoula, MT. September 14.

Olsen, K., T. Beyreuther, C. Poor, T. Laninga, and M. Wolcott. 2012. *IDeX Studio Design*. Panel Presentation at NARA Annual Meeting. Missoula, MT. September 14.

Martinkus, N. 2012. *GIS as a Decision Support Tool for Supply Chain Analysis in the Western Montana Corridor*. Panel Presentation at NARA Annual Meeting. Missoula, MT. September 14.

Beyreuther, T. 2012. *Design Programming for Post-Industrial Site Reuse*. Plenary Speaker. Brownfields and Land Revitalization Conference. Spokane, WA. June 21-22.

Posters

Schlonga, V. 2016. *Solids Depot at Hermann Brothers Logging and Construction: Civil Site Design*. (poster). Northwest Wood-Based Biofuels + Co-Products Conference. Seattle, WA. May 3.

Kerschner, T. 2016. *Milled Wood Distributed Depot Model for Olympic Peninsula, WA*. (poster). Northwest Wood-Based Biofuels + Co-Products Conference. Seattle, WA. May 3.

Camenzind, D. and B. Siegfried. 2016. *Micronized Wood Solids Depot Process Implementation.* (poster). Northwest Wood-Based Biofuels + Co-Products Conference. Seattle, WA. May 3.

Camenzind, D. 2016. *Biofuels Conversion Facility Hydrolysis Preparation of Micronized Wood*. (poster). Northwest Wood-Based Biofuels + Co-Products Conference. Seattle, WA. May 3.

Arndt, T., C. Torres, C. Wuestney, D. Seiler, and J. Malloy. 2016. *Capstone Design Project of a NARA Pilot Plant Biofuels Facility on the Olympic Peninsula, WA*. (poster) Northwest Wood-Based Biofuels + Co-Products Conference. Seattle, WA. May 3.

Wuestney, C., D. Camenzind, T. Kerschner, C. Torres, T. Thornton, T. Arndt, V. Schlonga, J. Malloy, and D. Seiler. 2016. *Locating a Distributed Model for Biofuels Production*. (poster). Northwest Wood-Based Biofuels + Co-Products Conference. Seattle, WA. May 3.

Smith, I., S. Diekman, S. Keith, C. Lane, A. Martin, C. Williams, M. Jarrett. 2015. "Wood to Wing: Sustainable Site Design for a Biofuel Supply Chain." (poster). NARA Annual Meeting, Spokane, WA. September 15.

Lane, C., I. Smith, S. Diekman, S. Keith, C. Lane, A. Martin, C. Williams, M. Jarrett. 2015. "Wood to Wing: Site Selection Methods for a Biofuel Supply Chain." (poster). NARA Annual Meeting, Spokane, WA. September 15.

Smith, I., S. Diekman, S. Keith, C. Lane, A. Martin, C. Williams, M. Jarrett. 2015. "Wood to Wing: Sustainable Site Design for a Biofuel Supply Chain." (poster). National Extension Energy Summit, Seattle, WA. April 7-10.

Lane, C., I. Smith, S. Diekman, S. Keith, C. Lane, A. Martin, C. Williams, M. Jarrett. 2015. "Wood to Wing: Site Selection Methods for a Biofuel Supply Chain." (poster). National Extension Energy Summit, Seattle, WA. April 7-10.

Millman, S., M. Payne and T. Laninga. 2014. From Wood to Wing: Opportunities to Build an Advanced Biofuels Industry in the Pacific Northwest Utilizing its Timber-based Assets. (Poster). NARA Annual Meeting. Seattle, WA. September 16.

Laninga, T., M. Payne and S. Millman. 2014. "From Wood to Wing: Opportunities to build an advanced biofuels industry in the Pacific Northwest by utilizing its timber-based assets" (Poster). Northwest Wood-based Biofuels and Co-Products Conference. Seattle, WA. April 29.

Savas, D., S. Strickler, Elias Hansen. 2014. NARA Liquid Depot. (Poster). Northwest Wood-based Biofuels and Co-Products Conference. Seattle, WA. April 29.

McIntyre, V., B. Beaudett, Liz Boyden, Liwei Huang. 2014. Site Specific Design for a Liquid Depot: Weyerhaeuser Bay City Log Yard in Aberdeen, WA. (Poster). Northwest Wood-based Biofuels and Co-Products Conference. Seattle, WA. April 29.

Zednick, C., J. Bodolay, Jorge Jordan and Nick Kirsch. 2014. IDX- Solid Depot – Bradwood, OR. (Poster) Northwest Wood-based Biofuels and Co-Products Con ference. Seattle, WA. April 29.

Graves, L. 2014. MC2P Site Selection Methodology. (Poster) Northwest Wood-based Biofuels and Co-Products Conference. Seattle, WA. April 29.

Graves, L., L. Fracas, T. Schlect, D. Irwin, J. Hightree, S. Yoon, M. Wang, Z. Krein. 2014. Site Specific designs for an Integrated biorefinery: Cosmo Specialty Fibers Incorporated in Cosmopolis, WA. (Poster) Northwest Wood-based Biofuels and Co-Products Conference. Seattle, WA. April 29.

Potter, J. 2014. MC2P Supply Chain Analysis. (Poster). Northwest Wood-based Biofuels and Co-Products Conference. Seattle, WA. April 29.

Gray, P. 2013. "Supply Chain Research." (Poster). NARA Annual Meeting, Corvallis, OR, September 10.

IDX 2012/2013 Class. 2013. "Western Montana Corridor Summary." (Poster). NARA Annual Meeting, Corvallis, OR, September 10.

Potter, J. 2013. “Supply Chain – Libby Scenario.” (Poster). NARA Annual Meeting, Corvallis, OR, September 10.

Potter, Jon. 2013. “Feedstock Availability.” (Poster). NARA Annual Meeting, Corvallis, OR, September 10.

Martinkus, N. , M. Wolcott and J. Potter. “GIS-Based Conversion Facility Site Selection Process in the Western Montana Corridor.” (Poster). NARA Annual Meeting, Corvallis, OR, September 10.

Gray, P. 2012. *Economics of an isobutanol supply chain – research plan*. (Poster). NARA 2012 Annual Meeting. Missoula, MT. September 13.

Jiang, J., J. Wang and M. Wolcott. 2012. *Preconversion of sodium sulfite treated wood with taguchi method*. (Poster). NARA 2012 Annual Meeting. Missoula, MT. September 13.

Johnson, D., K. Merslich, J.M. Moroney, and L. Nabahe. 2012. *Clearwater Basin Biomass Supply Chain Challenges and Opportunities*. (Poster). NARA 2012 Annual Meeting. Missoula, MT. September 13.

Johnson, D., K. Merslich, J.M. Moroney, and L. Nabahe. 2012. *Clearwater Basin Biomass Atlas*. (Poster). NARA 2012 Annual Meeting. Missoula, MT. September 13.

Liu, Y., J. Wang and M. Wolcott. 2012. *Factors affecting wood pellet densification*. (Poster). NARA 2012 Annual Meeting. Missoula, MT. September 13.

Martinkus, N., T. Morgan, and M. Wolcott. 2012. *GIS as a Decision Support Tool for Supply Chain Analysis in the Western Montana Corridor*. (Poster). NARA 2012 Annual Meeting. Missoula, MT. September 13.

Moroney, J.M. and D. Johnson. 2012. *Clearwater Basin Bioenergy Survey.* (Poster). NARA 2012 Annual Meeting. Missoula, MT. September 13.

Olsen, K., and C. Poor. 2012. *Bioregional Mapping Analysis using ArcGIS.* (Poster). NARA 2012 Annual Meeting. Missoula, MT. September 13.

Poor, C., T. Beyreuther, K. Olsen, and M. Wolcott. 2012. *Integrated design pedagogy in higher education.* (Poster). NARA 2012 Annual Meeting. Missoula, MT. September 13.

Johnson, D. 2012. *Clearwater Basin Biomass Atlas*. (Poster). International Wood Composite Symposium. Seattle, WA. April 11-13.

Merslich, K., and L. Nabahe. 2012. Clearwater Basin Biomass Supply Chain Challenges and Opportunities. (Poster). International Wood Composite Symposium. Seattle, WA. April 11-13.

Moroney, J.M., and D. Johnson. 2012. *Clearwater Basin Bioenergy Survey*. (Poster). International Wood Composite Symposium. Seattle, WA. April 11-13.

Other Publications

Laninga, T., Olsen, K. & Yadama, V. (2016). Olympic peninsula: site analysis report (Vol.2). Pullman, WA. Northwest Advanced Renewables Alliance (NARA). https://research.libraries.wsu.edu/xmlui/handle/2376/6476

Laninga, T., Olsen, K. & Yadama, V. (2016). Olympic peninsula liquids depot and lignin-based co-products study: preliminary scoping (Vol.1). Pullman, WA. Northwest Advanced Renewables Alliance (NARA). https://research.libraries.wsu.edu/xmlui/handle/2376/6475

Olsen, K., Laninga, T., Austin, G. & Vachon, M. (2016). Pacific Northwest wood-based biofuels: site selection & design (Vol. 2). Pullman, WA. Northwest Advanced Renewables Alliance (NARA). https://research.libraries.wsu.edu/xmlui/handle/2376/6474

Laninga, T., Olsen, K., McIntyre, V., Millman, S., Potter, J., Vachon, M., . . . Zhu, R. (2014). Pacific Northwest wood-based biofuels: preliminary scoping (Vol. 1). Northwest Advanced Renewables Alliance (NARA). https://research.libraries.wsu.edu/xmlui/handle/2376/5666

Laninga, T., Olsen, K., Vachon, M. & Wolcott, M. (2014). Mid-cascade to pacific corridor: analysis (Vol. 2). Northwest Advanced Renewables Alliance (NARA). https://research.libraries.wsu.edu/xmlui/handle/2376/5664

Laninga, T., Olsen, K., Vachon, M. & Wolcott, M. (2014). Mid-cascade to pacific corridor: profile (Vol. 1). Northwest Advanced Renewables Alliance (NARA). https://research.libraries.wsu.edu/xmlui/handle/2376/5663

Laninga, T., Olsen, K., Vachon, M. & Wolcott, M. (2015). Mid-cascade to pacific corridor: historical. Pullman, WA. Northwest Advanced Renewables Alliance (NARA). https://research.libraries.wsu.edu/xmlui/handle/2376/6472

Laninga, T., Olsen, K., Vachon, M. & Wolcott, M. (2015). Mid-cascade to pacific corridor: supplemental. Pullman, WA. Northwest Advanced Renewables Alliance (NARA). https://research.libraries.wsu.edu/xmlui/handle/2376/6473

Olsen, K., Laninga, T., Austin, G. & Vachon, M. (2015). Mid-cascade to pacific corridor: conceptual design (Vol. 3). Pullman, WA. Northwest Advanced Renewables Alliance (NARA). https://research.libraries.wsu.edu/xmlui/handle/2376/6471

The Northwest Advanced Renewables Alliance (2013). Western Montana corridor: site selection and supply chain analysis (Vol. 3). Pullman, WA. https://research.libraries.wsu.edu/xmlui/handle/2376/5670

The Northwest Advanced Renewables Alliance (2013). Western Montana corridor: regional capacity (Vol. 2). Pullman, WA. https://research.libraries.wsu.edu:8443/xmlui/handle/2376/5669

The Northwest Advanced Renewables Alliance (2013). The executive summary of the northwest advanced renewables alliance western Montana corridor. Pullman, WA: NARA. https://research.libraries.wsu.edu/xmlui/handle/2376/5667

Poor, C., Olsen, K., Beyreuther, T., Wolcott, M., Laninga, T., Vachon, M., & Zhu, R. (2013). Western Montana corridor: overview. Northwest Advanced Renewables Alliance (NARA). https://research.libraries.wsu.edu/xmlui/handle/2376/5668

IDX. "Clearwater Basin Bioenergy Assessment Project." NARA. University of Idaho and Washington State University, Moscow, ID. June.

Akhadov, A., Ding, L., Johnson, D., Lewis, K., Merslich, K., Nabahe, L., & Volkema, M. (2011). Clearwater basin biomass atlas. Northwest Advanced Renewables Alliance (NARA). https://research.libraries.wsu.edu/xmlui/handle/2376/5672

IDX. "Clearwater Basin Community Profile." University of Idaho, Moscow, ID. August.

Videos and Webinars

IDX. 2016. Micronized Wood Depot and Conversion Facility Site Designs in Port Angeles, WA. Webinar. Pullman, WA. May 2. https://www.youtube.com/watch?v=HikcCnDIy-M

IDX. 2015. *Pacific Northwest Site Design for Liquids Depot at Wauna Paper Mill, Clatsop, OR*. Webinar. Pullman, WA. April 29. https://www.youtube.com/watch?t=2454&v=ZpxCcDGMpNo

IDX. 2015. *Overview of Programing and Market Analysis for Liquids Depot*. Webinar. Pullman, WA. September 23. https://www.youtube.com/watch?v=t-X1U5txG90

IDX. 2015. *Hermann Brothers, Port Angeles, WA, Micronized Wood Depot SWOT Analysis*. Webinar. Pullman, WA. November 16. https://www.youtube.com/watch?v=xBCtfTXjgoQ

IDX. 2015. *Port Townsend Paper Corporation, Port Townsend, WA, Liquids Depot SWOT Analysis*. Webinar. Pullman, WA. November 16. https://www.youtube.com/watch?v=hgR0PXMDths

IDX. 2015. *LCA Integrated Biorefinery Siting Selection SWOT Analysis*. Webinar. Pullman, WA. November 18. https://www.youtube.com/watch?v=t-X1U5txG90

IDX. 2015. *Hermann Brothers Micronized Wood Depot Schematic Design*. Webinar. Pullman, WA. December 14. https://www.youtube.com/watch?v=1I5N7dweiJk

IDX. 2015. *Port Townsend Paper Corporation Schematic Design*. Webinar. Pullman, WA. December 14.. https://www.youtube.com/watch?v=ENzrn_3LBic

IDX. 2014. Pacific Northwest Supply Chain - Site Selection Webinar. Pullman, WA. November 19. https://sites.google.com/a/idexstudio.org/class/live/past-webinars

IDX. 2014. Pacific Northwest Supply Chain – Preliminary Site Selection Webinar. Pullman, WA. October 20. https://sites.google.com/a/idexstudio.org/class/live/past-webinars

IDX. 2014. Site Analysis Presentations. Washington State University, Pullman, WA. March 12, 2014.
IDX Presentation - Integrated Biorefinery - Cosmo
IDX Presentation - Liquid Depot - Weyerhaeuser (Bay City)
IDX Presentation - Liquid Depot - Kapstone
IDX Presentation - Solids Depot - Sierra Pacific Industries
IDX Presentation - Solids Depot - Bradwood

IDX. 2013. Supply Chain Site Selection Final presentations. Washington State University, Pullman, WA. December 4. https://www.youtube.com/watch?v=8q-usW6AVq0

Trainings, Education and Outreach Materials

Laninga, T. "Renewable Energy Case Study: Wood-based Biofuels + Co-Products." Net Impact Western Washington University Undergraduate Chapter. Bellingham, WA. April 12.

Laninga, T. "Flying Planes with Trees? Overview of Wood-based Aviation Biofuels Supply Chains in the Pacific Northwest." Fueling our Future: Exploring Sustainable Energy Use, Snohomish County PUD Teacher Workshop. Everett, WA. February 27.

Laninga, T. Olympic Peninsula Biomass-Bioenergy Community Stakeholder Open House. Sponsored by: WSU Jefferson County Extension Office and NARA. Port Townsend, WA, October 19.

Laninga, T. 2014. "Wood-Based Aviation Biofuels Supply Chains." McCall Outdoor Science School Summer Teacher Workshop. June 17.

Laninga, T. 2014. "Wood-based Biofuels Supply Chains in the Pacific Northwest." MaCall Outdoor Science School Teacher Professional Development Webinar. February 13.

Laninga, T. 2013. "Cascade to Pacific: Woodbased Biofuels Supply Chain Analysis." Washington Forest Biomass Coordination Group. Olympia, WA. December 10.

Laninga, T. and C. Rawlins. 2013. *Western Montana Corridor Supply Chain Region Lessons Learned*. MC2P Stakeholder Meeting. Vancouver, WA. May 21.

Martinkus, N. 2013. *GIS-Based Supply Chain Analysis in the Mid Coast and Cascade Range Region (MC2R2).* MC2P Stakeholder Meeting. Vancouver, WA. May 21.

Olsen, K, and T. Laninga. 2013. *IDX Structure, Collaboration, Deliverables and Data Needs*. MC2P Stakeholder Meeting. Vancouver, WA. May 21.

Laninga, T. 2013. *Pilot Supply Chain Analysis and Overview*. MC2P Stakeholder Meeting. Vancouver, WA. April 12.

Bio-IDeX. 2013. *Western Montana Corridor Atlas*. NARA Open House and Student Poster Session (50 Posters). Rocky Mountain Elk Foundation. Missoula, MT.

Wolcott, M., and T. Laninga. 2013. *Western Montana Corridor Atlas Overview*. 2013. Montana Wood Products Retention Roundtable. Missoula, MT. January 18.

Laninga, T., J. Moroney, and M. Vachon. 2012. *Clearwater Basin Pilot Biofuels Supply Chain Project*. Clearwater County Economic Development Board Meeting. Orofino, ID. October 17.

Beyreuther, T. 2012. *Sustainable Community Design*. Center for Environmental Research, Education, and Outreach (CEREO) Advisory Board Annual Meeting. Washington State University: Pullman, WA. October 14.

Thesis and Dissertations

Martinkus, Natalie. (2016). *A Multi-Criteria Decision Support Tool for Biorefinery Siting.* (Unpublished doctoral dissertation). Washington State University, Pullman WA.

Task 4: Imagine Tomorrow with Biofuels

Physical

The May 2012 Imagine Tomorrow competition was held in Pullman WA with 46 schools, 433 students, and 115 judges, in addition to numerous advisors, support personnel and interested individuals attending. There were 11 biofuels teams with 44 students. Overall, 48% of the students participating were female and 52% were male.

The May 2013 Imagine Tomorrow competition was held in Pullman WA with 51 schools, 502 students, 133 teams and 130 judges, in addition to numerous advisors, support personnel and interested individuals attending. There were 21 biofuels teams with 71 students. Overall 48% of the students participating were female and 52% were male.

The May 2014 Imagine Tomorrow competition was held in Pullman WA with 45 schools, 542 students, 140 teams and 120 judges, in addition to numerous advisors, support personnel and interested individuals attending. There were 30 biofuels teams with 87 students. Overall 45% of the students participating were female and 55% were male.

The May 2015 Imagine Tomorrow competition was held in Pullman WA with 32 schools, 429 students, 115 teams and 114 judges, in addition to numerous advisors, support personnel and interested individuals attending. There were 18 biofuel teams with 69 students. Overall 44% of the students attending were female and 565 were male.

The May 2016 Alaska Airlines Imagine Tomorrow competition was held in Pullman WA with 407 students, 116 teams, 112 judges and numerous advisors, support personnel and interested individuals attending. There were 11 biofuel teams (45 students) of which three used behavior, four used design and four used technology to address the challenges they focused on. Overall 43% of the students attending were female, and 57% were male.

Refereed Papers (accepted or completed)

Langfitt, Q., Haselbach, L., and Hougham, R.J. (2015), Artifact Based Energy Literacy Assessment Utilizing Rubric Scoring. *J. Prof. Issues Eng. Educ. Pract,,* 141(2).

Langfitt, Q., Haselbach, L., & Hougham, R.J. (2015). Refinement of an energy literacy rubric for artifact assessment and application to the Imagine Tomorrow high school energy competition. *Journal of Sustainability Education*, 8.

Hougham, R.J., Eitel, K., Hendrickson, D., Gotch, C., Laninga, T., James, L., Hough, B., Schwatrz, D.,Pressley, S., Olsen, K., Haselbach, L, Langfit, Q., and Moslemi, J. (2015) Education at the Speed of Research: An Overview of the NARA approach to BioEnergy Literacy. *Journal of Sustainability Education*, 8.

Research Presentations

Haselbach, L. Imagine Tomorrow – 6th annual problem-solving competition for grades 9-12. Poster presentation at NARA 2012 Annual Meeting, Missoula, MT, Sept 13-14, 2012.

Haselbach, L., Imagine Tomorrow. Poster Presentation at the BNARA 2013 Annual Meeting, Corvallis, Oregon, September 2013

Langfitt, Q., Haselbach, L. and Hougham, R.J., 2014. Graduate Student Research Poster Presentation on Energy Literacy Rubric Development, at the WSU Showcase, Pullman, WA. March 28, 2014.

Langfitt, Q., L. Haselbach and R.J. Hougham. Artifact based energy literacy assessment utilizing rubric scoring. Poster presented at 2014 NARA Annual Meeting, Seattle, WA, September 15-17, 2014.

Liv Haselbach was an invited presenter at Biomass 2014 on July 30th, 2014 in Washington DC. She participated in the panel discussion on: "Building Market Confidence and Understanding III: Engaging Key Audiences in Bioenergy"

Gotch, C., French, B., Langfitt, Q. and Haselbach, L. Determining Reliability of Scores from an Energy Literacy Rubric, Presentation and Proceedings ASEE Conference June 2015, Seattle, WA.

Langfitt, Q. and Haselbach, L. Rubric-Based Energy Literacy Assessment of Student Posters: Effects of Extended Calibration and Addition of Raters. Presentation and Proceedings ASEE June 2016 meeting. June 27, 2016.

Pate, S., Langfitt, Q., Sendele, T. and Haselbach, L. Energy Literacy and Sustainability Topics in a High School Problem-Solving Competition. Poster Presentation at the NARA SURE Poster Session, August 2, 2016. Washington State University.

Other Publications

Beaver, J., Gotch, C. and French, B., Impact and Experiences of Imagine Tomorrow 2013, Report submitted to the WSU Imagine Tomorrow Steering Committee, July 2013 by the WSU Learning & Performance Research Center.

Langfitt, Q. and Haselbach, L. Imagine Tomorrow High School Energy Competition 2014 Energy Literacy and Biofuels Literacy Assessment of Abstracts and Posters, Submitted to the IT Steering Committee, September 2014.

Gotch, C., French, B. and Beaver, J. 2014 Imagine Tomorrow Competition STEM Report Prepared for the Imagine Tomorrow Steering Committee 2015

Langfitt, Q. and Haselbach, L. Imagine Tomorrow High School Energy Competition 2015 Energy Literacy Assessment of Posters. Report Prepared for the Imagine Tomorrow Steering Committee Sept. 23, 2015.

Gotch, C., French, B. and Beaver, J. 2015 Imagine Tomorrow Competition STEM Report Prepared for the Imagine Tomorrow Steering Committee

Langfitt, Q. and Haselbach, L. Alaska Airlines Imagine Tomorrow High School Energy Competition 2016 Energy Literacy Assessment of Posters. Report Under Preparation for the Imagine Tomorrow Steering Committee

Gotch, C., French, B. and Austin, B. 2016 Imagine Tomorrow Competition STEM Report Under Preparation for the Imagine Tomorrow Steering Committee

Videos and Webinars

Langfitt, Q. and Haselbach, L., Imagine Tomorrow High School Energy Competition, The Department of Energy National Town Hall on Energy Literacy, August 5, 2014.

Task 5: Summer Undergraduate Research Experiences (BF-SURE)

Research Posters

2016

Comminution of Unmerchantable Forest Residuals to Determine Power and Energy

Consumption as a Function of Moisture Content and Size Reduction Range| John Barth, Kelley Welsch, Vincent McIntyre, Jinwu Wang, Michael Wolcott

Development of Epoxy Coating Technology on Lignosulfonate Hydrogel | Muhui Chen, Hui Xu, Junna Xin, Jinwen Zhang

The Value of Slash Trees and Snags in Forest Ecosystems | Jessica Curry, Karla Eitel

Characterization of Molecular Structure and Interlinkage Network for Seven

Representative Biorefinery Lignin | William Daniels, Ruoshui Ma, Xiao Zhang

Regional equations for streams in forested watersheds in the Pacific Northwest | Allie Davis, Kaleb Madsen, John Petrie

Biofuel Concept Learning Assessment of Middle School and Elementary School Youth through the Value of a Tree Lesson Plan | McKayla Drozd, Peter Schumann, R. Justin Hougham, and Marc Nutter

Types of Energy with Biofuels Applications | Abigail Flowers, Karla Eitel

Lesson Plan Design: Life Cycle Assessment of NARA Jet Biofuel | Sarah Knue, Karla Eitel

Energy Literacy and Sustainability Topics in a High School Problem-Solving Competition | Sarah Pate, Quinn Langfitt, Trace Sendele, Liv Haselbach

DES for the Extraction of Lignin from Biomass | Thomas Potolicchio, Senthil Subramaniam, Xiao Zhang

Educating Youth on the Carbon Cycle within Biofuel Production | Shalonda Robinson, Karla Eitel

Water-based Acrylic Polymer Incorporating Cellulose Nanocrystal for Coating of Food Packaging Films | Guadalupe Salazara, Lanxing Dub, Jinwu Wang, Michael Wolcott

Application Development for Kraft Lignin and Waste Cooking Oil-Based Epoxy Asphalt | Emily Sun, Ran Li, Junna Xin, Jinwen Zhang

2015

Comminution of Unmerchantable Forest Residuals to Determine Power and Energy Consumption as a Function of Moisture Content and Size Reduction Range | John Barth, Kelly Welsch, Vincent Mcintyre, Dr. Jinwu Wang, and Dr. Michael Wolcott

Characterization and Modification of Asphalt With Epoxy Resins Synthesized From Pyrolysis Oil, a Derivative of Lignocellulosic Biomass | Kyle Thompson, Junna Xin, Jinwen Zhang

Characterization of Biorefinery Lignins and Comparison of Reactivity for Value-added Chemical Production | Oshauna Morgan, Ruoshui Ma, Mand Guo and Xiao Zhang

Making the Chemistry of the NARA Project Visible | Adriana Guzman, Karla Eitel

Activated Carbon by Chemical Activation of Lignin with Potassium Hydroxide | Shakema Haynes, Ian Dallmeyer

Modifying Lignin and its Model Compounds to Enhance Oxidative Ring Cleavage to Dicarboxylic Acids | Kasey Markland, Ruoshui Ma, Mond Guo, Carlos Hiroaki Kuwabara, Xiao Zhang

Educating Youth on Air Pollution Caused by Transportation | Jennifer Murphy, Karla Eitel

Forest Ecology and Biofuel Production Potential for Tribally-Managed Forests in the Northern Rockies | Emily Schwartz, Karla Eitel

Synthesis of Lignosulfonate Hydrogels cross-linked with PEGDGE | Maika Bui, Xiaoxu Teng, Junna Xin, Jinwen Zhang

Preventing Nitrogen Depletion in Forests Undergoing Forest Residual Removal | Aleksandr Kirpach, Rob Harrison, Jason James, Austin Himes, Kim Littke

Screening of Value-Added Market Opportunities for Lignin | Mark Wohlpart, Dr. Paul M. Smith, Steve Cline, Dr. Wenping Shi

Biofuel Transportation and CO2 Emission Adventure Race | Sarah Wilkins, Karla Eitel

Air Quality Impact of the NARA Aviation Biofuel Refinery | Bailey Tebou , Vikram Ravi and Brian K. Lamb

2014

Ball Milling: Effective pretreatment leading to a clean biomass to cellulosic sugar conversion | Eileen Wu

Mechanistic kinetics study of biomass derived inhibitory compounds on cellulase hydrolysis of biomass substrate | Cassandra Sanders

Potential technological pathways for the production of alternative jet fuel | Preenaa Venugopal

Spatial distribution of grain sizes in sampling heterogeneous stream beds | Eric Sorensen

Testing lignin as an additive to wooden pellets | Rodney Seals

2013

Determining the effect of densification of pretreated harvested forest residue on enzymatic monosaccharide production | Andrea Laguna

Isolation of high purity lignin from bio-jet biorefinery hydrolysis residue | Steve Cline

Nanocellulose reinforcement for bio-based thermo-responsive resins | Calvin Silas

Not all Douglas Fir trees are created equally for conversion to biofuels | Karissa Garcia

Partical depolymerization of lignin using hydrogenolysis over raney nickel | Daniel Leong

Physical methods for breakdown of cellulose crystallinity | Kane Norton

Preparation and characterization of porous carbon adsorbent materials from ligno cellulosic residuals | Chanel Casayuran

Surface characterization of lignocellulosic biomass for understanding the enzymatic hydrolysis | Jing-Li

2012

Analysis of bioproducts from ultra-low cost biomass processing | Lucy Cheadle

Assessing moisture content in biomass piles | Maggie Buffum

Assessing risks of arson in biomass piles | Brady Do

Biobased curing agent for epoxy | Ellen Simonsen

Diluted acid and peroxide pretreatments of Douglas Fir | Pedro Guajardo Jr.

Evaluation at nano-scale of hot water extracted Ponderosa Pine chips | Anthony Lathrop

NARA biofuels production emissions | Madeline Fuchs

Scale up of an ultra-low cost in forest thermal processing of biomass | Burdette Birdinground

Silas, C., Sahaf, A., and Englund, K. Nanocellulose reinforcement for bio-based phenolic thermo-responsive resins. Poster presented at the American Indian Science and Engineering Society Annual Conference. Denver, CO. Oct. 31 – Nov. 2, 2013.

Publications, Presentations, Press Releases, News Stories

Story entitled "Summer undergraduates = hot research" was written by Charles Burke, PhD NARA Communications and Publicity Director and submitted to the September NARA newsletter.

Sept. 14, 2012 NARA Annual Meeting, Missoula, MT poster presentation: NARA SURE Summer Undergraduate Research Experiences, David Bahr, Shelley Pressley and Michael Wolcott.

Aug. 9, 2012 University College News website:http://universitycollege.wsu.edu/units/undergraduateresearch/News-Events/headlines/2012reupostersession/ WSU Hosts Summer 2012 Undergraduate Research Poster Symposium

Aug. 3, 2012 WSU News http://news.wsu.edu/pages/publications.asp?Action=Detail&PublicationID=32252&PageID=&ReferrerCode=uggc%3A%2F%2Farjf.jfh.rqh%2Fcntrf%2Ffrnepu.nfc%3FCntrVQ%3D%26Xrljbeqf%3DANEN Summer Undergraduate Research Poster Symposium at CUE

July 27, 2012 University College News website: http://universitycollege.wsu.edu/units/undergraduateresearch/News-Events/headlines/2012SummerResearchSymposium/

Undergraduate Research poster Symposium August 3 at WSU Signals End of Summer STEM Programs and Special Efforts

July 11, 2012 University College News website: http://universitycollege.wsu.edu/units/undergraduateresearch/News-Events/headlines/reu2012kickoff/ WSU Hosts Summer 2012 REU

Pressley, S., and M. Wolcott. NARA SURE Summer Undergraduate Research Experience. Poster presentation at the NARA Annual Meeting. Seattle, WA. Sept 15-17, 2014.

Summer 2014 Undergraduate Research Poster Symposium at Washington State University – abstract book. http://universitycollege.wsu.edu/units/undergraduateresearch/photos-docs-pdfs/2014_REU_Abstract-Booklet_LowRes.pdf

WSU News Story "WSU Hosts Eight Summer Research Programs for Undergraduates" http://universitycollege.wsu.edu/units/undergraduateresearch/News-Events/headlines/summerresearchkickoff/

WSU News Story "WSU Poster Symposium Friday, Aug. 1, for 59 Undergraduate Researchers from 37 Universities" http://universitycollege.wsu.edu/units/undergraduateresearch/News-Events/headlines/2014PosterPreview/

NARA Newstory: http://nararenewables.org/blog/?p=238

WSU News Story (July 30, 2013): http://universitycollege.wsu.edu/units/undergraduateresearch/News-Events/headlines/wsuhostspostersymposium/

Summer 2013 Undergraduate Research Poster Symposium Abstract Booklet: http://universitycollege.wsu.edu/units/undergraduateresearch/photos-docs-pdfs/2013-REU-CompleteAbstractBooklet-FINAL3.pdf

Summer 2013 Undergraduate Research Poster Symposium. August 2, 2013 in Smith CUE atrium at Washington State University. http://universitycollege.wsu.edu/units/undergraduateresearch/share/reuposter/

Sorensen, E. 2012. A Summer of Science, Washington State Magazine, Winter 2012/13, v12 n1, page 31-36. http://wsm.wsu.edu/s/index.php?id=998#.UVnCZqt36aI

WSU News Story (July 30, 2013): http://universitycollege.wsu.edu/units/undergraduateresearch/News-Events/headlines/wsuhostspostersymposium/

Pressley, S., and M. Wolcott. NARA SURE Summer Undergraduate Research Experience. Poster presentation at the NARA Annual Meeting. Corvallis, OR. Sept 10-12, 2013.

WSU News Story/Announcements: https://news.wsu.edu/announcement/friday-930-a-m-1-p-m-2015-summer-undergraduate-research-symposium/

Summer 2015 Undergraduate Research Poster Symposium at Washington State University – abstract book. https://summerresearch.wsu.edu/wp-content/uploads/sites/907/2015/10/Abstract-Book_Undergradiate-Research-Poster-Symposium-2015.pdf

WSU News Story "WSU's July 31 symposium features work of U.S., international undergraduate researchers" http://universitycollege.wsu.edu/units/undergraduateresearch/News-Events/headlines/2015sumugresearch/

Task 6: NARA Salish Kootenai College Summer Undergraduate Research Experiences (SURE)

Thesis and Dissertations

Two senior thesis presentations (Table NE-outcome.2) on NARA funded projects that were presented to SKC faculty, students and interested community members

Table NE-output.2. High school senior theses related to NARA

Name	Affiliation	Role	Contribution
Travis Beauvais	SKC	Student researcher	Senior thesis on culverts and tribal forest road hydrology
Robert Davis	SKC	Student researcher	Senior Thesis on hydrological climate change impacts on tribal forest roads

NARA OUTCOMES

Task 1: Bioenergy and Bioproducts Graduate Education and Research in Partnership with Northwest Tribes

We continue to provide research support to one of the largest Tribes in the Pacific Northwest, as an extension to the Western Montana Corridor (WMC) project. The Confederated Salish & Kootenai Tribes (CSKT) have requested and received a complete inventory of their available biomass residues for their next ten years of harvest management activities. We are investing forestry residue potential from existing tribal stewardship sites in adjacent federal lands, as well as the overall residue potential of a ten mile buffer around the reservation, which is nominally available to the tribe through the Tribal Forest Protection Act. We are also looking at the policy conflict between the Tribal Forest Protection Act and the prohibitions against using RIN credits to support biomass extraction form federal forests. Finally, we are investigating emissions from a sulfite-based sugar processing depot on the reservation, one of the potential options proposed for the western Montana corridor. The CSKT also contributed forest residues (in forest chipping with transfer to Oregon collection site) to NARA's 1,000 gallon goals.

We've also been able to pull in one of the newest Tribal forest landowners in Indian Country with the addition of the Muckleshoot Indian= Tribe (MIT) to the NARA Tribal Partnership projects. Muckleshoot also contributed forest residues (in-forest collection and transfer to chipping site, then delivered to Oregon collection site) via their current forest managers, Hancock Forest Management. Dr. John Sessions from NARA OSU assisted us in gaining tribal participation by providing a quick assessment and approval of their residues. NARA TPP provided the funding support to get Dr Sessions out to CSKT and MIT and to hire tribal contractors and trucking to deliver the residues. This is a major event for our tribal partners. Finally, Charles Burke and Vikram Yadama assisted this effort by capturing the residue collection on video at both the Montana and Washington sites. Video interviews were completed by: Jim Durglo (CSKT Forestry Department Head), Rod Couture (CSKT Forester), Louie Ungaro (MIT Tribal Councilman) and Lefi Tasauga (Hancock Forest Management= representative). Student interviews were completed by Blake Hough (University of Washington) and Cody Sifford (University of Washington).

Task 2: GreenSTEM K-12 Initiatives

Lessons created and taught at MOSS resulted in increased energy literacy for attending students, as seen from the results of the energy literacy assessment tool. Pre, post test and one-month post test results show that students energy literacy increased from students' time at MOSS and continued to increase one month later. Follow up assessment in 2015 indicates MOSS lessons are still effective for increasing energy literacy. Teachers participating in workshops and trainings also demonstrated increased energy literacy and expressed increased familiarity and comfort with teaching bioenergy education.

Task 3. IDX

IDX is a teaching, research, and outreach vehicle for students, faculty, clients and mentors to analyze complex natural and built environment problems and design innovative solutions in interdisciplinary teams. IDX was launched in 2009 with seed funding from the NSF and the Washington State University Institute for Sustainable Design (ISD) using a gift from Weyerhaeuser. In the IDX model, students and faculty are mutual learners, working collaboratively to achieve both teaching and research outcomes.[4] In this environment, faculty are less likely to be the sole providers of information and students the sole consumers of the provided information. Specific objectives of IDX are twofold: 1) deliver an interdisciplinary educational experience for students and 2) foster faculty development and collaboration between diverse disciplines.

Between 2011 and 2016, faculty at WSU collaborated with University of Idaho faculty to lead 5 years of IDX, which contributed to the NARA project by conducting supply chain analyses; site selection for biofuels facilities; and site designs for solids, liquids, and micronized wood depots, and IBRs in the Pacific Northwest.

During the 5-year period, IDX has participation from 15 separate majors. A majority of students were engineering, design, and planning students, however, students from other disciplines were included to assist in specialized aspects of a given project including law, economics, and accounting. A total of 195 students, 110 undergraduate, 82 masters, and 3 PhD, participated in the NARA IDX classes.

IDX completed a survey of 61 alumni that participated in the course (27 responded, for a 44% response rate). The survey, which included 25 questions, asked IDX alumni about their current employment status, the skills they acquired in the course and use in their current positions, and knowledge gained from the course. Nearly 90% of survey respondents said that IDX prepared them for their current position (see Figure NE-outcome.1).

[4] Steiner, Gerald, and Alfred Posch. (2006). "Higher Education for Sustainability by Means of Transdisciplinary Case Studies: An Innovative Approach for Solving Complex, Real-world Problems." Journal of Cleaner Production 14.9-11:877-90.

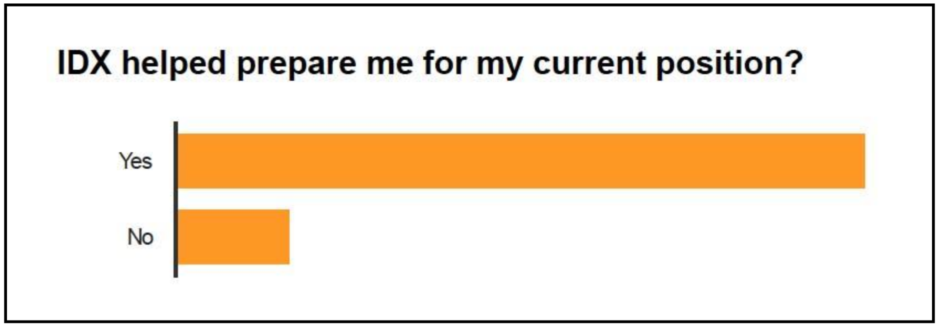

Figure NE-outcome.1. Preparation for current position

The survey asked about a number of skills that IDX students acquired, and their importance in their current employment experience. Skills that IDX students were asked about included working in teams, accessing and analyzing data, statistical analysis, effective oral and written communication, graphic design, preparing technical drawings, construction documents, and using numerous computer applications (e.g., GIS, Civil 3D, Adobe Creative Suite, AutoCAD, etc). Figure NE-outcome.2 shows that, in general, 70% of IDX alumni say that the skills acquired in IDX have been moderately to extremely important in their current employment experience.

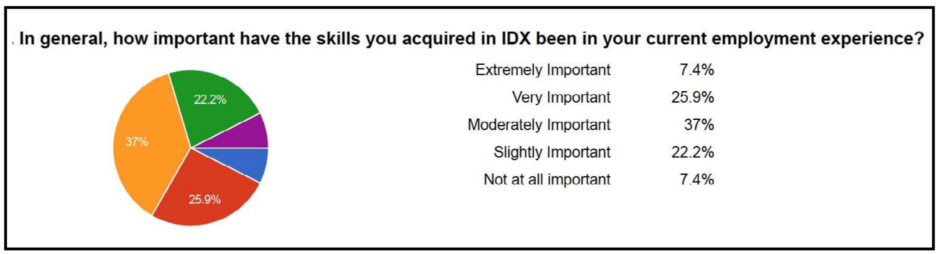

Figure NE-outcome-2. IDX Alumni skills acquired and used in current position

Finally, the survey asked IDX Alumni about the extent to which their level of knowledge increased about a number of topics. Specifically the question asked: Did IDX increase your level of knowledge about: renewable energy, liquid biofuels, using woody biomass to produce biofuels, and forest health issues (where 1 = strongly disagree, 4 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree). Figure NE-outcome-3 shows that, in general, the majority of survey respondents agreed or strongly agreed that they gained knowledge in all areas asked about in the survey.

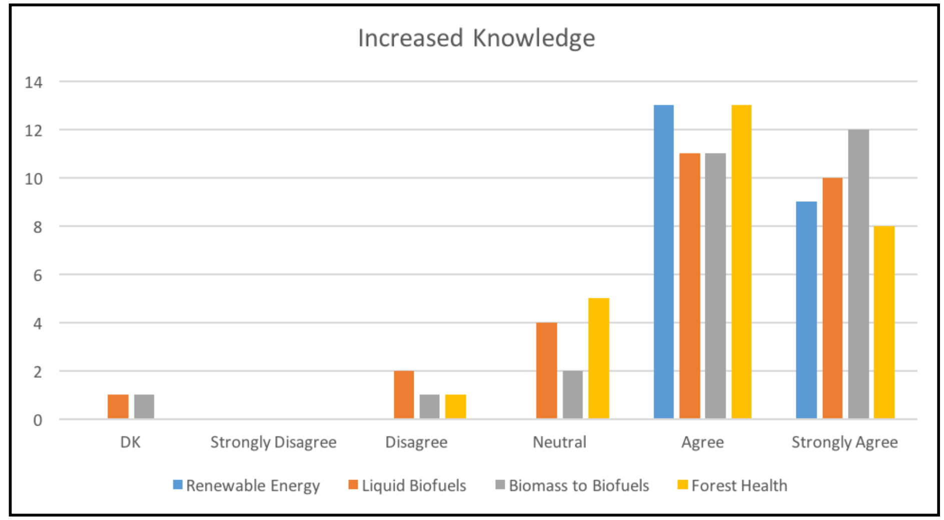

Figure NE-outcome.3. IDX students' increased knowledge about Renewable Energy, Liquid Biofuels, Biomass to Biofuels, and Forest Health

In conclusion, during the 6 years that IDX has been operating at Washington State University and the University of Idaho, there have been significant outcome successes to the program including curriculum improvements, strong university and government agency partnerships, high demand for our graduates, and even build-out of some IDX student designs.

Task 4: Imagine Tomorrow with Biofuels

The biofuels challenge introduced with the NARA involvement resulted in 91 teams with 319 students participating specifically in the biofuels challenge overall in the 2012 through 2016 competitions. These numbers do not include other teams competing in other challenges which also were then exposed to biofuel-based projects, nor the teams which may have worked on biofuels projects, but were not able to attend the competition.

As previously mentioned, based on the experience with Biofuels as a topical area for the first four years that NARA was part of the competition, the Imagine Tomorrow High School energy competition has been re-arranged, mainly based on the interest in different topical areas such as biofuels and emphasizing that the challenge can be met in any of three ways; through technology, design or behavior. These changes are intended to expand the technical reach of the competition by providing directional sustainability, particularly energy-related, topics for exploration, and to expand the breadth by embracing technical and social sciences more broadly.

In addition, the biofuels challenge has brought expanded energy literacy to the competition as shown by the energy literacy assessments. The biofuels challenge is expected to remain in the competition for at least two years beyond the end of the NARA grant.

Task 5: Summer Undergraduate Research Experiences (BF-SURE)

The NARA BF-SURE successfully trained and educated students each summer over 5 years. A total of 47 students spent their summer engaged in research full time in the area of biofuels and bioproducts research. Students were engaged and excited about their research experience, with many of them continuing on to graduate school in STEM disciplines. Through this experience, students developed skills needed for future biofuels and bioproducts research careers. Overall the BF-SURE program was very successful, as indicated by the continued funding through the USDA Agriculture and Food Research Initiative (AFRI) Competitive Grants Research and Extension Experiential Learning for Undergraduate (REEU) Fellowships Program.

Task 6: NARA Salish Kootenai College Summer Undergraduate Research Experiences (SURE)

- Students and Natural Resource faculty at SKC more aware of biofuels, especially in context of utilization of woody materials
- Tribal forestry department has gained knowledge on feasibility of using woody residue and also received extensive information on current state of tribal forest road culverts and potential climate change impacts to them
- SKC students have increased academic confidence and interest in graduate school
- This project has supported 6 students (all have graduated) and been crucial in the successful graduation of two of these students from Masters programs

FUTURE DEVELOPMENT

An emerging and evolving discourse around energy education theory, practice and research is strengthening nationally. A central idea emerging from that discourse is for a vision or energy education generally, and bioenergy education in particular, where the divide between science and community is bridged through radically accessible shared knowledge. In that future, energy education will be developed and delivered collaboratively - involving many faces and voices. In that future, future energy literacy will valued as a direct benefit to individuals, communities, and the environment. Energy education will be mainstreamed into communities large and small, urban and rural, ethnically delineated and racially mixed, rich and poor. Communities will practice energy education, and through their practice, contribute to energy science discourse and broaden the context within which energy science is conducted. In this future, everyone can contribute to our transition to a renewable energy future.

And although everyone will not choose to pursue energy careers, all will recognize the power, practicality and possibility that energy literacy brings to:

- discover how energy systems work in the context of climate change,
- understand the energy challenges we face,
- resolve tensions between multiple goals and alternative solutions,
- bound those challenges and solutions locally, regionally, globally, and multiculturally, and
- develop sustainable bioenergy/bioproduct alternatives to fossil feedstocks.

This is a crucial time to broaden participation in energy science and policy. Energy education is critical to our transition to climate-friendly energy systems, U.S. energy independence, and sustainable rural economic development. The ultimate goal is to develop P-12, technical, associate, and baccalaureate educational programs that produce teachers, students, citizens, and workforces prepared to lead the low-carbon economy.

The American STEM workforce lags significantly behind the increasing diversity of society; a consequence both of history, and of the culture and climate of science. A bioeconomic workforce that does not reflect the diversity of society limits the likelihood that the urgent challenges associated with the Anthropocene will be met, while also decreasing the likelihood that findings will be accepted by the broader public. This is partly because environmental consequences are not evenly felt. Lower socioeconomic groups often sustain the brunt of human impacts on the environment. Despite the firsthand experience of many underrepresented groups with environmental inequities, diversity in related STEM fields lags troublingly behind the rest of American society.

Thus, the fundamental energy education challenge we face is the imperative to develop an energy-literate citizenry and workforce to accelerate the transition to a low-carbon economy and sustainable communities. Transition to the bioeconomy requires the participation of the entire breadth of society to find and test novel solutions. Improving the energy literacy of citizens and the workforce is a critical element in this effort. The energy education landscape has become more diverse, sophisticated, and able to respond at the speed of research.