## Authors

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<tr>
<th>Authors</th>
<th>Organization</th>
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</thead>
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## LIST OF ACRONYMS

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

<table>
<thead>
<tr>
<th>Topic</th>
<th>Title</th>
<th>General Description</th>
<th>Grade Level(s)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>All stages</td>
<td>Biomass Adventure Race</td>
<td>Students follow clues to make pine tea following the process of making biofuel</td>
</tr>
<tr>
<td>2</td>
<td>Biojet &amp; Co-products</td>
<td>Biofuel (evening program) (Adapted from FtF)</td>
<td>Students learn about various sources of biofuel and evaluate their sustainability.</td>
</tr>
<tr>
<td>3</td>
<td>Biojet &amp; Co-products</td>
<td>Biofuel (evening program) (Adapted from FtF)</td>
<td>Students debate about the more sustainable fuel option for our region.</td>
</tr>
<tr>
<td>4</td>
<td>Biojet &amp; Co-products</td>
<td>Lifecycle of a Fuel (evening program) (Adapted from FtF)</td>
<td>Students use a lifecycle assessment framework to evaluate the impacts of producing various types of fuel.</td>
</tr>
<tr>
<td>5</td>
<td>Biojet &amp; Co-products</td>
<td>Planes in Flight (evening program) (Adapted from FtF)</td>
<td>Students evaluate the sustainability of jet fuel from the perspective of various government agencies.</td>
</tr>
<tr>
<td>Lesson</td>
<td>Title</td>
<td>Grade</td>
<td>Description</td>
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</tr>
<tr>
<td>7</td>
<td>Biojet &amp; Co-products Value of a Tree</td>
<td>6th-12th</td>
<td>Students determine how many miles of biojet fuel a Ponderosa Pine tree can convert to from the leftover slash.</td>
</tr>
<tr>
<td>8</td>
<td>Forest Management Trees, Water and the Landscape</td>
<td>5th – 6th grade students</td>
<td>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.</td>
</tr>
<tr>
<td>9</td>
<td>Forest Residues Preparation CSKT Forest Management History &amp; Biomass in Your Own Backyard</td>
<td>8th-10th</td>
<td>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 &quot;finding biofuel potential in Your own Backyard&quot; is to have students begin to understand how changes in ecosystems, from less densely vegetated to more densely vegetated, provides different biofuel potential.</td>
</tr>
<tr>
<td>10</td>
<td>Forest Residues Preparation Matchbox Forests Pre &amp; Post European Simulated Forests</td>
<td>8th-10th</td>
<td>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.).</td>
</tr>
<tr>
<td>11</td>
<td>Forest Residues Preparation Mechanical Thinning and Biofuel Production</td>
<td>8th-10th</td>
<td>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.</td>
</tr>
<tr>
<td>12</td>
<td>Forest Residues Preparation Posters &amp; Holistic Forest Management Plans (summative of previous 3)</td>
<td>8th-10th</td>
<td>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.</td>
</tr>
<tr>
<td>13</td>
<td>Forest Residues Preparation &amp; Transportations From Forest to Fuel</td>
<td>High School</td>
<td>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.</td>
</tr>
<tr>
<td>14</td>
<td>General Energy Literacy Classifying Energy</td>
<td>Students learn about different types of energy from a physics perspective (e.g. kinetic, potential, thermal, nuclear, etc.)</td>
<td>5th-12th</td>
</tr>
<tr>
<td>15</td>
<td>General Energy Literacy Energy Audit</td>
<td>Students will engage in an energy scavenger hunt to determine what items on campus use the most electricity.</td>
<td>6th-8th</td>
</tr>
<tr>
<td>16</td>
<td>General Energy Literacy Energy Ethics</td>
<td>Students will explore the ethics behind energy choices.</td>
<td>6th-8th</td>
</tr>
<tr>
<td>17</td>
<td>General Energy Literacy Greenhouse Gases</td>
<td>Students will understand the greenhouse effect and the role of greenhouse gases in Earth's atmosphere.</td>
<td>7th-12th</td>
</tr>
<tr>
<td>18</td>
<td>General Energy Literacy Local Sustainable Energy</td>
<td>Students should understand how biofuels can help create energy independence for a local community.</td>
<td>7th-12th</td>
</tr>
<tr>
<td>19</td>
<td>General Energy Literacy MOSS Energy Day</td>
<td>Students will explore how energy moves through trophic levels, learn about various sources of energies and their advantages and disadvantages.</td>
<td>5th-12th</td>
</tr>
<tr>
<td>20</td>
<td>General Energy Literacy Reducing Your Carbon Footprint, One Step at A Time</td>
<td>During this lesson, students will understand that carbon dioxide (CO2) is one of the largest contributors to climate change and learn how they can reduce CO2 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.</td>
<td>5th-12th</td>
</tr>
<tr>
<td>21</td>
<td>General Energy Literacy Renewable Energy (evening program) (Adapted from FtF)</td>
<td>Students learn about various types of energy sources and evaluate the pros and cons of each.</td>
<td>6th-12th</td>
</tr>
<tr>
<td>22</td>
<td>General Energy Literacy The Great Debate</td>
<td>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.</td>
<td>6th-12th</td>
</tr>
<tr>
<td>23</td>
<td>General Energy Literacy Tool for Oil (Adapted from FtF)</td>
<td>Learn about renewable and nonrenewable resources while “drilling for oil” with beans.</td>
<td>5th-8th</td>
</tr>
<tr>
<td>24</td>
<td>General Energy Literacy Tool for Oil Beans - revised</td>
<td>Learn about renewable and nonrenewable resources and identify issues related to the environment from using them.</td>
<td>5th-6th</td>
</tr>
<tr>
<td>25</td>
<td>General Energy Literacy Tool for Oil Tag</td>
<td>Learn about renewable and nonrenewable resources and identify issues related to the environment from using them.</td>
<td>5th-6th</td>
</tr>
<tr>
<td>26</td>
<td>General Energy Literacy Vacation Carbon Footprint</td>
<td>Students will examine the carbon used on a vacation involving a flight.</td>
<td>5th-12th</td>
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<td>---</td>
</tr>
<tr>
<td>23</td>
<td>General Energy Literacy</td>
<td>Toil for Oil (Adapted from FIF)</td>
<td>Learn about renewable and nonrenewable resources while “drilling for oil” with beans.</td>
</tr>
<tr>
<td>24</td>
<td>General Energy Literacy</td>
<td>Toil for Oil Beans - revised</td>
<td>Learn about renewable and nonrenewable resources and identify issues related to the environment from using them.</td>
</tr>
<tr>
<td>25</td>
<td>General Energy Literacy</td>
<td>Toil for Oil Tag</td>
<td>Learn about renewable and nonrenewable resources and identify issues related to the environment from using them.</td>
</tr>
<tr>
<td>26</td>
<td>General Energy Literacy</td>
<td>Vacation Carbon Footprint</td>
<td>Students will examine the carbon used on a vacation involving a flight.</td>
</tr>
<tr>
<td>27</td>
<td>General Energy Literacy</td>
<td>What’s a Watt Worth</td>
<td>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.</td>
</tr>
<tr>
<td>28</td>
<td>General Energy Literacy</td>
<td>Wind &amp;/or Solar Hunt</td>
<td>Students will explore renewable sources of energy and which would provide the most energy on the MOSS campus</td>
</tr>
<tr>
<td>29</td>
<td>General Energy Literacy</td>
<td>Winter Photosynthesis</td>
<td>Students understand the flow of energy in an ecosystem.</td>
</tr>
<tr>
<td>30</td>
<td>General Energy Literacy &amp; Fermentation</td>
<td>Energy Values</td>
<td>A demonstration of how different fuels have different energy densities.</td>
</tr>
<tr>
<td>31</td>
<td>General Energy Literacy / Ecosystem Energy</td>
<td>Life in a Food Chain</td>
<td>Students understand the flow of energy in an ecosystem</td>
</tr>
<tr>
<td>32</td>
<td>General Energy Literacy &amp; Forest Residues Preparation</td>
<td>Forest Management</td>
<td>Student will be able to evaluate the benefits and drawbacks of forest management strategies.</td>
</tr>
<tr>
<td>33</td>
<td>LCA</td>
<td>LCA over a cup of coffee</td>
<td>Following the lesson, students will have an understanding of the creation and uses of life cycle assessments.</td>
</tr>
<tr>
<td>34</td>
<td>LCA</td>
<td>Life Cycle Assessment</td>
<td></td>
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</tr>
<tr>
<td>35</td>
<td>NARA project as case study</td>
<td>MOSS Teacher Institute</td>
<td>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.</td>
</tr>
<tr>
<td>36</td>
<td>NIFA</td>
<td>Beetle Kill to Bioenergy</td>
<td>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.</td>
</tr>
<tr>
<td>37</td>
<td>Pre-treatment</td>
<td>Making Chemistry Visible</td>
<td>The objective is to explain and demonstrate the chemical process of turning woody biomass into biofuel.</td>
</tr>
<tr>
<td>38</td>
<td>Pre-treatment</td>
<td>Plant Cell Walls to Alcohol</td>
<td>Students are challenged with separating the usable cellulose and hemicellulose from the lignin co-product.</td>
</tr>
<tr>
<td>39</td>
<td>Residuals prep</td>
<td>Value of Slash</td>
<td>Students learn about the value of slash and potential fire mitigation reasons for removing slash from a forest.</td>
</tr>
<tr>
<td>40</td>
<td>Sustainability/Wildlife</td>
<td>Value of a Dead Tree</td>
<td>Students will learn about the value of standing dead trees for wildlife habitat</td>
</tr>
<tr>
<td>41</td>
<td>Transportation</td>
<td>Cleaning up our Air</td>
<td>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.</td>
</tr>
<tr>
<td>42</td>
<td>Transportation</td>
<td>CO2 &amp; Biofuel Adventure Race</td>
<td>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 go on their own “adventure race” that models their respective process.</td>
</tr>
</tbody>
</table>
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 “missed”. 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 posttest (t(304) = -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 posttest (t(304) = -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 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.
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-2.2. “Adventures in Bioenergy” teacher workshops.

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

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

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

### Table NE-2.4. Paired Samples Test for teacher workshop

<table>
<thead>
<tr>
<th>Questions</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Interval of the Difference</th>
<th>Lower</th>
<th>Upper</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1 I include bioenergy as a topic in my classroom</td>
<td>-2.040</td>
<td>3.116</td>
<td>.623</td>
<td>-3.267</td>
<td>-3.754</td>
<td>-.754</td>
<td>-3.274</td>
<td>24</td>
<td>.003*</td>
</tr>
<tr>
<td>Pair 2 I engage students in critical thinking about global issues</td>
<td>-3.460</td>
<td>1.325</td>
<td>.260</td>
<td>-3.881</td>
<td>-3.132</td>
<td>.189</td>
<td></td>
<td>25</td>
<td>.195</td>
</tr>
<tr>
<td>Pair 3 Energy education is important</td>
<td>-1.192</td>
<td>3.099</td>
<td>.608</td>
<td>-2.444</td>
<td>-2.059</td>
<td>.489</td>
<td>-1.000</td>
<td>25</td>
<td>.061</td>
</tr>
<tr>
<td>Pair 4 Energy is relevant to and connected to the subject(s) I teach</td>
<td>-1.462</td>
<td>2.353</td>
<td>.462</td>
<td>-2.142</td>
<td>-1.789</td>
<td>.489</td>
<td></td>
<td>25</td>
<td>.327</td>
</tr>
<tr>
<td>Pair 5 I am knowledgeable about bioenergy issues</td>
<td>-2.320</td>
<td>2.610</td>
<td>.522</td>
<td>-3.397</td>
<td>-2.445</td>
<td>.489</td>
<td></td>
<td>24</td>
<td>.000*</td>
</tr>
<tr>
<td>Pair 6 I am comfortable teaching about bioenergy in my classroom</td>
<td>-2.720</td>
<td>2.441</td>
<td>.488</td>
<td>-3.728</td>
<td>-2.172</td>
<td>.571</td>
<td></td>
<td>24</td>
<td>.000*</td>
</tr>
</tbody>
</table>

* Indicates statistical significance at p<.05
• 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

<table>
<thead>
<tr>
<th>STATE</th>
<th>Idaho</th>
<th>Montana</th>
<th>Oregon</th>
<th>Washington</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Teacher’s Guides and Free Lessons</td>
<td>24</td>
<td>2</td>
<td>47</td>
<td>140</td>
</tr>
<tr>
<td>Potential Student Reach*</td>
<td>720</td>
<td>60</td>
<td>1,410</td>
<td>4,200</td>
</tr>
</tbody>
</table>

*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:
Other outreach efforts included:

- 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. However, questions 12-15 were written by FTF to address sustainability and to help inform FTF program.

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.

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

* 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.

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 ($t (41) = -0.57, p = .588$). 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

<table>
<thead>
<tr>
<th>Construct</th>
<th>Mean Pretest Score</th>
<th>Standard Deviation Pretest</th>
<th>Mean Posttest Score</th>
<th>Standard Deviation Posttest</th>
<th>Significance* Pretest vs. Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-Assessment (15 points possible)</td>
<td>8.75</td>
<td>1.67</td>
<td>9.12</td>
<td>0.99</td>
<td>.528</td>
</tr>
<tr>
<td>Affective (40 points possible)</td>
<td>33.50</td>
<td>5.48</td>
<td>34.50</td>
<td>5.42</td>
<td>.104</td>
</tr>
<tr>
<td>Behavior (20 points possible)</td>
<td>12.38</td>
<td>2.39</td>
<td>13.38</td>
<td>2.97</td>
<td>.200</td>
</tr>
<tr>
<td>Cognitive (22 points possible)</td>
<td>15.38</td>
<td>2.39</td>
<td>16.00</td>
<td>3.02</td>
<td>.588</td>
</tr>
<tr>
<td>Total (92 points possible)</td>
<td>70.00</td>
<td>9.12</td>
<td>73.00</td>
<td>10.31</td>
<td>.106</td>
</tr>
</tbody>
</table>

* 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

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.

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

<table>
<thead>
<tr>
<th>Question</th>
<th>After taking this workshop, I am more likely to integrate sustainability into my curriculum.</th>
<th>After taking this workshop, I am more likely to integrate energy into my curriculum.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>POST</td>
<td>POST</td>
</tr>
<tr>
<td>Average</td>
<td>4.43</td>
<td>4.55</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0.60</td>
<td>0.76</td>
</tr>
</tbody>
</table>
• 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.
**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 chains. 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 four-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).

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.

![Figure NE-3.1. NARA Supply Chain](image-url)
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, for wood-based biofuels facilities are listed in Table NE-3.1.

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.

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

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

**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.

**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 conversion 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 M2P, 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 multi-
ple 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.

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

**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 Drs. 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)
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-4.5. 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)

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.

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.

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 tech-
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 Voiland 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.

![Number of applications and participants for 2012-2016.](chart)

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

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>36%</td>
<td>61%</td>
<td>48%</td>
<td>49%</td>
<td>54%</td>
</tr>
<tr>
<td>Male</td>
<td>64%</td>
<td>39%</td>
<td>52%</td>
<td>51%</td>
<td>46%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>18%</td>
<td>11%</td>
<td>6%</td>
<td>12%</td>
<td>14%</td>
</tr>
<tr>
<td>Native American/African American</td>
<td>9%</td>
<td>11%</td>
<td>18%</td>
<td>12%</td>
<td>4%</td>
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<tr>
<td>Multi-cultural</td>
<td>NA</td>
<td>5%</td>
<td>NA</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>Asian/Pacific Islander</td>
<td>9%</td>
<td>34%</td>
<td>31%</td>
<td>19%</td>
<td>36%</td>
</tr>
<tr>
<td>Caucasian</td>
<td>64%</td>
<td>39%</td>
<td>37%</td>
<td>45%</td>
<td>39%</td>
</tr>
</tbody>
</table>
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>
<thead>
<tr>
<th>Year</th>
<th>male</th>
<th>female</th>
<th>hispanic</th>
<th>NA/AA</th>
<th>Caucasian</th>
<th>Asian</th>
<th>non research institution</th>
<th>freshman/sophomore</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>2012</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>1</td>
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<td>7</td>
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<td>2013</td>
<td>6</td>
<td>3</td>
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<td>1</td>
<td>3</td>
<td>4</td>
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<td></td>
<td>9</td>
</tr>
<tr>
<td>2014</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>2015</td>
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<td>8</td>
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<td>8</td>
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<td>2</td>
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<td>13</td>
</tr>
<tr>
<td>2016</td>
<td>4</td>
<td>9</td>
<td>1</td>
<td>1</td>
<td>9</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td>All years</td>
<td>20</td>
<td>27</td>
<td>6</td>
<td>7</td>
<td>25</td>
<td>9</td>
<td>12</td>
<td>12</td>
<td>47</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>2016</th>
<th>John Barth</th>
<th>Commination of Unmerchantable Forest Residuals to Determine Power and Energy Consumption as a Function of Moisture Content and Size Reduction Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Muhui Chen</td>
<td>Development of Epoxy Coating Technology on Lignosulfonate Hydrogels</td>
</tr>
<tr>
<td></td>
<td>Jessica Curry</td>
<td>The Value of Slash Trees and Snags in Forest Ecosystems</td>
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<tr>
<td></td>
<td>William Daniels</td>
<td>Characterization of Molecular Structure and Interlinkage Network for Seven Representative Biorefinery Lignin</td>
</tr>
<tr>
<td></td>
<td>Allie Davis</td>
<td>Regional equations for streams in forested watersheds in the Pacific Northwest</td>
</tr>
<tr>
<td></td>
<td>McKayla Drozd</td>
<td>Biofuel Concept Learning Assessment of Middle School and Elementary School Youth through the Value of a Tree Lesson Plan</td>
</tr>
<tr>
<td></td>
<td>Abigail Flowers</td>
<td>Types of Energy with Biofuels Applications</td>
</tr>
<tr>
<td></td>
<td>Sarah Knue</td>
<td>Lesson Plan Design: Life Cycle Assessment of NARA Jet Biofuel</td>
</tr>
<tr>
<td></td>
<td>Sarah Pate</td>
<td>Energy Literacy and Sustainability Topics in a High School Problem-Solving Competition</td>
</tr>
<tr>
<td></td>
<td>Thomas Potolicchio</td>
<td>DES for the Extraction of Lignin from Biomass</td>
</tr>
<tr>
<td></td>
<td>Shalonda Robinson</td>
<td>Educating Youth on the Carbon Cycle within Biofuel Production</td>
</tr>
<tr>
<td></td>
<td>Guadalupe Salazar</td>
<td>Water-based Acrylic Polymer Incorporating Cellulose Nanocrystal for Coating of Food Packaging Films</td>
</tr>
<tr>
<td></td>
<td>Emily Sun</td>
<td>Application Development for Kraft Lignin and Waste Cooking Oil-Based Epoxy Asphalt</td>
</tr>
<tr>
<td>2015</td>
<td>John Barth</td>
<td>Commination of Unmerchantable Forest Residuals to Determine Power and Energy Consumption as a Function of Moisture Content and Size Reduction Range</td>
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<tr>
<td></td>
<td>Kyle Thompson</td>
<td>Characterization and Modification of Asphalt With Epoxy Resins Synthesized From Pyrolysis Oil, a Derivative of Lignocellulosic Biomass</td>
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<tr>
<td></td>
<td>Oshauna Morgan</td>
<td>Characterization of Biorefinery Lignins and Comparison of Reactivity for Value-added Chemical Production</td>
</tr>
<tr>
<td></td>
<td>Adriana Guzman</td>
<td>Making the Chemistry of the NARA Project Visible</td>
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<tr>
<td></td>
<td>Shakerma Haynes</td>
<td>Activated Carbon by Chemical Activation of Lignin with Potassium Hydroxide</td>
</tr>
<tr>
<td></td>
<td>Kasey Markland</td>
<td>Modifying Lignin and Its Model Compounds to Enhance Oxidative Ring Cleavage to Dicarboxylic Acids</td>
</tr>
<tr>
<td></td>
<td>Jennifer Murphy</td>
<td>Educating Youth on Air Pollution Caused by Transportation</td>
</tr>
<tr>
<td></td>
<td>Emily Schwartz</td>
<td>Forest Ecology and Biofuel Production Potential for Tribally-Managed Forests in the Northern Rockies</td>
</tr>
<tr>
<td></td>
<td>Maika Bui</td>
<td>Synthesis of Lignosulfonate Hydrogels cross-linked with PEGDGE</td>
</tr>
<tr>
<td></td>
<td>Aleksandr Kirpach</td>
<td>Preventing Nitrogen Depletion in Forests Undergoing Forest Residual Removal</td>
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<td></td>
<td>Mark Wohlpart</td>
<td>Screening of Value-Added Market Opportunities for Lignin</td>
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<tr>
<td></td>
<td>Sarah Wilkins</td>
<td>Biofuel Transportation and CO2 Emission Adventure Race</td>
</tr>
<tr>
<td></td>
<td>Bailey Yebou</td>
<td>Air Quality Impact of the NARA Aviation Biofuel Refinery</td>
</tr>
<tr>
<td></td>
<td>Eileen Wu</td>
<td>Ball Milling: Effective pretreatment leading to a clean biomass to cellulose sugar conversion</td>
</tr>
<tr>
<td></td>
<td>Cassandra Sanders</td>
<td>Mechanistic kinetics study of biomass derived inhibitory compounds on cellulose hydrolysis of biomass substrate</td>
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<tr>
<td></td>
<td>Preenaa Venugopal</td>
<td>Potential technological pathways for the production of alternative jet fuel</td>
</tr>
<tr>
<td></td>
<td>Eric Sorensen</td>
<td>Spatial distribution of grain sizes in sampling heterogeneous stream beds</td>
</tr>
<tr>
<td></td>
<td>Rodney Seals</td>
<td>Testing lignin as an additive to wooden pellets</td>
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<tr>
<td>2013</td>
<td>Andrea Laguna</td>
<td>Determining the effect of densification of pretreated harvested forest residue on enzymatic monosaccharide production</td>
</tr>
<tr>
<td></td>
<td>Steve Cline</td>
<td>Isolation of high purity lignin from bio-jet biorefinery hydrolysis residue</td>
</tr>
<tr>
<td></td>
<td>Calvin Sitas</td>
<td>Nanocellulose reinforcement for bio-based thermo-responsive resins</td>
</tr>
<tr>
<td></td>
<td>Karissa Garcia</td>
<td>Not all Douglas Fir trees are created equally for conversion to biofuels</td>
</tr>
<tr>
<td></td>
<td>Daniel Leong</td>
<td>Partial depolymerization of lignin using hydrogenolysis over raney nickel</td>
</tr>
<tr>
<td></td>
<td>Kane Norton</td>
<td>Physical methods for breakdown of cellulose crystallinity</td>
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<tr>
<td></td>
<td>Chanel Casayuran</td>
<td>Preparation and characterization of porous carbon adsorbent materials from lignocellulosic residuals</td>
</tr>
<tr>
<td></td>
<td>Jing-Li</td>
<td>Surface characterization of lignocellulosic biomass for understanding the enzymatic hydrolysis</td>
</tr>
<tr>
<td>2012</td>
<td>Lucy Ch Adelaide</td>
<td>Analysis of bioproducts from ultra-low cost biomass processing</td>
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<tr>
<td></td>
<td>Maggie Buffum</td>
<td>Assessing moisture content in biomass piles</td>
</tr>
<tr>
<td></td>
<td>Brady Do</td>
<td>Assessing risks of arson in biomass piles</td>
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<td></td>
<td>Ellen Simonsen</td>
<td>Biobased curing agent for epoxy</td>
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<tr>
<td></td>
<td>Pedro Guajardo Jr.</td>
<td>Diluted acid and peroxide pretreatments of Douglas Fir</td>
</tr>
<tr>
<td></td>
<td>Anthony Lathrop</td>
<td>Evaluation at nano-scale of hot water extracted Ponderosa Pine chips</td>
</tr>
<tr>
<td></td>
<td>Madeleine Fuchs</td>
<td>NARA biofuels production emissions</td>
</tr>
<tr>
<td></td>
<td>Burdette Birdground</td>
<td>Scale up of an ultra-low cost in forest thermal processing of biomass</td>
</tr>
</tbody>
</table>

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.
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.
NARA OUTPUTS

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

Refereed Publications


Research Presentations


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).


Conference Proceedings and Abstracts from Professional Meetings


Research Presentations


Videos and Webinars

Trainings, Education and Outreach Materials


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

<table>
<thead>
<tr>
<th>Date</th>
<th>Workshop/Training</th>
<th>Venue</th>
<th>City, State</th>
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<td>Fueling Our Future: Exploring Sustainable Energy Use</td>
<td>Snohomish County PUD</td>
<td>Everett, WA</td>
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<td>5/21/2016</td>
<td>Biofuels in the Pacific Northwest</td>
<td>Imagine Tomorrow</td>
<td>Pullman, WA</td>
<td>17</td>
<td>Danica Hendrickson</td>
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<td>4/1/2016</td>
<td>Fueling Our Future</td>
<td>Montana Environmental Education Association Annual Conference</td>
<td>Bozeman, WA</td>
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<td>Spring 2016</td>
<td>Open Lab for K-5 Teachers - How can FOF be used to meet NYS Draft Standards?</td>
<td>SUNY- Fredonia</td>
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<td>3/1/2016</td>
<td>Peer Educator Online Meeting: Energy</td>
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<td>Online</td>
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<td>1/28/2016</td>
<td>Biofuels in the Pacific Northwest</td>
<td>Storming the Sound</td>
<td>La Conner, WA</td>
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<td>7/29/2015</td>
<td>Fueling Our Future</td>
<td>Facing the Future</td>
<td>Seattle, WA</td>
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<td>Danica Hendrickson</td>
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<td>6/22 to 6/26/15</td>
<td>FOF Lessons 8 and 9</td>
<td>MOSS Summer Institute</td>
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<td>Imagine Tomorrow</td>
<td>Pullman, WA</td>
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<td>Danica Hendrickson; Karla Eitel</td>
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<td>3/6/2015</td>
<td>Interdisciplinary and Interconnected: Social Studies Takes on Energy</td>
<td>WA State Council for the Social Studies Spring Chelan Conference</td>
<td>Chelan, WA</td>
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<td>Danica Hendrickson; Alicia Keefe</td>
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<td>11/8 to 11/9/2014</td>
<td>FOF Lessons 2, 8, and 9</td>
<td>U of Wisconsin KEEP and Upham Woods Outdoor Learning Center</td>
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<td>6/20/2014</td>
<td>Classroom Lessons to Teach About Sustainability</td>
<td>MREA: The Energy Fair</td>
<td>Custer, WI</td>
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<td>Fall 2013</td>
<td>Fueling Our Future Imagine Tomorrow MOSS-NARA Webinar</td>
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<td>Fall 2013</td>
<td>Fueling the Future: Energy Interconnections and Sustainable Choices</td>
<td>National Science Teachers Association</td>
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<td>Dave Wilton</td>
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<td>11/15/13</td>
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<td>Global Sustainability Webinar Series, Archived as YouTube video.</td>
<td>Online</td>
<td>278 views</td>
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<td>June 2013</td>
<td>Workshop featuring FOF Lessons</td>
<td>Webster University’s Summer Sustainability PK-12 Institute</td>
<td>St. Louis, MO</td>
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<td>April 2013</td>
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<td>Dave Wilton</td>
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</table>
Task 3: IDX

**Refereed Publications**


**Research Presentations**


**Posters**


Other Publications


The Northwest Advanced Renewables Alliance (2013). Western Montana corridor: site selection and supply chain analysis (Vol. 3). Pullman, WA.


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


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

Videos and Webinars


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


**Thesis and Dissertations**


**Task 4: Imagine Tomorrow with Biofuels**

**Physical**

The May 2012 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 2013 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 56% 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)**


**Research Presentations**


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.


Other Publications


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


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

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

Partial 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 lignocellulosic 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

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.


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


WSU News Story “WSU Hosts Eight Summer Research Programs for Undergraduates” http://universitycollege.wsu.edu/units/undergraduate research/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/undergraduate research/News-Events/headlines/2014PosterPreview/

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

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


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


WSU News Story “WSU’s July 31 symposium features work of U.S., international undergraduate researchers” http://universitycollege.wsu.edu/units/undergraduate research/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

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<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Role</th>
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<td>Travis Beauvais</td>
<td>SKC</td>
<td>Student researcher</td>
<td>Senior thesis on culverts and tribal forest road hydrology</td>
</tr>
<tr>
<td>Robert Davis</td>
<td>SKC</td>
<td>Student researcher</td>
<td>Senior Thesis on hydrological climate change impacts on tribal forest roads</td>
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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. 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).

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.

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.

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
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 multicursively, 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.