NARA Goal Four

3RD Cumulative Report

April 2014 - March 2015

Supply Chain Coalitions

Envision and delineate pilot supply chains within the NARA region.

SUMMARY

The NARA project is designed to develop a roadmap for industry to produce biojet and co-products from forest residues. This roadmap can only become reality when regional stakeholders (businesses, government agencies, and private individuals) are empowered to actually build the industry. Involving stakeholders in the research process and using their input to shape the supply chain analysis is an integral step on the pathway to this new industry. We are using the Outreach and Education Teams in key roles toward this end. Regional stakeholders are identified, organized, and/or engaged by the Outreach Team working to develop regional assets and needs. The Education Team then partners with these stakeholders and mentors student teams who analyze and design regional supply chains for potential biofuels production. This two-pronged alliance both engages stakeholders in the research process and develops the regional knowledge and interest to carry the industry forward. Finally, the diverse student teams researching the supply chains develop into the trained workforce of the future.

NARA is building regional capacity to implement a biofuels industry by focusing on three areas:

1) Identifying and engaging key stakeholders and incorporating them into the planning process
2) Cataloging regional supply chain assets, analyzing the logistical and economic relationship among these assets, and providing recommendations and strategies on how best to employ them
3) Communicating researched-based strategies to stakeholders and facilitating business development where feasible


Supply chain presentations in Montana. NARA Photo

Facilitating the development of pilot supply chains actually engages all NARA members; however, groups within the NARA Outreach and Education Teams have tasks dedicated to this goal. To engage regional stakeholders and foster working collaborations to develop a wood-based biofuel and co-product industry, the NARA Outreach Team hosted and completed a NW Wood-based Biofuels + Co-Products Conference (April 28-30, 2014) in Seattle. This first-time conference provided a mix of industry and academic representatives followed by a large student and government presence. This mix fit well with NARA's mission to provide multiple stakeholder groups with analyses and data that facilitate a wood to biofuels and co-product industry. In addition, the sizable student presence complemented NARA's goal to enhance bioenergy literacy for a sustainable work force. Another opportunity to involve stakeholders with NARA research occurred in conjunction with NARA's annual meeting in Seattle (Sept. 15-17). Here, regional stakeholders attended a one-day series of presentations and panel discussions devoted to NARA's work on the economic, social and environmental sustainability of using wood residuals to make biojet fuel and other bio-related co-products. The invited guests provided critical recommendations and perspectives to NARA's work. The NARA Outreach team represented NARA at the WA Biomass Coordination Group and MT Forest Products Industry Roundtable and described the ongoing progress with NARA regional supply chain studies at seven regional stakeholder meetings. For this reporting period, NARA researchers presented over 150 times at 69 separate venues throughout the world.

Laurel James meets with forestry professionals . NARA Photo

STUDENT/STAKEHOLDER INTERACTION

To envision regional supply chain assets and provide recommendations and strategies on their utility, the Education Team assists the outreach efforts by forming collaborations between students, NARA mentors and stakeholders to provide regional supply chain analyses. NARA researchers and university students participate in a year long integrated design course called Integrated Design Experience (IDX), offered through the [Institute for Sustainable Design]() at Washington State University. In this collaborative course, multidisciplinary student teams analyze biofuel supply chain scenarios in partnership with regional stakeholders. For this reporting period, this group focused their supply chain analysis on the entire NARA region of Idaho, Montana, Oregon, and Washington, as opposed to sub-regional analyses in previous years. They identified and ranked facility sites that could accommodate varied segments of the supply chain and refined the forest residual volume calculations for the various facility sites considered. These sites are categorized as either solids depots, liquid depots, conversion plants or integrated biorefinery. The IDX group communicated their findings to regional stakeholders via [webinars]() on 10/20/14 and 11/19/14. The Wauna Pulp and Paper Mill was highlighted as a high ranking site for a liquid depot and integrated biorefinery and will be the subject of a site inventory and design project completed in May, 2015 (Task E-3).

A similar collaboration of students, NARA mentors, and stakeholders was employed with the NARA Tribal Partnership Program (TPP). The TPP group provided the Confederated Salish and Kootenai Tribes (CSKT) a 10-year biomass supply projection study in NARA Year-3. In this reporting period, they will investigate the Tribe's 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. The TPP will also investigate the availability of Renewable Identification Numbers (RINs) credits associated with lands under the Tribal Forest Protection Act and project emissions from a potential sulfite-based sugar-processing depot on the reservation. The TPP group arranged for Douglas-fir forest residuals to be acquired from CSKT and Muckleshoot tribal forests to be used by NARA to generate 1000 gallons of biojet fuel (Task E-1).

SUGAR DEPOT ANALYSIS

To utilize forest residuals from remote areas where direct woody feedstock transport to a biorefinery is cost prohibited, a distributed production scenario is being explored where forest residuals are converted into "sugar syrup" that can be transported for further product development. Achieving this goal could potentially decrease biomass transport and labor costs while extending utilization of existing facilities. Distributed production can also provide a diversified biomass source to mitigate supply risks and reduce the supply radius. To investigate this potential, experiments were conducted to explore transforming wood residuals inexpensively into a transportable pellets, panels or sugars. Douglas-fir residuals were milled to 30 µm particles, hydrolyzed, and fermented using Gevo's GIFT™ technology (Task C-AF-1; E-8). The yeast biocatalysts were able to grow and produce isobutanol in 100% wood-milled hydrolysate, which contrasts to a limitation of 40% hydrolysate for yeast biocatalyst fermentation using sulfite-based hydrolysate. The energy consumption and sugar yields for wood milling have been determined, and a preliminary techno-economic analysis (TEA) indicates that sugar production through this milling process is economically competitive with processes used to generate sugar from other cellulosic materials. A more complete TEA for all unit operations anticipated in a sugar depot refinery model, using milled wood pretreatment, is underway (Task subE-8). Structural and chemical characterizations were determined for the milled particles; further analysis revealed that that no chemical inhibitors to the fermentation process were in the sugar stream and that the lignin was highly reactive. These results indicate that the milling process can produce pretreated material from Douglas-fir residuals that is as good if not superior to thermal-chemical pretreated material and is a promising technology for depot sized facilities (Task E-8).

MUNICIPAL SOLID WASTE

Forest residues constitute a majority of the wood biomass supply considered for producing biojet. Another source of wood residue feedstock is construction and demolition debris (C&D) portion of municipal solid waste (MSW). NARA researchers characterized the waste wood residues from select material recovery facilities (MRF) and determined that carbohydrate content is similar between MRF wood supplies and forest residuals. MRF wood supplies do, however, contain higher levels of ash, metals and alkanes. The MRF wood materials were pretreated using a sulfite-based method (SPORL), and the hydrolysate was enzymatically hydrolyzed. A mass balance from the pretreatment and hydrolysis experimentation will be available in Summer 2015 (Task E.7).

SIGNIFICANT OUTPUTS REPORTED THIS PERIOD FOR NARA TEAMS SUPPORTING SUPPLY CHAIN COALITIONS

- NARA Outreach Team hosted and completed a NW Wood-based Biofuels + Co-Products Conference (April 28-30, 2014) in Seattle: Proceedings (Task O-1)
- An Analysis report was completed ranking sites in the western Oregon and Washington (MC2P) for solids depots, liquid depots, conversion plants or integrated biorefinery (Task E-3).
- A webinar was provided to educate and receive stakeholder comments regarding facility site ranking results (Task E-3).
- A Preliminary Scoping report was created to outline the analysis work being done by IDX for the Pacific Northwest region (Task E-3).
- Supplemental information regarding mitigation plans for natural disasters in the MC2P region were developed and posted (Task E-3).
- Douglas-fir forest residuals were acquired from CSKT and Muckleshoot tribal forests to be used by NARA to generate 1000 gallons of biojet fuel (Task E-1).

SIGNIFICANT OUTCOMES

To participate in first production of bio-jet fuel from forest residuals and the resulting demonstration flight, the Confederated Salish and Kootenai Tribes (CSKT) and the Muckleshoot Tribe provided forest residuals from their tribal forests (Task E-1; Task O-1).

TRAINING

Name	Affiliation	Role	Contribution
Mond Guo	WSU-TC	Graduate Student (PhD)	
Sanne' Rijkhoff	Ruckelshaus Center/DGSS	DGSS RA	
James Casey	University of Idaho	Graduate Student	Data collection on slash pile volumes
Jon Potter	WSU	Graduate Student (MS)	IDX fellow. Tasked with assisting with external communications for the class, including templates for presentations, printing posters, etc. Jon has also been the primary lead on the supply chain analysis for the MC2P region and is in the process of writing a paper to compare the WMC with the MC2P region
Vincent McIntyre	WSU	Graduate Student (MS), started June 2014	IDX fellow. Tasked with analyzing the markets in the PNW region. Vince has also been assisting with creating a new IDX GIS repository for all data pertinent to the PNW region.
Peter Gray	WSU, Economic Sciences	Graduate Student (PhD)	Lead Supply Chain specialist for the IDX team. His responsibilities include an economic analysis of the supply chain for distributed and localized models of biomass collection.
Natalie Martinkus	WSU, Civil Engr.	Graduate Student (PhD)	Lead GIS specialist for the IDX team. Her responsibilities include collection, documentation, and analysis of all GIS assets in the PNW region.
McKenzie Payne	University of Idaho	Graduate Student (MS)	Writing articles on the following: developing opportunities for an emerging biofuels industry in the Pacific Northwest, examining environmental impacts, and stakeholder support for wood-based biofuels.
Scott Millman	University of Idaho	Graduate Student (MS)	Writing articles focused on developing opportunities for an emerging biofuels industry in the Pacific Northwest. Writing literature review for paper on biofuels site selection, and searching for newspaper articles chronicling support or opposition to biofuels facilities.
Joshua Hightree	University of Idaho	Graduate Student (MS)	Worked on facility and sizing needs for IBR at Cosmo Specialty Fibers and Kapstone Pulp and Paper
Jorge Jordan	University of Idaho	Graduate Student (MS)	Developing traffic impact models for IBR and liquid depot sites in the PNW.
Ryan Jacobson	University of Idaho	Graduate Student (MS)	Working on biomass estimates for solids, liquids and IBR facilities in the Pacific Northwest. Developing an online biomass and cost estimator.
Alexandria Marienau	University of Idaho	Graduate Student (MS)	Examining economic develop organizations & their support for wood-based biofuels and bioenergy
Courtney Mattoon	University of Idaho	Graduate Student (MS)	Examining economic develop organizations & their support for wood-based biofuels and bioenergy
Rui Zhu	WSU, Civil Engr.	Graduate Student (MS)	Outreach responsibilities: maintain stakeholder master list, NARA's official Twitter account; compile database of assets; and assist with other outreach activities. Research responsibilities: study the effects of hot water extraction (HWE) on Douglas-fir biomass and understand the influence of processing factors; investigate the impact of HWE on the downstream sulfite pretreatment of Douglas-fir biomass and corresponding sugar yields; exploring the reinforcing potentials of cellulose nanofibrils (CNFs) using electrospinning technology.

Sarah Dossey	CMEC, WSU	Technical Assistant	Developing Knowledge Base; assisting with conferences; compiling database of stakeholders
Janna Loeppky	Oregon State Univ	Graduate Student	Reporting on NARA OSU research
Raul Pelaez Samaniego	WSU	Post-Doc	Raul is performing all the testing and data analysis for this study.
Lanxing Du	CMEC	Visiting PhD Student	Characterization of lignin residues
Jinxue Jiang	WSU, Materials Science & Engr.	Graduate Student (PhD)	Fundamental understanding of milling effect on recalcitrance of biomass
Yalan Liu	WSU, Materials Science & Engr.	Graduate Student (PhD)	Size Reduction and Sulfite Pretreatment of Softwood for Efficient Hydrolysis and High Value Products Yield
Huinan Liu	WSU, Engr.	Graduate Student (MS)	Enhancing the Milled Wood Enzymatic Hydrolysis Through Post-Milling Kneading by a Torque Rheometer
Rodney Seals	University of Arkansas	SURE student	Testing the milled wood lignin residues as an binder for wood pellets
Eileen Wu	University of California at Berkeley	SURE student	Characterization and comparison of hydrolysates from the mechanical pretreatment and other thermochemical pretreatments

RESOURCE LEVERAGING

Resource Type	Resource Citation	Amount	Relationship or Importance to NARA
Grant	FAA ASCENT Project 1. Alternative Jet Fuel Supply Chain Analysis		A proposal has been accepted by the FAA to support collection of data on perceptions of biofuel, market dynamics and logistical challenges associated with widespread adoption of aviation biofuel. This proposal includes the NARA region for initial implementation, but will extend into other regions as well. The CAAM model will be augmented with additional data from this effort.
	China Scholarship Council (CSC)		Support for Yalan Liu and Jinxue Jiang
RA Funding	WSU, Provost Office		Support for Mond Guo
RA Funding	WSU, Provost Office		Support for Natalie Martinkus
RA Funding (submitted 1/2016)	U.S. Department of Energy	$100,000	Extend NARA/IDX research in Clearwater basin to examine small-scale biofuels production
Scholarship	China Scholarship Council (CSC)		Support for Yalan Liu and Jinxue Jiang
RA Funding	WSU, Provost Office		Support for Huinan Liu
Grant funding	The Joint Center for Aerospace Technology Innovation (JCATI)	$98,000	Title: Mechanical Pretreatment to Produce Cellulosic Sugars at a Pilot Scale

SUPPLY CHAIN

OUTREACH TEAM

TASK O-1: WASHINGTON STATE UNIVERSITY NARA EXTENSION INITIATIVES

Key Personnel	Affiliation
Vikram Yadama	Washington State University
Karl Englund	Washington State University

Task Description

NARA units, research, extension and industry members, will act as partners and facilitators with the ultimate goal of empowering the stakeholders to plan and implement the changes needed to build, develop, and sustain a biorefinery infrastructure. The goal of the outreach team is to promote stakeholder bioenergy literacy and build regional supply chain coalitions for development of a framework of biofuel and co-products production from woody biomass. End outcomes of this goal are sustainable production of biojet fuel and co-products and rural economic development. Following are the objectives of the outreach team to reach this goal:

I. Bioenergy Literacy, where we: a) disseminate the research-based information (on technology and markets) to our industrial stakeholders and understand the technical challenges regarding implementation at industrial scale (industry-focus); b) relate the feedstock development and logistics information to our resource-based stakeholders (local communities, forest landowners, forest managers) and hear their concerns regarding the type of information that will assist them in keeping their costs low and marketable value high (resource-focus); and, engage the organizations and partnerships in connecting with public-interest groups and policymakers (public-focus). These activities will be carried out via a variety of communication mechanisms, including social media, newsletters, briefing papers, extension publications, workshops/seminars, conferences, field trips, and stakeholder meetings. Bioenergy literacy to professionals will be achieved through following tasks.
1) Implement targeted outreach activities for engaging stakeholders and advancing bioenergy literacy to professionals.
2) Catalog activity outcomes and benchmark reports and studies.

II. Build Supply Chain Coalitions (logistical support and stakeholder development and engagement), where we will form working groups with stakeholders at community and bioregion levels to involve them through collaboration across the supply chain: forestland owners and managers, environmental NGOs, businesses, regulatory facilitators, and community infrastructure working groups to interact with and inform policymakers at regional, state, and federal levels. These stakeholders will be internal and external focused around the NARA communities (NCs) selected in the four-state region. This process will rely on support from other teams, such as Education and EPP, and consider physical and social assets along with practical aspects in narrowing down the list to a manageable number of communities with the four-state region. A long list will be shortened through surveying community-based stakeholders in the PNW and intermountain region to strategically choose several NCs for studying the viability of a biofuel-based infrastructure. Once communities are identified, focus group meetings involving a wide variety of stakeholders will be held at each community to discuss feedstock specifications and logistics, technology adoptions within the existing infrastructure, and viable strategies practical and beneficial for the communities. This process will involve industrial stakeholders and NARA industry partners as well. Establishing a meaningful dialogue on what local experts perceive to be the barriers and opportunities for establishing a biorefinery infrastructure in their community is critical. Building supply chain logistics consists of two major tasks.
1) Engaging stakeholders to assist in compiling supply chain assets, analyzing potential supply chain structure, and forming regional alliances.
2) Assist in establishing NARA pilot supply chain (PSC) study region and coordinating activities with NARA's IDX and other research teams for conducting supply chain analysis in the region.

Activities and Results

Bioenergy Literacy

TASK 1:

NARA's Outreach Team hosted and completed the NW Wood-based Biofuels + Co-Products Conference (April 28-30, 2014) in Seattle. Proceedings of the conference are archived and available to the public. A report summarizing the event statistics is attached in Appendix A.

To describe NARA's progress, outputs and activities to NARA members, stakeholders and the general public, 37 newsletter stories were distributed to 976 email subscribers with an average viewing percentage at 27.3 %. Additional information regarding NARA related activities were disseminated through 77 NARA blog posts. 151 NARA presentations were made throughout the world at 69 separate events.

One hundred and four posts on NARA Facebook were generated linking USDA blogs, NARA updates and newsletters, NARA YouTube videos, meetings/events in biofuel/cellulosic bioenergy fields, and other AFRI-CAP information. Post about the NARA ELP

Matrix had the largest reach. Of the people accessing NARA's Facebook, 71% are men and 29% women.

The NARA website reached 11,893 individual users throughout the world of which 57.6% were new users during this annual reporting period.

Seventeen videos were posted on the NARA YouTube channel. These videos present NARA researchers describing their work to determine the sustainability of a wood residual to biojet fuel and co-products industry.

An infographic was developed to articulate the broad impacts provided by NARA Education and Outreach activities, and three fact sheets were developed to highlight the NARA's Tribal Partnership Program, NARA education programs and the supply chain flow and products derived from the production of biojet fuel from forest residuals.

TASK 2:

A repository of unbiased scientific knowledge on wood-based biased biofuels and co-products (Knowledge Base) was converted to a dynamic stakeholder resource. Over 950 users throughout the world (at least one user from 84 countries; majority of users are from the U.S. and Brazil) have accessed the site since it has been established in 2014.

The Outreach and the Education teams are capitalizing on NARA's effort in Year 5 to produce 1000 gallons of biojet fuel by documenting and producing professional-quality media to promote bioenergy literacy. In order to secure a U.S Northwest representative Douglas-fir feedstock supply to produce 1000 gallons of biojet fuel made from forest residuals and used for a demonstration flight, forest residuals from Washington, Oregon and Montana were collected (Figure O.1.1). The Outreach Team video recorded the collection of these feedstocks and conducted interviews with the landowners and foresters. The video recordings will be used to document the production of biojet fuel from forest residuals and construct educational videos.

Figure O.1.1. Forest residuals used for NARA 1000 gallons biofuel production. A) Weyerhaeuser site in southwest Oregon, B) Confederated Salish and Kootenai Tribe forest in northwest Montana, C) Muckleshoot Tribe forest in northwest Washington.

Build Supply Chain Coalitions

TASK 1:

The NARA Outreach team represented NARA at the WA Biomass Coordination Group and MT Forest Products Industry Roundtable (serve as stakeholder leadership teams providing guidance with regional supply chain analyses) and described the ongoing progress with NARA regional supply chain studies at seven regional stakeholder meetings.

Recognizing the need to actively engage ENGOs, the Outreach team compiled a list of individuals and environmental organizations for a personal visit for their perceptions and opinions.

The involvement of the Outreach Team at the varied feedstock sites (Tribal lands and Weyerhaeuser property) during media production reinforced the engagement between NARA and stakeholders and enhanced stakeholder knowledge regarding NARA activities.

TASK 2:

The NARA Outreach team assisted the Education Team's IDX group with planning and writing a Profile document for NARA's Year 4 Supply Chain Study, which summarizes available assets; connected the IDX team with key industry stakeholders (GP, Weyerhaeuser, Port Townsend Paper Company, and ZeaChem); and organized fieldtrips to familiarize students with production/conversion facilities relevant to the NARA project. The Outreach Team also assisted the Education Team in reviewing and compiling the MC2P supply chain study report.

Recommendations | Conclusions

Based on our interactions with the stakeholders and team members, following are the three tasks we would like to concentrate on in the final year of the NARA project:

1) Engage ENGOs. Environmental communities haven't been well represented at stakeholder meetings, conferences, and/or surveys. To capture their concerns and opinions regarding utilization of forest residuals for biofuels, we will need to engage through personal visits and communications.
2) Develop media to capture biojet fuel production within the context of NARA's biofuel process.
3) Dissemination of NARA research findings through an International Conference in Spring 2016.

Physical and Intellectual Outputs

RECOMMENDATIONS/CONCLUSIONS

Zhu, R. and V. Yadama. 2014. "Effects of hot water extraction (HWE) pretreatment on compositional and physicochemical changes of Douglas-fir," Biomass and Bioenergy (Submitted)

Zhu, R. and V. Yadama. "Isolation and characterization of cellulose nanofibrils (CNFs) from hot water extraction (HWE) treated Douglas-fir." In preparation for submission to a refereed journal.

CONFERENCE PROCEEDINGS AND ABSTRACTS FROM PROFESSIONAL MEETINGS

Proceedings of the NW Wood-Based Biofuels + Co-Products Conference, Seattle, WA, April 28-30, 2014.

Yadama, V. 2015. "Siting of Processing Facilities for Wood-To-Biojet Conversion in Oregon," 77th Oregon Logging Conference, Eugene, OR, February 19-21, 2015

Yadama, V. 2015. "Web-based portals for dissemination of research-based findings to stakeholders on wood-to-biofuel conversion," Poster Presentation, National Extension Energy Summit: Climbing Toward Energy Sustainability, Seattle, WA, April 7-10.

RESEARCH PRESENTATIONS

Gray, Peter. 2014. "Wood-based Aviation Biofuels Supply Chain," the Western Region Forest Resources Association 2014 Spring Meeting, Pasco, WA, April 23.

Rawlings, Craig. 2014. "Tribal Forest Enterprises: 30,000 Feet View with an Economic Development Perspective," at the Forest Economics & Managing Resources in a Rising Market Workshop, The Intertribal Timber Council Meeting, Worley, Idaho, June 26.

Zhu, R. and V. Yadama. 2014. "Effects of hot water extraction (HWE) pretreatment on compositional and physicochemical changes of softwood Douglas-fir," 68th Forest Products Society International Convention, Quebec City, Quebec, Canada, August 10-14.

Englund, Karl. 2014. "Overview of NARA," the Western Development Committee Forestry Meeting, Richland, WA, August 20.

Englund, Karl. 2014. "Education and Outreach for educating the future employees of the "green" industry workforce," WA Clean Tech Alliance Meeting, Seattle, WA, October 8.

OTHER PUBLICATIONS

Burke, C., S. Leavengood, and V. Yadama. 2015. "Using slash piles to make chemical products: an update on the Northwest Advanced Renewables Alliance (NARA) activities," The Western Forester, Jan/Feb, pp 7-9. (http://www.forestry.org/northwest/westernforester/2015/)

NEWSLETTERS

NARA Newsletters: (http://www.nararenewables.org/news/newsletter)

ONE-PAGERS WERE DEVELOPED AND POSTED TO THE NARA WEBSITE

https://nararenewables.org/docs/one-pager/SupplyChainProducts.pdf

https://nararenewables.org/docs/one-pager/BioenergyEducation.pdf

NEWS STORIES AND PRESS RELEASES

4/24/14	AgInfoNet	Wood Based Biofuels Conference
4/24/14	The Eco Report	Towards a wood based aviation biofuel
4/29/14	KPLU Seattle	Progress turning woody debris into biofuels
5/6/14	the Eco Report	Will utilizing Forest Residuals Deplete Soil Nutrients
5/13/14	the Eco Report	Dr Kevin Boston on the Availability of Biomass
8/29/14	WSU TV Advertisement	Go-Coogs Ad
11/12/14	WSU News	WSU honored for strengths in clean technology
11/19/14	WSU News	Nov.19: Students present potential biorefinery sites

VIDEOS AND WEBINARS

Preliminary Site Selection for NARA Supply Chain

Site Selection Webinar

17 other videos produced by NARA's Outreach Team

TRAININGS, EDUCATION AND OUTREACH MATERIALS

NARA's Outreach Team hosted and completed the NW Wood-based Biofuels + Co-Products Conference (April 28-30, 2014) in Seattle. Proceedings of the conference are archived and available to the public.

Knowledge Base: A repository of unbiased scientific knowledge on conversion of woody biomass into bio-jet fuel and co-products.

Appendix A

REPORT ON NORTHWEST WOOD-BASED BIOFUELS + CO-PRODUCTS CONFERENCE SEATTLE, WA, APRIL 28-30, 2014

The goal of this conference was to bring together the community of researchers, business leaders, government agencies, and economic development personnel to share and exchange research findings, ideas, and strategies for the common goal of sustainable development of wood-based bio-refineries for production of biofuels and co-products in the Pacific Northwest. (Agenda)

Conference outputs (presentations) are archived in the form of Proceedings. In addition, six conference presentations were posted at the NARA YouTube page (https://www.youtube.com/user/nararenewables).

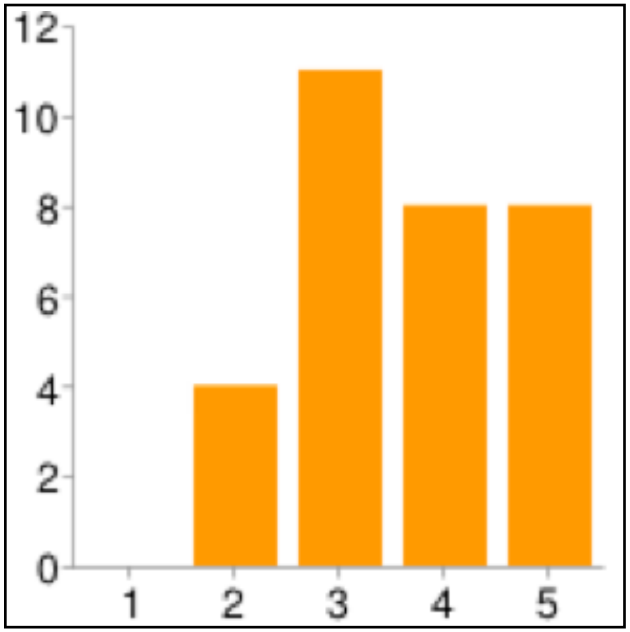
Registrations by State	
California	5
Colorado	3
District of Columbia	2
Idaho	13
Illinois	1
Louisiana	1
Michigan	2
Minnesota	1
Mississippi	1
Montana	10
Nevada	1
North Dakota	1
Oregon	24
Tennessee	1
Virginia	1
Washington	127
Wisconsin	3

Following are the summary statistics of the conference:
Total Registrations: 211
Speakers: 50
Student registrations: 41
Posters in Poster Session: 33 submitted

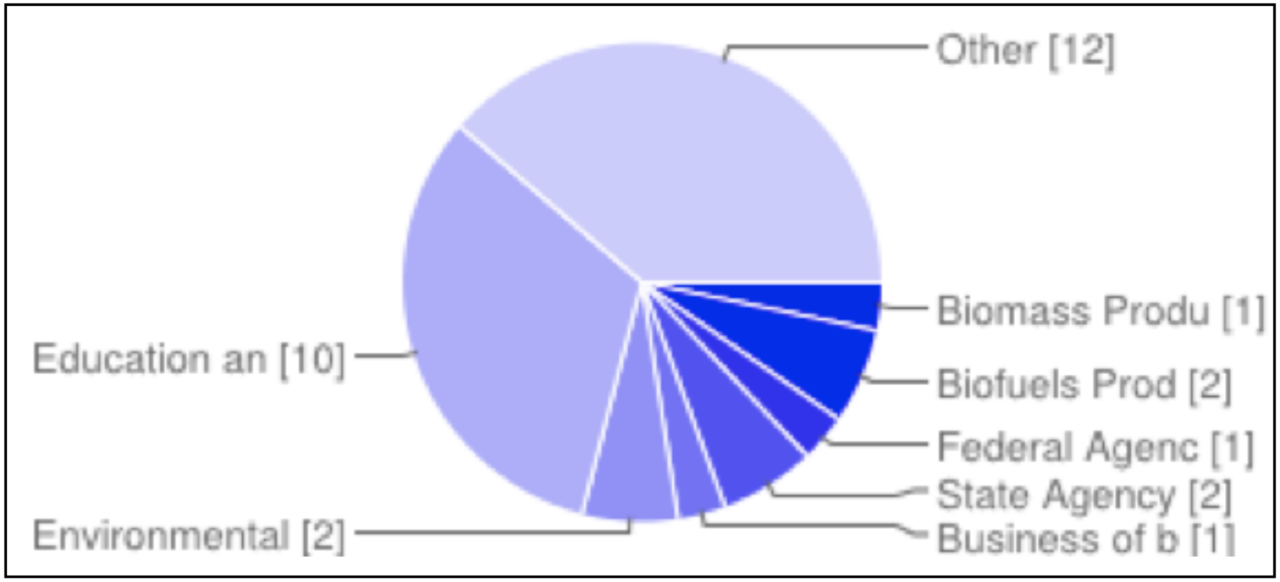
Demographic Data: Data breaking down attendee composition is shown in the tables below. More demographic information can be also found in May 2014 NARA Newsletter.

Registrations by Country	
Canada	9
Germany	1
Greece	1
Sweden	1
United States	199

My knowledge about converting woody biomass to biofuels and co-products has increased as a result of attending the conference (scale of 1 to 5, with 5 signifying a significant change).

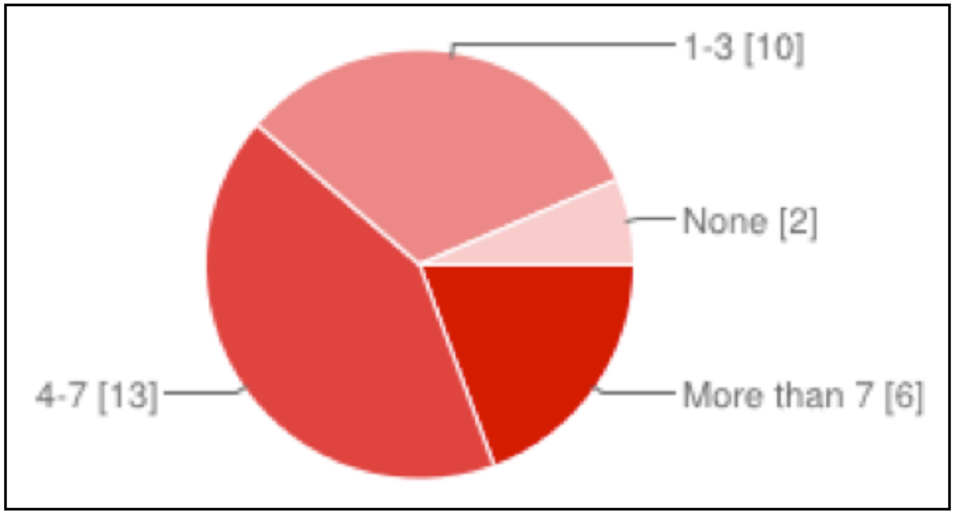


Summary of Post-Conference Survey (Based on 31 responses; 15% response rate)
Description of conference attendees:

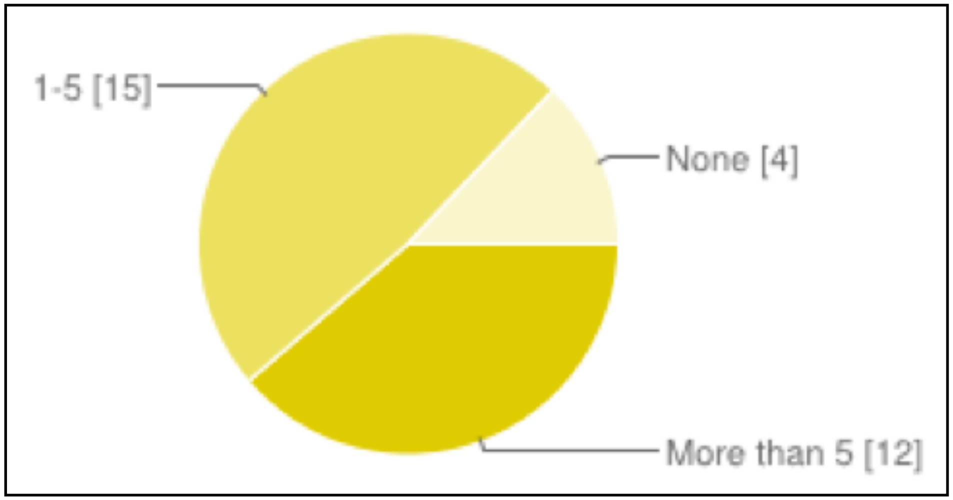


Total Companies/Universities/State Agencies Represented: 89	
State Agencies Represented: 11	
Universities Represented: 17	
All others (NGOs, private companies): 61	
Alaska Airlines	Montana State University Extension Forestry
American Science and Technology Corporation	Mt. Adams Resource Stewards
Avista Utilities	NARA Tribal Partnership Projects
BacGen Technologies	OFIC
BASF SE	Oregon State Department of Energy
BC Bioenergy Network	Oregon State University
Bio[Fuels & Mass] Consulting	Pacific Northwest National Laboratory
Biomass Magazine	PCS Biofuels
Boeing Commercial Airplanes	Port Blakely Tree Farms L.P.
Borregaard LignoTech USA	Rayonier
BRUKS Rockwood	Rehrmann & Associates
Catchlight Energy	Roseburg Forest Products
Chimas Hellas S.A.	Seneca Sustainable Energy
Clearwater Forestry Services	Sundrop Fuels
Climate Solutions	TerraPower, LLC
College of Forestry and Conservation at the University of Montana	The Watershed Center
Colorado State University	The William D. Ruckelshaus Center
Confederated Tribes of Warm Springs	Thomas Spink International
Conifex Timber Inc.	University of British Columbia
Cosmo Specialty Fibers	University of California, Davis
Desert Research Institute	University of Idaho
DR Systems Inc	University of Idaho McCall Outdoor Science School
Ena Energi AB	University of Minnesota, Twin Cities
Ensyn Corporation	University of Montana
Eureka Rural Development Partners	University of Tennessee
EWTA	University of Washington
F.H. Stoltze Land and Lumber Co.	University of Wisconsin
Facing the Future	USDA Forest Service
Forest Business Network	USDA, Rural Development
Forest Concepts, LLC	USDA-FS Rocky Mountain Research Station
Forestry Equipment Company	WA Department of Commerce
Forterra	Washington Forest Protection Association
Gevo, Inc.	Washington State Department of Agriculture
Gifford Pinchot Task Force	Washington State Department of Natural Resources
Global Verde Media LLC	Washington State Department of Ecology
GreenWood Resources Inc.	Washington State University
Hermann Brothers Logging	Washington State University Extension
Humboldt State University	Waterfall Group
Idaho National Laboratory	Weyerhaeuser Co
International Climate Energy Program and National Wildlife Federation	Whatcom Conservation District
John Jump Trucking	Whole Energy
Kittitas County Chamber of Commerce	William D. Ruckelshaus Center
Lorenzen Engineering, Inc.	Wind River Biomass Utility LLC
Mercer International	WoodLife Environmental Consultants LLC
Mercurius Biorefining	
Michigan Technological University	

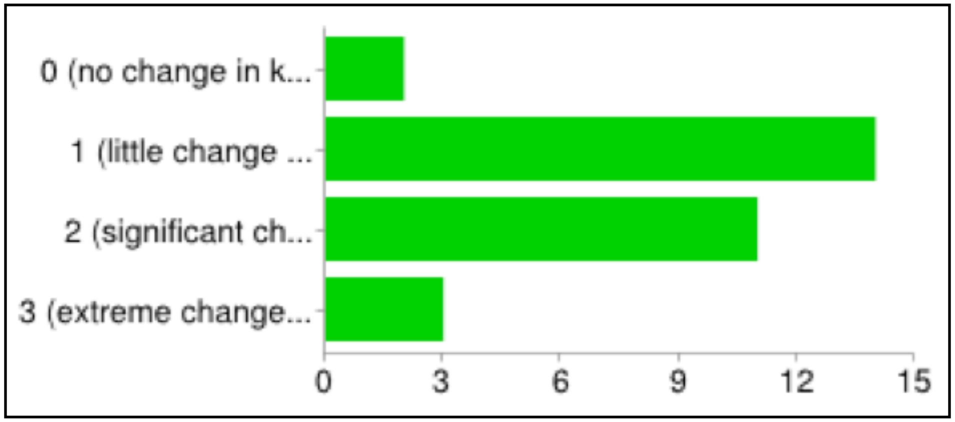
Number of new ideas and connections between ideas from which you gained a better understanding? (through talks and networking)



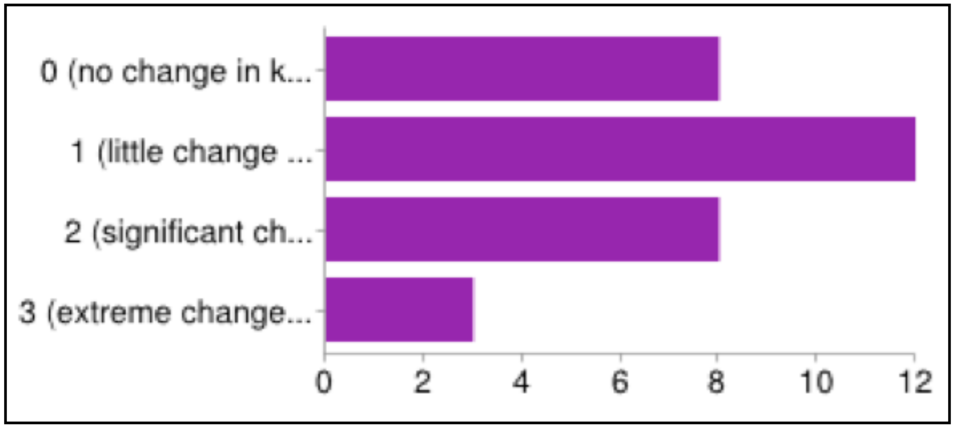
How many important contacts did you make at this Symposium?



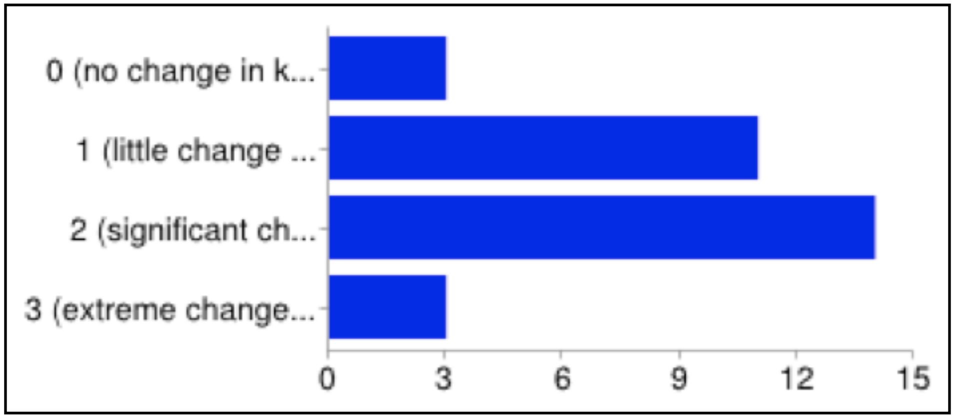
Stakeholder perceptions about use of woody biomass for biofuels [Please indicate, with a check mark, any increase in the level of your knowledge in the areas described by the statements below.]



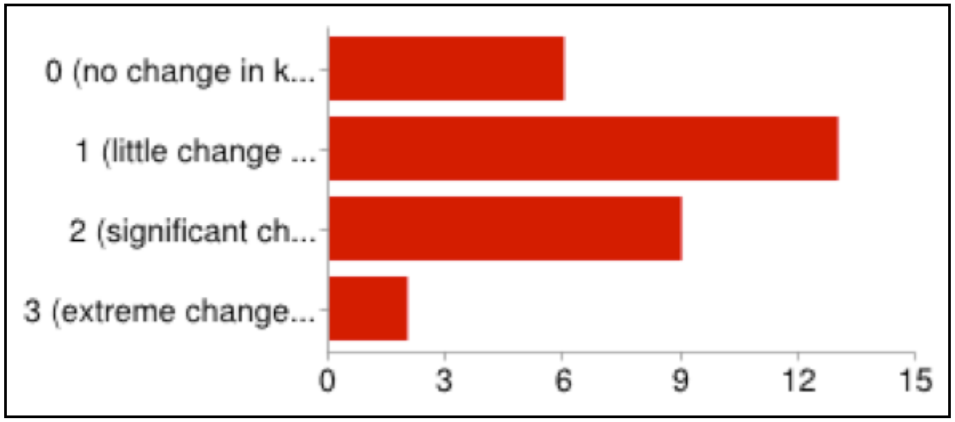
Why woody biomass can be used for biofuels [Please indicate, with a check mark, any increase in the level of your knowledge in the areas described by the statements below.]



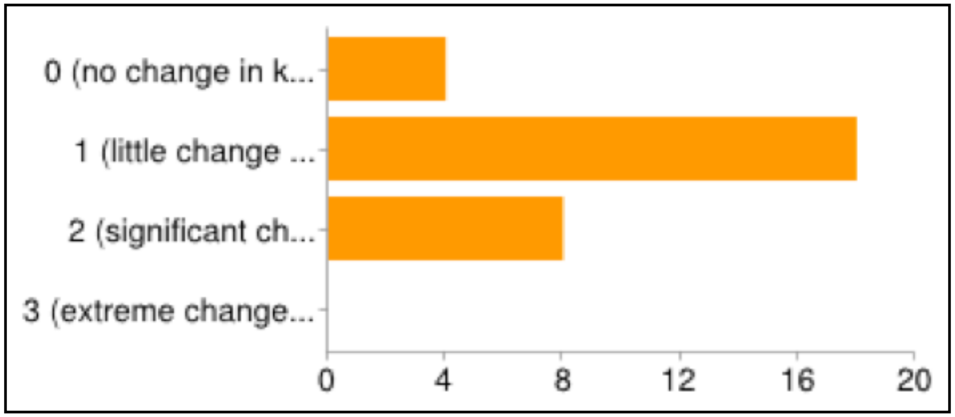
Potential for chemical co-products from woody biomass [Please indicate, with a check mark, any increase in the level of your knowledge in the areas described by the statements below.]



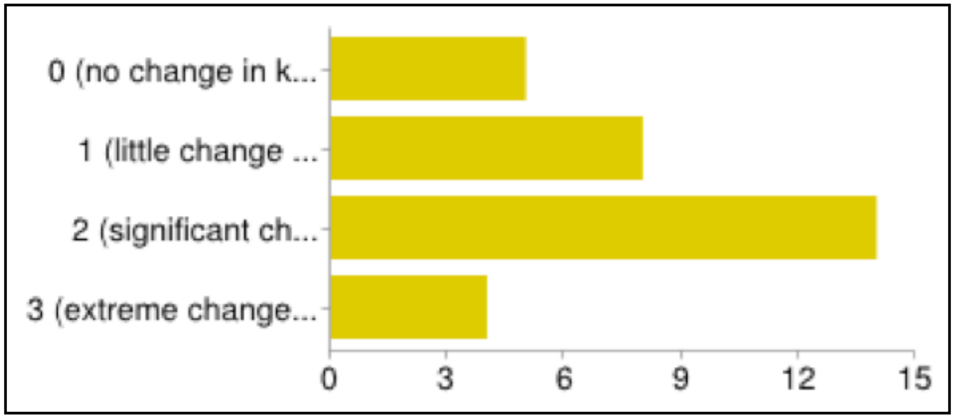
Biomass pre-conversion options [Please indicate, with a check mark, any increase in the level of your knowledge in the areas described by the statements below.]



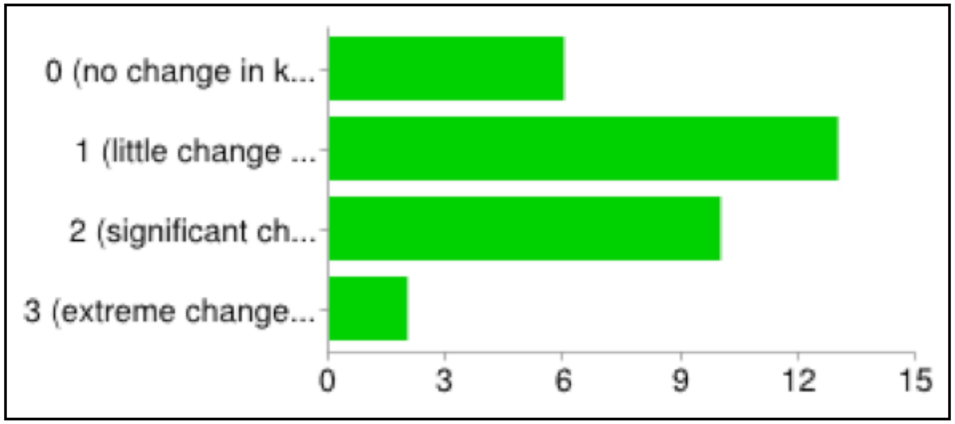
Biomass collection technologies [Please indicate, with a check mark, any increase in the level of your knowledge in the areas described by the statements below.]



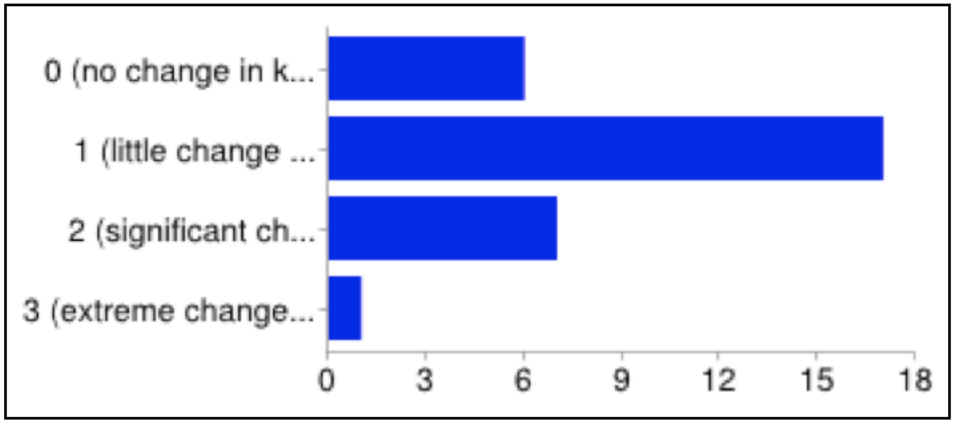
Chemical conversion of biomass into biofuels [Please indicate, with a check mark, any increase in the level of your knowledge in the areas described by the statements below.]



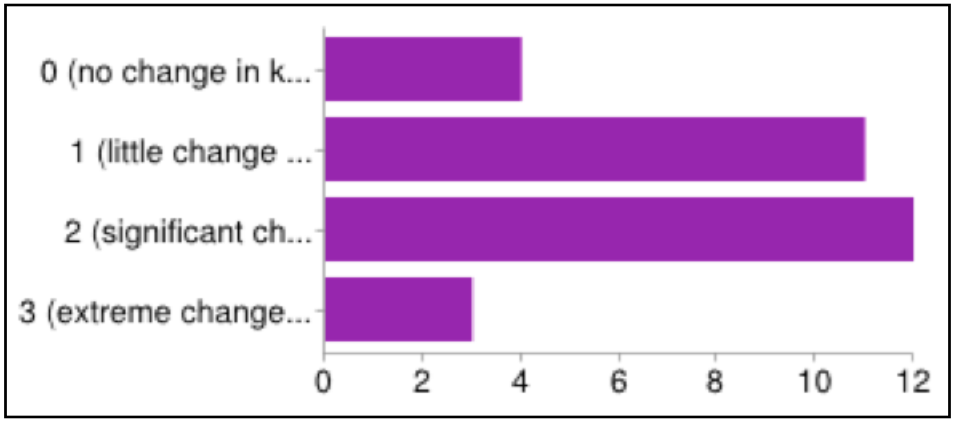
Enzymatic conversion of biomass into biofuels [Please indicate, with a check mark, any increase in the level of your knowledge in the areas described by the statements below.]



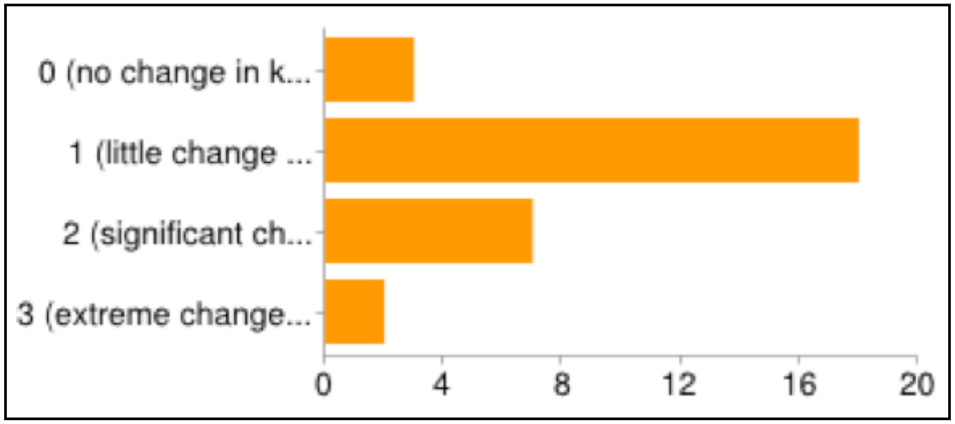
Environmental impacts of producing biofuels from woody biomass [Please indicate, with a check mark, any increase in the level of your knowledge in the areas described by the statements below.]



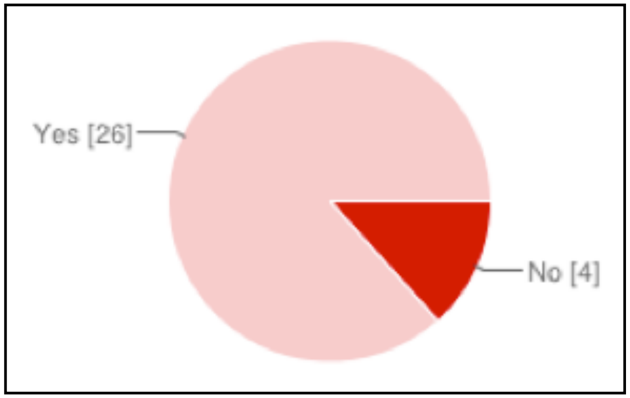
Challenges of converting woody biomass into biofuels and co-products [Please indicate, with a check mark, any increase in the level of your knowledge in the areas described by the statements below.]



Supply chain for converting wood to biofuels and co-products [Please indicate, with a check mark, any increase in the level of your knowledge in the areas described by the statements below.]



Would you consider attending a follow-up conference in 2016?



PLEASE SUGGEST TOPICS YOU WOULD LIKE TO SEE ADDRESSED IN 2016 CONFERENCE.

- Rotary shear production of biofuel feedstock
- Densification of biomass for transport
- Results of current pilot programs; (if data available) more on actual yields as opposed to projected models; more case studies on outreach efforts
- A lot more on biochar as another product in the chain from biomass--pluses, minuses, etc. How does biochar work with (or against) anaerobic digestion as an overall energy scheme, for example.
- Valuable chemical production from lignocellulosic sugar, besides biofuel; Techno-economics analysis of both chemical production and biofuel production from woody biomass.
- World wide impacts of Bio fuel on the economy, the environment and social justice.
- Thanks WSU for providing this conference. It had important resource and technical content and was done very well. Please offer the conference again -- if not every year, at least every other year. Maintain a good technical content re conversion. PS: I attended the first day and second morning (conversion track), and found most of those presentations quite helpful, especially in the conversion track. A full day on conversion technology would be helpful for me. You might also wish to consider adding a few presentations on utilization -- pros and cons of biofuels in application in engines and power generation.
- Plans for integration of policies necessary to ensure industry viability.
- The marketing of products derived from woody biomass.
- The fundamentals of moving treated/untreated biomass to a processing facility from the woods needs to be addressed either as a future topic or additional research. The cost of doing so needs to come down significantly to make this work.
- I really enjoyed the format of speakers on Tuesday morning. 20 minutes for each presenter with time at the end of all speakers within the 1.5 hour time frame worked very well.
- Environmental organizations’ concerns along with our industry’s responses. Biochar applications updates.
- mobile /modular pre conversion technologies renewable chemical / biobased co product opportunities

TASK O-2: MONTANA STATE UNIVERSITY NARA EXTENSION INITIATIVES

Key Personnel	Affiliation
Peter Kolb	Montana State University

Task Description

Montana State University Extension Forestry will assist with the NARA Extension Working Group by providing information about the NARA program and research updates to Montana stakeholders including industry, logging and landowner professional organizations and conferences. In addition we will produce and publish brochures, popular articles and guidelines for these groups as well as assist with the scoping process and development of a test bed site.

Milestones Year 1:
Meet with NARA extension group and develop guidelines for selecting test bed sites. Cooperate with NARA team to develop and launch web site. Meet with Montana interest groups including Montana biomass working group, Montana Logging Association, Montana Forest Council, Montana Tree Farm, Montana Forest Owners Association and introduce the NARA project and scoping for test bed site in Montana. Develop outline for woody biomass harvesting guidelines for forest landowners.

Milestones Year 2:
Develop draft of woody biomass harvesting guidelines for review by multiple Montana interest groups. Meet with stakeholders in various communities for outline and discussion of possible test bed sites. Organize several field trips for field reviews of potential test bed sites. Write 3 articles on NARA project for statewide media outlets. Contribute towards NARA website.

Milestones Year 3:
Write woody biomass harvesting retention guidelines for Montana BMP booklet. Conduct one workshop for Montana landowners and Logging Association on woody biomass harvesting guides for ecological sustainability in the context of climate change. Provide woody biomass harvesting guides and instruction to two annual SFI logger and producer workshops. Continue to contribute towards test bed site selections in Montana. Distribute NARA test bed site information and biomass harvesting guidelines to various stakeholder groups across Montana.

Milestones Year 4:
Finalize and publish Woody Biomass Harvesting Guidelines for Montana. Provide feedstock specification information to major stakeholder and landowner groups across Montana for feedback. Provide updates to SFI training workshops. Develop biomass informational component for incorporation into Montana Forest Stewardship training program and Stewardship/Treefarm management plan template. Write 2 popular articles on NARA program progress for popular media outlets. Provide updates for NARA website.

Milestones Year 5:
Update and finalize feedstock brochure for potential Montana suppliers. Provide 2 woody biomass fieldtrips for test bed community. Write 3 popular articles for media outlets across Montana, and two articles for forest landowner publications and websites. Offer updates to annual logger and mill SFI training and landowner workshops. Assist with NARA web page and conference.

Activities and Results

MSU Extension Forestry presented posters with NARA research results to-date for our Montana Landowner minicollege (83 participants) as well as reported NARA progress and status as both the Montana Statewide Wood Energy Team conference and Montana Wood Products Roundtable. In addition final edits to the new Montana Forestry Best Management Practices Guide that include wood retention recommendations for forest harvesting activities were conducted and this guide was published. Editing continued on the 5-part YouTube video series entitled “Understanding how forests of the Northern Rockies function and the implications of management and climate change” and an expected release is June 2015. Planning for a biomass harvesting workshop for the Montana Logging Association was initiated with an expected workshop delivery of April 28.

Recommendations | Conclusions

The NARA project has concluded that, for the time being, western Montana is unsuitable for initial biomass harvesting to the specification required by existing technologies. We continue to monitor NARA progress with the hope that a viable market for forest harvesting residuals will eventually develop. We are also working with another research project (BANR) and use references and information gained through the NARA project to enhance and guide this projects research development.

Physical and Intellectual Outputs

REFEREED PUBLICATIONS

- Final edit and release of Montana Forestry Best Management Practices 3rd edition with new specific references throughout text to address preferred biomass retention following harvest (pg 59).

RESEARCH PRESENTATIONS

- Display at 2015 Forestry MiniCollege, Missoula; (Audience: Non-industrial private forest landowners, forestry professionals)
- Provided NARA update to the Montana Statewide Wood Energy Team (USDA award of $250,000 to stimulate development of wood energy projects in the state.) http://goo.gl/tuhc2x
- Provided NARA updates to the Montana Wood Products Roundtable forum

OTHER PUBLICATIONS

- Biomass to energy, woody debris retention and carbon accounting—future markets or conflicts? http://www.forestseedlingnetwork.com/media/53540/mtforest_landowner_conf_e-broch_2014.pdf
- http://e3a4u.info/wp-content/uploads/Wood-Heat-Entire-Document.pdf - published
- http://www.msuextension.org/forestry/Resources/pdf/FF_CaseStudyFridelyFire_PK.pdf - published
- Developed new online tool for wood energy education: How much Energy is in a Slab of Wood? http://www.msuextension.org/forestry/WB2E/slabenergycalc.htm
- Wrote one popular article with the intent of increasing public understanding of forest harvesting of beetle killed lodgepole pine forests – was printed in most Montana newspapers.
- Submitted/published three articles on eXtension Wood Energy CoP:
  o Estimating Space Heating Demand and Effective Costs;
  o A Simple Comparison of Heating Fuels;
  o How much Energy is in a Slab of Wood?

VIDEOS AND WEBINARS

- Edited and worked on three videos on the role of forest management in the future for wood supply, biomass energy and climate change across the northern Rockies for projected release on YouTube in June 2015.

TRAININGS, EDUCATION AND OUTREACH MATERIALS

- http://www.msuextension.org/forestry/NARA.html
- Online Resource Library for Wood Pellets http://www.msuextension.org/forestry/WB2E/pellets.htm
- Review and Adaptation of the NARA pilot Assessment Tool for Bioenergy Literacy (http://goo.gl/KO3TDr) to audience response system.
- Online adaptation and implementation of NARA surveys:
  o Energy Literacy Assessment (https://montana.qualtrics.com/SE/?SID=SV_1Yo4uDkriL8qlpj)
  o NARA Stakeholder Survey (https://montana.qualtrics.com/SE/?SID=SV_5ziVmIKOa8BeX89)
- Online adaptation and implementation of Annual Montana Wood Biomass Energy Facilities Survey
  o Survey, http://goo.gl/t7jYGe
  o Data compilation and analysis
  o Facilities online reports/time series, http://goo.gl/sxma4E

TASK O-3: UNIVERSITY OF MONTANA NARA EXTENSION INITIATIVES

Key Personnel	Affiliation
Todd Morgan	University of Montana

In NARA project Year-3, the University of Montana Extension effort was canceled to focus on logging residue assessments (Task SM-SP-7). Montana outreach interests will be maintained through Montana State Extension faculty in Task O-2.

TASK O-4: OREGON STATE UNIVERSITY NARA EXTENSION INITIATIVES

Key Personnel	Affiliation
Scott Leavengood	Oregon State University

Task Description

NARA units, research, extension and industry members, will act as partners and facilitators with the ultimate goal of empowering the stakeholders to plan and implement the changes needed to build, develop, and sustain a biorefinery infrastructure. The goal of the outreach team is to promote stakeholder bioenergy literacy and build regional supply chain coalitions for development of a framework of biofuel and co-products production from woody biomass. End outcomes of this goal are sustainable production of biojet fuel and co-products and rural economic development. Following are the objectives of the outreach team to reach this goal:

1) Bioenergy Literacy, where we: a) disseminate the research-based information (on technology and markets) to our industrial stakeholders and understand the technical challenges regarding implementation at industrial scale (industry-focus); b) relate the feedstock development and logistics information to our resource-based stakeholders (local communities, forest landowners, forest managers) and hear their concerns regarding the type of information that will assist them in keeping their costs low and marketable value high (resource-focus); and, engage the organizations and partnerships in connecting with public-interest groups and policymakers (public-focus). These activities will be carried out via a variety of communication mechanisms, including social media, newsletters, briefing papers, extension publications, workshops/seminars, conferences, field trips, and stakeholder meetings. Bioenergy literacy to professionals will be achieved through following tasks.
   a. Develop a bioenergy literacy platform for flow of information and knowledge between NARA research teams and the stakeholders.
   b. Implement targeted outreach activities for engaging stakeholders and advancing bioenergy literacy to professionals.
   c. Catalog activity outcomes and benchmark reports and studies.

2) Build Supply Chain Coalitions (logistical support and stakeholder development and engagement), where we will form working groups with stakeholders at community and bioregion levels to involve them through collaboration across the supply chain: forestland owners and managers, environmental NGOs, businesses, regulatory facilitators, and community infrastructure working groups to interact with and inform policymakers at regional, state, and federal levels. These stakeholders will be internal and external focused around the NARA communities (NCs) selected in the four-state region. This process will rely on support from other teams, such as Education and EPP, and consider physical and social assets along with practical aspects in narrowing down the list to a manageable number of communities with the four-state region. A long list will be shortened through surveying community-based stakeholders in the PNW and intermountain region to strategically choose several NCs for studying the viability of a biofuel-based infrastructure. Once communities are identified, focus group meetings involving a wide variety of stakeholders will be held at each community to discuss feedstock specifications and logistics, technology adoptions within the existing infrastructure, and viable strategies practical and beneficial for the communities. This process will involve industrial stakeholders and NARA industry partners as well. Establishing a meaningful dialogue on what local experts perceive to be the barriers and opportunities for establishing a biorefinery infrastructure in their community is critical. Building supply chain logistics consists of four major tasks.
   a. Define stakeholders and articulate stakeholder communication mechanism.
   b. Define and establish NARA pilot supply chain (PSC) study regions to engage stakeholders in compiling supply chain assets, analyzing potential regional supply chain structure, and forming regional alliances.
   c. Stakeholder development in the four-state region and pilot supply chain study regions.
   d. Assist EPP with PSC selection process and support index study to develop a decision support tool.

Activities and Results

My primary role with respect to this project has been to serve as the key outreach liaison for Oregon. In that regard, I have focused my efforts on identifying the key stakeholders in Oregon, keeping them and others informed of the activities of the project, and working to ensure stakeholders are able to engage and participate in the project. These efforts have included giving presentations to the Oregon Forest Biomass Working Group, organizing meetings between members of the working group and NARA team members, developing newsletter articles and web pages, and giving lectures for graduate students and faculty at OSU.

My efforts have also included providing other NARA teams with information to assist in their efforts, e.g., coordinating completion of the 'stakeholder assessments' for the EPP team.

Janna Loeppky, a graduate research assistant at OSU, interviewed NARA researchers at OSU to produce a series of short NARA 'Research Briefs' that describe the research and its practical implications, with a particular focus on the private woodland owner audience. This target audience was selected in that I have asked my colleagues in Forestry & Natural Resources Extension at OSU to help disseminate these briefs to their stakeholders (e.g., through their newsletters) – which are primarily private woodland owners. Prior to graduation, Janna developed five research briefs.

One sign of results is that Oregon agency personnel (e.g., Matt Krumenauer with the Oregon Department of Energy and Marcus Kauffman with the Oregon Department of Forestry) with responsibilities related to forest biomass utilization organized conference calls and meetings about the NARA project independently of my efforts or of the efforts of other NARA team members; and Sue Safford with Oregon BEST has asked for information about technology commercialization opportunities from the project that might come about for Oregon. I believe this shows that outreach efforts are having their desired effect of ensuring that key stakeholders in Oregon are engaged and committed to the project's success.

Recommendations | Conclusions

The results mentioned in the paragraph above and participation in meetings indicate that my outreach efforts are having some level of success, at least with regards to the task 2 - Building Supply Chain Coalitions. However, as mentioned in previous quarterly reports, stakeholders have asked me for more of the details about the research efforts connected with this project, i.e., tasks related to task 1 - Bioenergy Literacy. Therefore, I will focus future efforts on keeping stakeholders informed about progress with respect to efforts of the research teams – forest residues preparation, transportation, pretreatment, enzymatic hydrolysis, fermentation, and co-products as well as information related to life cycle assessment. Assisting with the organization of conferences is one approach I've used to achieve this goal as is working with other outreach team members to develop educational materials such as articles for Western Forester, newsletter articles for OSU Extension Forestry faculty, and maintaining a NARA page on the Oregon Wood Innovation Center website.

Physical and Intellectual Outputs

RESEARCH PRESENTATIONS

Leavengood, S. 2014. Northwest Advanced Renewables (NARA) Project Update – Fall 2014. October 22. Corvallis, OR. Seminar for WSE 507.

OTHER PUBLICATIONS

Burke, C., Leavengood, S, & Yadama, V. (2015, Jan./Feb.). Using slash piles to make chemical products. Western Forester, 60(1), 7-9. Retrieved from http://www.forestry.org/media/docs/western-forester/2015/WFJanFeb2015.pdf

Loeppky, J., J. Sessions. 2014. Transportation of Residues: Would you bundle?

Loeppky, J., K. Boston. 2014. Estimating Biomass Availability

Loeppky, J., D. Maguire. 2014. Estimating Nutrient Removals under Varying Intensities of Harvesting Residue Utilization.

Loeppky, J., 2014. NARA Graduate Student Research: The 2014 Western Forestry Graduate Research Symposium.

TASK O-5: UNIVERSITY OF IDAHO NARA EXTENSION INITIATIVES

Key Personnel	Affiliation
Randy Brooks	University of Idaho

Task Description

NARA units, research, extension and industry members, will act as partners and facilitators with the ultimate goal of empowering the stakeholders to plan and implement the changes needed to build, develop, and sustain a biorefinery infrastructure. The goal of the outreach team is to promote stakeholder bioenergy literacy and build regional supply chain coalitions for development of a framework of biofuel and co-products production from woodybiomass. End outcomes of this goal are sustainable production of biojet fuel and co-products and rural economic development. Following are the objectives of the outreach team to reach this goal:

1) Bioenergy Literacy, where we: a) disseminate the research-based information (on technology and markets) to our industrial stakeholders and understand the technical challenges regarding implementation at industrial scale (industry-focus); b) relate the feedstock development and logistics information to our resource-based stakeholders (local communities, forest landowners, forest managers) and hear their concerns regarding the type of information that will assist them in keeping their costs low and marketable value high (resource-focus); and, engage the organizations and partnerships in connecting with public-interest groups and policymakers (public-focus). These activities will be carried out via a variety of communication mechanisms, including social media, newsletters, briefing papers, extension publications, workshops/seminars, conferences, field trips, and stakeholder meetings. Bioenergy literacy to professionals will be achieved through following tasks.
   a. Develop a bioenergy literacy platform for flow of information and knowledge between NARA research teams and the stakeholders.
   b. Implement targeted outreach activities for engaging stakeholders and advancing bioenergy literacy to professionals.
   c. Catalog activity outcomes and benchmark reports and studies.

2) Build Supply Chain Coalitions (logistical support and stakeholder development and engagement), where we will form working groups with stakeholders at community and bioregion levels to involve them through collaboration across the supply chain: forestland owners and managers, environmental NGOs, businesses, regulatory facilitators, and community infrastructure working groups to interact with and inform policymakers at regional, state, and federal levels. These stakeholders will be internal and external focused around the NARA communities (NCs) selected in the four-state region. This process will rely on support from other teams, such as Education and EPP, and consider physical and social assets along with practical aspects in narrowing down the list to a manageable number of communities with the four-state region. A long list will be shortened through surveying community-based stakeholders in the PNW and intermountain region to strategically choose several NCs for studying the viability of a biofuel-based infrastructure. Once communities are identified, focus group meetings involving a wide variety of stakeholders will be held at each community to discuss feedstock specifications and logistics, technology adoptions within the existing infrastructure, and viable strategies practical and beneficial for the communities. This process will involve industrial stakeholders and NARA industry partners as well. Establishing a meaningful dialogue on what local experts perceive to be the barriers and opportunities for establishing a biorefinery infrastructure in their community is critical. Building supply chain logistics consists of four major tasks.
   a. Define stakeholders and articulate stakeholder communication mechanism.
   b. Define and establish NARA pilot supply chain (PSC) study regions to engage stakeholders in compiling supply chain assets, analyzing potential regional supply chain structure, and forming regional alliances.
   c. Stakeholder development in the four-state region and pilot supply chain study regions.
   d. Assist EPP with PSC selection process and support index study to develop a decision support tool.

Activities and Results

Efforts in the past quarter were coupled with existing Extension field based programs and activities where the NARA project was introduced and basic concepts of the project were discussed. As per request of other NARA researchers, I developed a spreadsheet of names and addresses of all wood processing facilities in Idaho. Graduate student is collecting data on forest residuals volumes in Idaho.

A survey of logging contractors was recently conducted to assess attitudes and beliefs towards utilizing woody biomass as a biofuel. Results have not been summarized, but briefly, many logging contractors would rather utilize other methods to dispose of slash besides burning it. Figure O-5.1 shows how slash is current disposed of in Idaho.

When asked if there was a cost effective alternative to burning forest residuals for disposal, would you consider using it, almost 75% of the logging contractors surveyed were likely to consider it (Figure O-5.2).

When asked how communities would benefit if an alternative to burning was available, the majority thought added jobs would be the biggest benefit (Figure O-5.3).

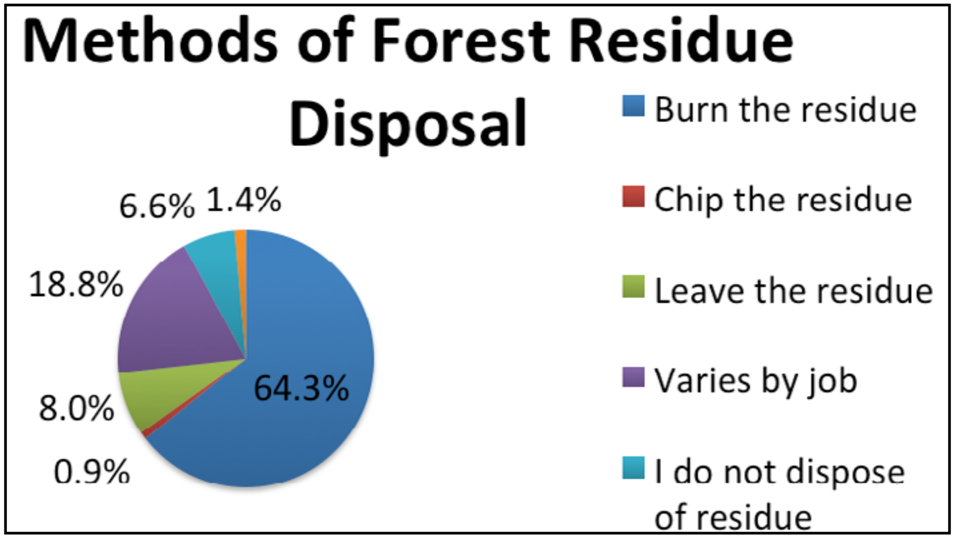


Figure O-5.1. Methods of forest residual disposal in Idaho

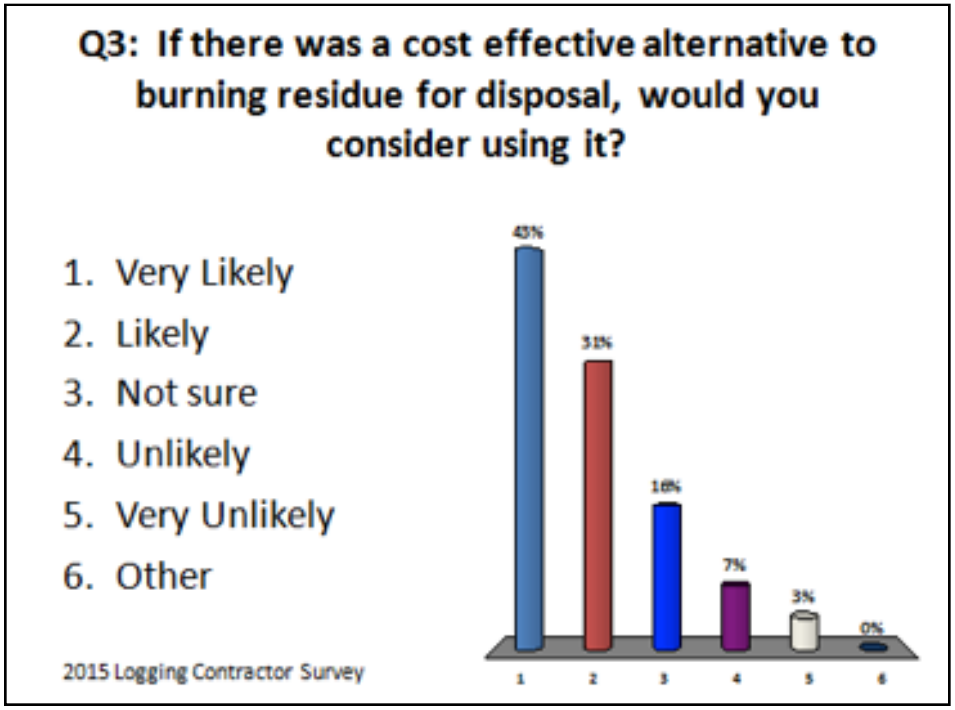


Figure O-5.2. Consideration to using cost effective alternative to burning forest residuals

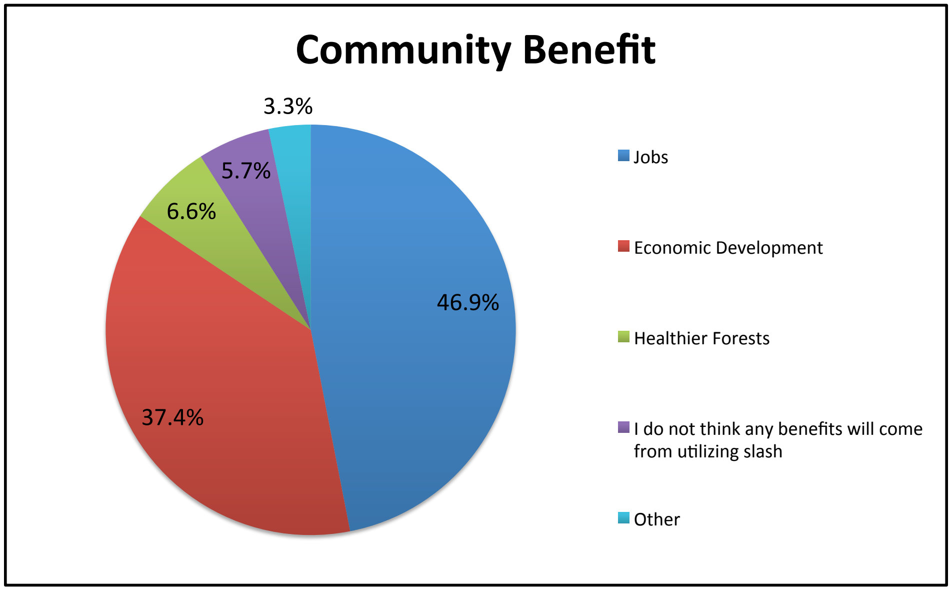


Figure O-5.3. Likely benefit if forest residuals were used for commercial use.

Recommendations | Conclusions

Logging contractors, who are the first step and critical link in the supply chain, are open to viable alternatives for slash utilization. Once technology is available, it would be rapidly adopted by the workforce.

Physical and Intellectual Outputs

PHYSICAL

- Stakeholder survey was created using turning point technologies and collected at 7 logging contractor workshops across Idaho

REFEREED PUBLICATIONS

Brooks, R. and J. Moroney. Forestry Tour Educates Youth in North Central Idaho. 2014. Journal of Extension. Vol. 52, No. 4. August, 2014. Available at: http://www.joe.org/joe/2014august/iw4.php

RESEARCH PRESENTATIONS

Cochran, A., and R. Brooks. 2015. Biofuels from forest residuals. Poster presented at National Extension Energy Summit. Seattle, WA. 9 April 2015

Brooks, R. 2015. Forest Resources Program at Idaho. Presentation given at American Forest Resource Council Annual Meeting. Portland, OR. 8 April, 2015.

Brooks, R., and A. Cochran. 2015. Biofuels from forest residuals. Presentation given at National Extension Energy Summit. Seattle, WA. 9 April 2015

Brooks, R. 2015. Biofuels from forest residuals. Presentation given at Small log conference. Spokane, WA. 25 March 2015

Cochran, A. and R. Brooks. 2015. Biofuel options from forest residuals. Presentation given at Idaho Loggers Education to Advance Professionalism workshop. UI Extension Workshop Series. Hayden, ID. 4 Mar. 2015

Cochran, A. and R. Brooks. 2015. Biofuel options from forest residuals. Presentation given at Idaho Loggers Education to Advance Professionalism workshop. UI Extension Workshop Series. Sandpoint, ID. 11 Mar. 2015

Cochran, A. and R. Brooks. 2015. Biofuel options from forest residuals. Presentation given at Idaho Loggers Education to Advance Professionalism workshop. UI Extension Workshop Series. Orofino, ID. 17 Mar. 2015

Cochran, A. and R. Brooks. 2015. Biofuel options from forest residuals. Presentation given at Idaho Loggers Education to Advance Professionalism workshop. UI Extension Workshop Series. McCall, ID. 20 Mar. 2015

Cochran, A. and R. Brooks. 2015. Biofuel options from forest residuals. Presentation given at Idaho Loggers Education to Advance Professionalism workshop. UI Extension Workshop Series. St. Maries, ID. 24 Mar. 2015

Cochran, A. and R. Brooks. 2015. Biofuel options from forest residuals. Presentation given at Idaho Loggers Education to Advance Professionalism workshop. UI Extension Workshop Series. Kamiah, ID. 27 Mar. 2015

Cochran, A. and R. Brooks. 2015. Biofuel options from forest residuals. Presentation given at Idaho Loggers Education to Advance Professionalism workshop. UI Extension Workshop Series. Moscow, ID. 31 Mar. 2015

TRAININGS, EDUCATION AND OUTREACH MATERIALS

Brooks, R. 2015. Idaho Loggers Education to Advance Professionalism workshop. UI Extension Workshop Series. Hayden, ID. 4 Mar. 2015

Brooks, R. 2015. Idaho Loggers Education to Advance Professionalism workshop. UI Extension Workshop Series. Sandpoint, ID. 11 Mar. 2015

Brooks, R. 2015. UI Extension Forestry Tree Planting Workshop. Moscow, ID. 13 March 2015

Brooks, R. 2015. Idaho Loggers Education to Advance Professionalism workshop. UI Extension Workshop Series. Orofino, ID. 17 Mar. 2015

Brooks, R. 2015. Idaho Loggers Education to Advance Professionalism workshop. UI Extension Workshop Series. McCall, ID. 20 Mar. 2015

Brooks, R. 2015. Idaho Loggers Education to Advance Professionalism workshop. UI Extension Workshop Series. St. Maries, ID. 24 Mar. 2015

Brooks, R. 2015. Idaho Loggers Education to Advance Professionalism workshop. UI Extension Workshop Series. Kamiah, ID. 27 Mar. 2015

Brooks, R. 2015. Idaho Loggers Education to Advance Professionalism workshop. UI Extension Workshop Series. Moscow, ID. 31 Mar. 2015

Brooks, R. and M. Vachon. 2015. IDEX students field trip to ZeaChem. 23 March, 2015.

Brooks, R. How biomass and biofuels fits in with a thinning regime. UI Extension Forestry Thinning & Pruning Field Day, McCall, ID.5/15/14

THESIS AND DISSERTATIONS

Casey, J., and R. Brooks. Examining Alternative Methods of Measuring Logging Residues: A Comparison of Traditional and Laser-Based Slash Pile Estimators. Dec. 8, 2014. Thesis proposal. Moscow, ID.

TASK O-6: FOREST SERVICE-PACIFIC NW RESEARCH STATION

Key Personnel	Affiliation
Eini Lowell	USDA FS PNWRS

Task Description

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   a. Develop a bioenergy literacy platform for flow of information and knowledge between NARA research teams and the stakeholders.
   b. Implement targeted outreach activities for engaging stakeholders and advancing bioenergy literacy to professionals.

2) Build Supply Chain Coalitions (logistical support and stakeholder development and engagement), where we will form working groups with stakeholders at community and bioregion levels to involve them through collaboration across the supply chain: forestland owners and managers, environmental NGOs, businesses, regulatory facilitators, and community infrastructure working groups to interact with and inform policymakers at regional, state, and federal levels. These stakeholders will be internal and external focused around the NARA communities (NCs) selected in the four-state region. This process will rely on support from other teams, such as Education and EPP, and consider physical and social assets along with practical aspects in narrowing down the list to a manageable number of communities with the four-state region. A long list will be shortened through surveying community-based stakeholders in the PNW and intermountain region to strategically choose several NCs for studying the viability of a biofuel-based infrastructure. Once communities are identified, focus group meetings involving a wide variety of stakeholders will be held at each community to discuss feedstock specifications and logistics, technology adoptions within the existing infrastructure, and viable strategies practical and beneficial for the communities. This process will involve industrial stakeholders and NARA industry partners as well. Establishing a meaningful dialogue on what local experts perceive to be the barriers and opportunities for establishing a biorefinery infrastructure in their community is critical. Building supply chain logistics consists of four major tasks.
   a. Define stakeholders and articulate stakeholder communication mechanism.
   b. Define and establish NARA pilot supply chain (PSC) study regions to engage stakeholders in compiling supply chain assets, analyzing potential regional supply chain structure, and forming regional alliances.
   c. Stakeholder development in the four-state region and pilot supply chain study regions.
   d. Assist EPP with PSC selection process and support index study to develop a decision support tool.

Activities and Results

BIOENERGY LITERACY

With other Outreach Team members, one-page fact sheets and infographics providing information on research progress being made by other NARA teams continue to be developed. These are posted on the website (http://www.nararenewables.org/about/info-graphics-fact-sheets) and available to NARA members for printing and distribution.

They include:
- Bioenergy in Education
- Supply Chain Products
- Environmental Impact Assessments

Providing feedback on various NARA communications team outputs is an ongoing task. An updated Congressional Briefing Paper was prepared for the PNW Research Station Director to take to Washington, DC (April 2015) for meetings with Congressional members and staff and other stakeholders.

Participation in meetings and conferences in a variety of capacities has occurred. I served as a member of the Steering Committee, moderator and attendee of first NARA conference Northwest Wood-based

Biofuels and Co-Products held in Seattle, WA Seattle (April 28-30, 2014). There were close to 200 attendees. A poster presentation titled “Wood-to-Biofuels Infrastructure: Supply Chain Analysis” was given at the Forest Products Society 68th International Convention (August 10-13, 2014). Quebec City, Canada. I attended the NARA annual meeting in Seattle, WA to hear the progress of other teams and discuss how best to use this information in reaching stakeholders. Following the meeting, the outreach team discussed the Advisory Board’s report and prepared a written response to address their comments.

The Outreach Team met in February 2015 to discuss final Outreach materials. Videos of various length and targeted audiences and an eBook to document the entire project were discussed. Following this, I have worked with a videographer to capture footage and interview material on NARA feedstock production.

BUILDING SUPPLY CHAIN COALITIONS

In conversations and at meetings relative to biomass and its utilization (such as the Small Log conference March 2015), I offer information on NARA and its goals and encourage stakeholders to visit the website and register or provide them with specific contacts in their area of interest. IDX efforts in evaluating specific sites as a solid, liquid, or IBR node now offer additional opportunities to connect with decision-making personnel that would further NARA’s goals.

Recommendations | Conclusions

The Outreach process is continual and adaptive. Efforts to identify and engage stakeholders continue, especially in the environmental community. I am connecting with Collaborative Forest Landscape Restoration Project (CFLRP) management teams and other partnerships where the US Forest Service has a presence to ensure active participation by the agency. Opportunities to leverage outreach efforts through professional channels continues. The depot concept developed by IDEX provides opportunities for rural communities to participate in this project and is of particular interest to rural communities, especially those with National Forest land in close proximity. Members of the outreach team will coordinate with IDX students to identify and meet with key personnel at the specific sites they have put forth as being likely candidates for NARA depots.

Physical and Intellectual Outputs

PHYSICAL

Video footage of in-woods chipping and interviews of key personnel to the process were conducted on the Weyerhaeuser site in Cottage Grove, OR.

RESEARCH PRESENTATIONS

A poster presentation titled “Wood-to-Biofuels Infrastructure: Supply Chain Analysis” was given by Lowell at the Forest Products Society 68th International Convention. Quebec City, CAN (8/10-13/2014).

TASK O-7: WILLIAM D. RUCKELSHAUS CENTER

Key Personnel	Affiliation
Michael Kern	Ruckelshaus Center
Michael Gaffney	Ruckelshaus Center

Task Description

The Ruckelshaus Center senior staff members will 1). Work with the Leadership Team to assist in the creation of a "Stakeholder Advisory Board," and 2). Facilitate monthly Leadership Team meetings, quarterly Advisory Board meetings, and an annual stakeholder meeting. Additionally the Center will assist in development of process protocol agreements and help engage policy makers through distribution of quarterly web-based newsletters and briefing papers from information provided by the Project Directors and Leadership Team. 3). Participate in an assessment of public perceptions to "connect social and technical aspects" of the project through quantitative surveys and focus groups.

SUPPLEMENTAL RESEARCH PROPOSAL

The Division of Governmental Studies and Services (DGSS) has been engaged on the NARA project since its inception – as a subcontractor to the William D. Ruckelshaus Center. The original set of deliverables for DGSS consisted solely of an assessment process to inform the development of the project Advisory Committee. Over time, DGSS has also participated in stakeholder (SH) Assessment and engagement efforts as a part of the Outreach team, and has been engaged in active participation with the EPP team on physical-social asset assessment efforts, supporting the Community Asset Assessment Model development effort. In order to secure additional effort from DGSS on the development and administration of SH Assessment interviews, and to facilitate the ground-truthing of large national database application to potential NARA communities through the use of existing DGSS community-level survey databases, and new primary data collected by other NARA participants in the EPP team, DGSS requests additional funding through year four of the project. Specific deliverables from an additional $40,000 (annual basis) include:

1. Support access to DGSS's web-survey capacity ("Remark" software) to facilitate data entry from SH Assessment telephone interviews to be conducted by EPP team.
2. Substantial data aggregation, manipulation and analyses to render data from existing DGSS community surveys into a format useful for analysis to be used in conjunction with national data and SH Assessment interview results in a triangulated approach ("Ground-truthing") for NARA Region social asset assessment.
3. Continued and expanded participation by elements of DGSS on the EPP team in support of team community stakeholder Assessment efforts.
4. Support and participation in preparation and submission of reports, presentations, and publications.
5. Finalization of the Community Asset Assessment Model for application across the NARA region and, in conjunction with other projects such as FAA ASCENT, nationally.

These efforts would be in addition to, and would complement, DGSS and Ruckelshaus participation in the Outreach team, and contracted project management support activities.

Activities and Results

Task O-7.1.
All of the Ruckelshaus Center responsibilities under this task have been completed with the exception of ongoing statistical analysis and development of the CAAM. Ruckelshaus/DGSS worked extensively with the Outreach Team, Team Leaders and the executive team to develop a structure for categorizing and engaging diverse stakeholders. The Ruckelshaus Center/DGSS completed an interview-based assessment of informed observers and senior stakeholders, to obtain input on the formation and management of an Advisory Board for the NARA project. A summary report of that effort was presented to the project's executive committee, with recommendations regarding the interests that should be considered when selecting potential board members, along with a list of individuals who had been suggested as potential members. This report was used to inform the executive committee's selection of Advisory Board members and in the management of interactions with that board. The inquiry also addressed the more general topic of stakeholder engagement, and recommendations on that topic were passed on to the executive committee and the Outreach team.

Task O-7.2.
The Ruckelshaus Center has continued to be actively engaged in facilitation and project management support – specifically supporting the project leadership with team facilitation, agenda development and establishment of ground rules and meeting protocols. Ruckelshaus senior staff facilitated the monthly leadership team meetings since the project kick-off in 2011. The monthly leadership team meetings have focused on a number of relevant topics, including the Phase & Gate process and various discussions related to the management of NARA teams and units.

The Center again assisted in the development, planning, and facilitation of the September 2014 NARA annual meetings in Seattle, Washington. The Center also facilitated the NARA Advisory Board meeting discussion during the 2014 annual meeting.

The Center, with the NARA leadership committee, communications team and outreach team, continued to work closely with the Advanced Hardwood Biofuels

Northwest (AHB) project to prepare a series of quarterly briefing papers aimed at jointly informing policy-makers in Washington, Oregon, Idaho, Montana and Northern California about the projects' progress. Three more briefings were sent out April 2014, July 2014, and December 2014.

Task O-7.3.
The Ruckelshaus Center/DGSS has been working with the NARA Environmental Preferred Products team on the assessment of potential NARA communities and targeted engagement of stakeholders in those communities, using a variety of research and outreach methods to develop the CAAM model. This effort is focused on the identification and refinement of several social asset tools to better focus on these NARA communities. Included in the process of NARA community assessment will be the use of numerous existing DGSS survey data sets to validate the use of national-level data sets in the selection process, as informed by new primary data collected by other EPP team members in the region.

Recommendations | Conclusions

- Continue to facilitate the monthly Leadership Team meetings, plan and facilitate the NARA annual meetings, and potentially help facilitate team or unit discussions if mutually agreeable.

- Continue to produce joint quarterly policy-maker briefings with the UW AHB project.

- Continue to work with the EPP team on NARA community assessment model development and testing.

- Continue participation on the Outreach Team regarding stakeholder engagement

Physical and Intellectual Outputs

- The Center, in collaboration with the NARA executive team, developed, planned, and facilitated the September 2014 NARA annual meetings in Seattle, WA.

- The Center, with the NARA leadership committee, communications team and outreach team, continued to worked closely with the Advanced Hardwood Biofuels Northwest (AHB) project to prepare a series of quarterly briefing papers aimed at jointly informing 1,500+ policy-makers in Washington, Oregon, Idaho, Montana and Northern California about the projects' progress.

- The EPP team has developed three conference posters, two conference presentations, and has had one publication accepted for publications, in addition to participating in at least one university academic showcase (WSU) with respect to the CAAM and community characteristic assessment projects.

RESEARCH PRESENTATIONS

Rijkhoff, Sanne, Season Hoard, Michael Gaffney, Paul Smith, Natalie Martinkus, Nicholas Lovrich, John Pierce and Michael Wolcott. Refining Community Asset and Attribute Modeling: Applying Social Data to Inform Bio-Fuel Project Site Selection in the NARA Region. Poster, 2014 NARA Annual Meeting, Seattle, WA, September 15-17.

Smith, Paul, Season Hoard, Michael Gaffney, Tammi Laninga and Jillian Moroney, 2014. The NARA Community Assessment Model. Poster, WSU 2014 Academic Showcase.

Gaffney, Michael, Season Hoard, Paul Smith, Sanne Rijkhoff, 2014. Paper presentation The NARA Community Assessment Model at the annual IBBC conference, Seattle, WA.

TASK O-8: STRATEGIC FEEDSTOCK PRODUCTION ANALYSIS FOR THE WESTERN MONTANA CORRIDOR

Key Personnel	Affiliation
Brian Stanton	GreenWood Resources

Task O-8 was completed in NARA project Year-2.

SUPPLY CHAIN

EDUCATION TEAM

TASK E-3: BIOREGIONAL INTEGRATED DESIGN EXPERIENCE (IDX)

Key Personnel	Affiliation
Tamara Laninga	University of Idaho
Michael Wolcott	Washington State University
Karl Olson	Washington State University

Task Description

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 the University of Idaho (UI) and Washington State University (WSU). The course is a trans-disciplinary planning and design studio that addresses planning and infrastructure needs of communities exploring their role in biofuel supply chain. Aimed at upper-level BS and MS students, the course is organized around service-learning experiences that link teams of students with communities. PhD students from NARA with special expertise in required areas act as consultants to the IDX teams, improving the level of analysis.

Five different pilot supply chain regions will be 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.). The goals for IDX studio are:

- Every student exits with strong collaborative research, questioning, and design methods to utilize in their academic and professional work within their discipline.
- 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.

Activities and Results

In year 4, IDX completed the Pacific Northwest (PNW) Supply Chain Analysis, examining the four-state NARA region. The goal was to characterize, describe and understand the linkages and evaluate the supply chain performance in various market regions in the PNW. A framework and site selection database was developed that enabled a greater understanding of the linkages among producers, processors, suppliers, distributors, and markets. Supply chain networks and product volumes vary from region to region based on available natural (e.g., feedstock availability) and physical (e.g., roads, rail, pipelines, mills) assets, as well as market demand.

The NARA Year-4 PNW analysis, while building on the first three studies conducted in years 1-3, refined the site selection methodology and biomass supply curves. IDX examined the region as a whole, and also performed sub-regional analyses based on market demand across the PNW to set feedstock requirements for integrated biorefinery (IBR) facilities. Embedded into this analysis, was the identification and ranking of viable processing sites (e.g. solids and liquids depots, conversion and IBR facilities) in each market region for converting forest residuals to isobutanol and/or biojet fuel. The facility types identified and examined by IDX are described below and shown in Figure E-3.1.

1. DEPOT FACILITY: A pretreatment facility that prepares the biomass for processing in a conversion facility. Two depot options are investigated and are detailed as follows:
Solids Depot: a pre-conversion facility that receives post-harvest forest residuals, forest thinnings, and/or C&D waste biomass. Mechanically processed materials 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).
Liquids Depot: a pre-treatment facility that receives raw and mechanically processed woody residuals directly from nearby forests, or chips from a solids 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.

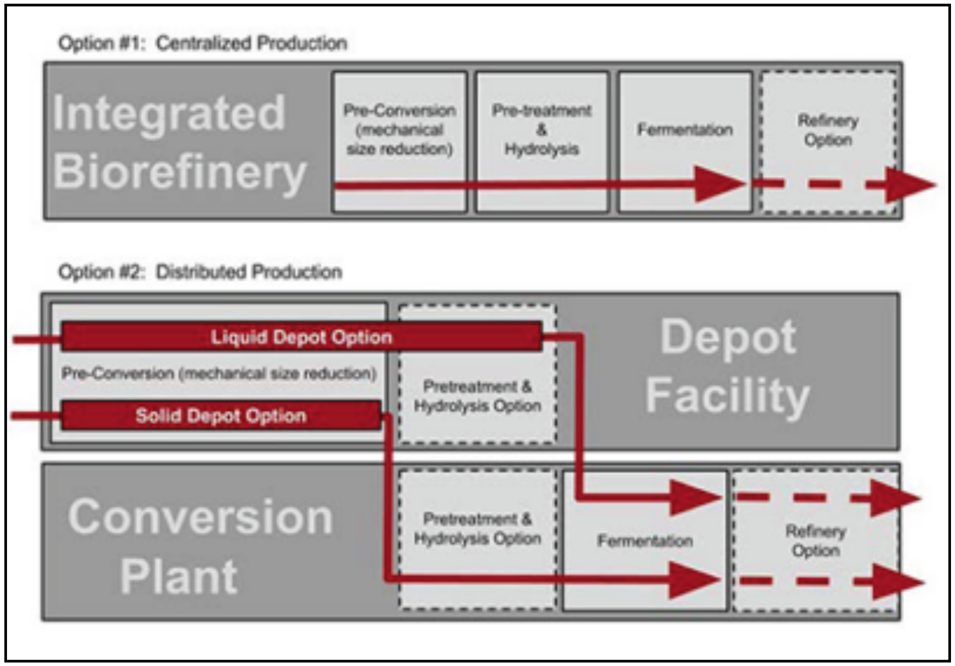

Figure E-3.1. IDX Facility Types

2. CONVERSION PLANT: A high-capacity plant that takes in chips from a solids depot or liquid sugars from a liquids depot and produces isobutanol.

3. INTEGRATED BIOREFINERY (IBR): A high-capacity plant that converts biomass from raw slash or other woody residuals all the way to biojet fuel.

The presentations for the PNW Site Selection Analysis, as well as the sub-regional analyses for the Olympic Peninsula, Northern Oregon, Southern Oregon, and the Western Montana Corridor and the are available at this link.

In addition to the PNW analysis, IDX selected the Wauna Pulp and Paper Mill for co-locating a liquids depot with the current operations. The Wauna Mill was the top facility in our site selection database for a liquids depot and IBR. Washington State University engineering students and University of Idaho planning and landscape architecture students completed a site inventory and analysis. Through this work, IDX selected two locations on the Wauna site for locating a liquids depot. The two site designs will be completed in April and presented in a webinar in early May.

Recommendations | Conclusions

Year 4 IDX incorporated detailed site characteristics and geographic data from years 1-3 into an improved site selection excel database, available for viewing here. The database was shared with NARA Research Teams for further refinement of site selection criteria to optimize the locations of solids and liquids depots, and IBRs. The improved database and decision matrix also incorporated new information from NARA feedstock logistics and pre-treatment technologies to further refine the PNW analysis. Specifically, NARA techno-economic analysis biomass volumes needed to be adjusted for the various types of models under analysis. To have a successful depot or an IBR, the biomass volumes needed to be scaled properly for proposed site operations. IDX worked with the as-

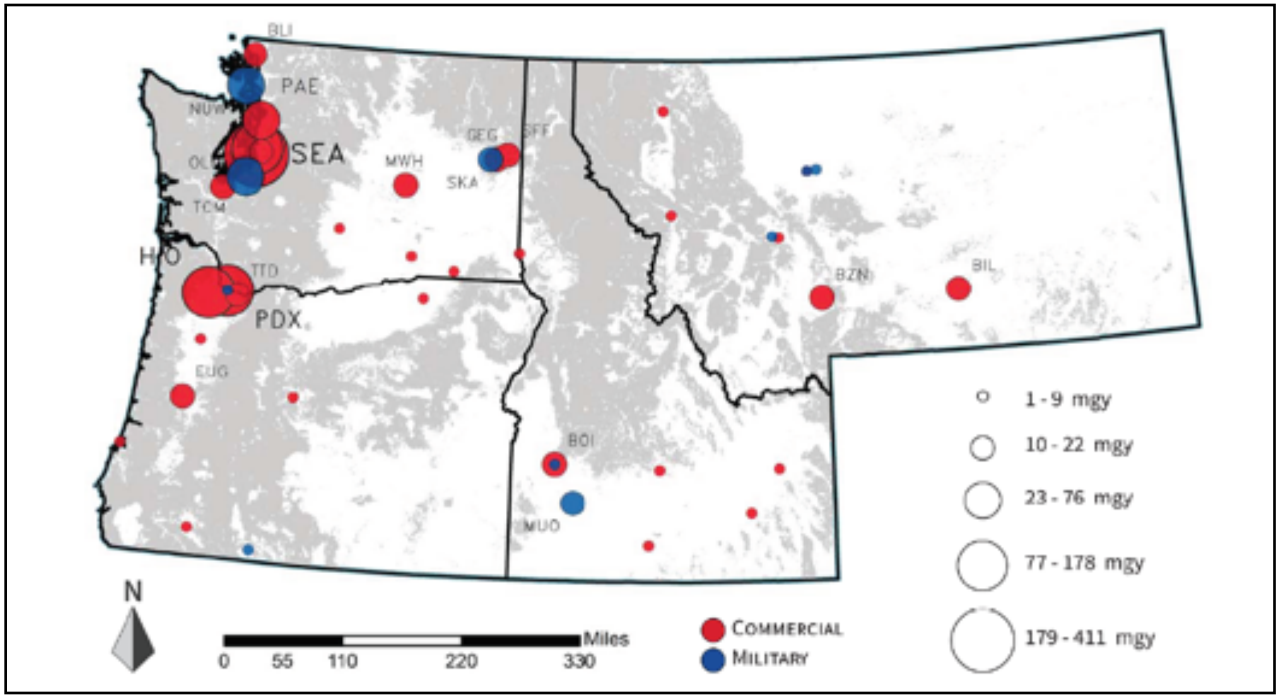

Figure E-3.2. Pacific Northwest Aviation Markets

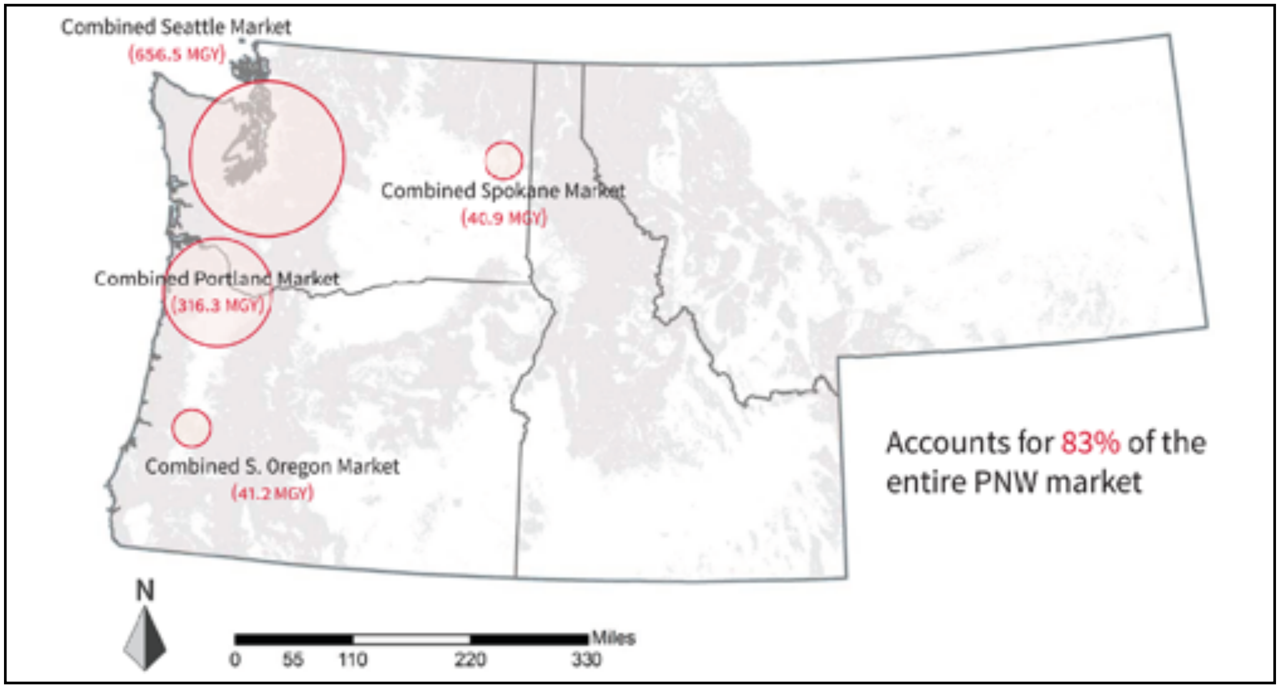

Figure E-3.3. Pacific Northwest Primary Jet Fuel Demand Centers sumption that an IBR, relying on direct haul required 770,000 BDT. However, in a distributed model, where solids or liquids depots supply a conversion facility, the feedstock supply per depot is less. IDX used 250,000 BDT per depot.

IDX further refined facility programming and volume calculations for various site operations and addressed the facility's proximity to the biojet market or demand centers. The original 770,000 BDT volume of biomass used in Years 1-3 analysis was "right-sized" for potential biojet fuel markets throughout the PNW region. This analysis worked backwards from the end of the supply chain, the customer, toward production and feedstock. Figure E-3.2 shows PNW markets; Figure E-3.3 shows PNW market demand.

Conversion efficiency of the current supply chain reports 45 gallons of iso-paraffinic kerosene (IPK) being produced from every bone-dry ton (BDT) of woody biomass. Assessing the local market fuel consumption and using this conversion value (45 gal/BDT) determines the necessary supply of forest residuals needed to sustain the current demand of aviation fuel. The Seattle and Portland demand could be sustained with 770,000 BDT of biomass annually. However, Spokane, Washington's international airport (GEG) consumes around 23 million gallons of jet fuel annually (Sustainable Aviation Fuels Northwest, 2011). Using a 50/50 blend of IPK and petroleum based fuel, GEG could be supported with around 256,000 BDT of woody biomass annually. Table E-3.1 shows the updated supply chain analyses for IDX studies completed in years 2-4.

Table E-3.1. Updated Supply Chain Analyses

IDX Study Year	NARA Sub-region	Model Analyzed	No. of Facilities	Market Demand	Biomass (BDT)
2	Western Montana Corridor (WMC)	Distributed solids depots	1 IBR	41 MG	<400,000
3	Mid-Cascade to Pacific (MC2P)	Distributed liquids (sugar) depots	1 IBR	973 MG	>770,000
3	MC2P	Centralized facility	1 IBR	973 MG	>770,000
4	Pacific Northwest	Centralized facilities (west of the Cascades)	2 IBRs	1,055 MG	>875,000
4	Olympic Peninsula	Centralized facility	1 Conversion	35 MG	<600,000
4	Northern Oregon	Centralized facility	1 Conversion	316 MG	TBD
4	Southern Oregon	Centralized facility	1 Conversion	41 MG	TBD
4	WMC revisited	Centralized facility	1 Conversion	41 MG	TBD

Physical and Intellectual Outputs

PHYSICAL

Database of pulp and paper mills and petroleum refineries in the PNW, with site and asset details.

REFEREED PUBLICATIONS

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

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

RESEARCH PRESENTATIONS

Conference Presentations

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

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

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

Laninga, T. and J. Moroney. 2014. Wood to Wing: Stakeholder Perspectives on a Wood-based Biofuels Industry in the Northwest United States. Associated Collegiate Schools of Planning. Philadelphia, PA. November 1.

Poster Presentations

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

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

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

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

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

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

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

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

OTHER PUBLICATIONS

IDX. 2014. Mid Cascade to Pacific Analysis Document. http://nararenewables.org/midcascadestopacific/docs/Vol2-Analysis.pdf

IDX. 2014. Mid Cascade to Pacific Historical Overview http://nararenewables.org/midcascadestopacific/docs/Vol4-Historical.pdf

IDX. 2014. Mid Cascade to Pacific Supplemental Materials http://nararenewables.org/midcascadestopacific/docs/Vol5-Supplemental.pdf

IDX. 2014. Pacific Northwest Wood-based Biofuels Profile. http://nararenewables.org/pacificnorthwest/docs/Vol1-Profile.pdf

VIDEOS AND WEBINARS

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

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

TRAININGS, EDUCATION AND OUTREACH MATERIALS

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

IDX Student Presentation. Biorefinery Sites. November 19, 2014. WSU News. https://news.wsu.edu/2014/11/17/nov-19-students-present-potential-biorefinery-sites/#.VHuYzGTF_Ak

TASK E-8: DISTRIBUTED SUGAR MODEL

Key Personnel	Affiliation
Jinwu Wang	Washington State University
Michael Wolcott	Washington State University

Task Description

This task aims to scope, develop and enable distributed production scenarios that can be cost-effectively operated for conversion of biomass to standardized feedstock or sugars. The primary aim of distributed production is to maintain small facility scales and decrease the complexity compared to an integrated biorefinery. Achieving these goals could potentially decrease biomass and labor costs while extending utilization of existing facilities. A techno-economic analysis (TEA) by the NARA systems metrics group in project years 1 and 2 projected that the cost of biomass feedstock contributes substantially to the overall production of biofuels. It is envisioned that decentralized sugar depots that locally transforms bulky biomass into cellulosic sugars provides potential for reducing the biomass transportation cost, which contributes substantially to the overall feedstock cost. If successful, a web of distributed sugar depots could become a key component in a forest residue supply chain for producing fuels. Such cellulosic sugars are versatile intermediate precursors, not only for producing fuels, but also developing valuable platform chemicals and polymers. They can be a “drop in” feedstock for existing and emerging ethanol plants worldwide in solid or syrup. Exploring opportunities to diversify NARA product portfolio to include cellulosic sugar intermediates can insulate from current uncertainties in advancing cellulosic biofuel markets.

Distributed sugar depots located in remote rural areas require a simple conversion process with low capital costs, decreased need for specialized workforce, and low environmental impact. In NARA Years 3 to 5, the feedstock and product characteristics and process performance necessary for analysis of technical feasibility and economical viability of a distributed sugar depot will be investigated in the context of realizing a cost-competitive cellulosic sugar production. We will use a pilot facility at WSU Composite Materials and Engineering Center (CMEC) to simulate the process and generate the necessary data to evaluate performance. A simulated sugar depot in the lab consists of a mechanical size reduction system, dispersive enzyme mixing with milled wood by a conical twin-screw extruder and subsequent enzymatic hydrolysis in a digester, and sugar stream separation and characterization. Specifically, woody biomass from a stakeholder mill in the East Washington and from one of municipal recycling facilities is hammer-milled into a targeted fineness and then pulverized for an optimal period of time. The mechanically activated wood meal is mixed with enzymes using a twin-screw extruder and digested in a reactor. The sugar stream is then separated and characterized.

Biomass comminution holds an analogy to ore comminution in the mining industry, in which about 50-70% energy used for mineral extraction is consumed on ore comminution (*Walkiewicz et al., 1989*). Mining engineering has developed algorithms and methodologies to design and scale-up comminution processes based on the lab-scale experimental data (*Herbst and Fuerstenau, 1980; Herbst et al., 1982; Man, 2001; Morrell and Man, 1997; Morrell, 2009*). For ore, primary size reduction is crushing, while for woody biomass, it is chipping or grinding. But late stages of comminution to the micro-scale level are quite similar to the tumbling mills used with ore. The cases, practices, designs, and process economic analysis in the mature mine comminution will be analyzed and tailored for biomass comminution. The algorithms will be developed linking small systems up to larger ones and used to project scale up production. Specifically, the relationships between comminution energy and product size is predicated on the assumption that the required energy for a differential decrease in size is proportional to the size change (dx) and inversely proportional to the size to some power n (*Jankovic et al., 2010*). One of explicit solutions describing size reduction follows a particular relationship as delineated by the well known “third theory” equation (*Bond, 1952*)): $W=W_i\,(10/\sqrt{P}-10/\sqrt{F})$, where W is the specific energy expenditure at an industrial scale, Wi is the work index from the standardized laboratory grinding tests, P is the 80% passing size for the product, and F is the 80% passing size for the feed (*Morrell, 2008, 2004*). The total power for a commminution system in a sugar depot can then be projected according to the designed capacity (*Schlanz, 1987*). The potential industrial scale comminution systems will be identified based on the required comminution power.

A sugar depot that prepares biomass into readily fermentable sugars, and ships them to conversion facilities draws various categories of biomass from a smaller fibershed including forest residuals and construction and demolition (C & D) wood waste from municipal solid waste streams. Diversifying the biomass sources could be a way to mitigate supply risks and reduce the supply radius. The viability of sugar depots will be enhanced if they can process multiple feedstocks. The tolerance to feedstock variability and feedstock purity is thus evaluated. Methods and barriers of measuring purity levels are investigated.

This technology is selected because 1) preliminary tests by Weyerhaeuser in Year 2 demonstrated that pulverizing alone can be an effective means of pretreating wood for enzyme hydrolysis, 2) such an approach would eliminate the need for chemicals thereby decreasing environmental permitting, labor cost without a need for chemical engineers, and environmental burdens; 3) mechanical activation can be accomplished at low temperatures and generate fewer inhibitors compared to thermochemical pretreatments under combined action of chemicals, temperature, and pressure; and 4) twin-screw extrusion is a mature "plug and play" technology adaptable for all scales, for mixing, shearing, and processing of high solids concentration reducing water usage in a continuous process mode. The limitation is that this biomass-to-sugar conversion consumes a large quantity of electrical energy for milling. However, it may be a good choice in the Pacific Northwest, where electricity is relatively low cost and large quantities are generated from relatively clean hydro and wind powers. Relevant unit processes will be specifically investigated for energy requirements, evolution of carbohydrate content, digestibility, and sugar specifications. Other unit process alternatives will be identified and integrated to create a novel sugar production line appropriate for a sugar depot. Mechanical pretreatment in combination with moderate chemical treatment may be an alternative to generate synergistic effect to enhance digestibility and lower energy consumption.

EXPECTED TASK OUTPUTS

1) *Design milling systems to achieve desired fineness and sugar recovery rate and yield.* Douglas-fir wood chips from a lumber mill and the C & D wood from one of the municipal recycling facilities in the NARA region are shipped to the CMEC, which are then screened to remove impurities. The accepts are subjected to a two-stage milling: coarse and fine milling. Specifically, wood chips are comminuted to a specific size with a combining milling system, then to activated states with different types of pulverizing machines including ball mill and ring & puck mill in dry or wet modes, or in combination with moderate chemical loading. For the coarse milling, different types of milling circuit processes (closed- vs. open-circuit grinding) are designed and evaluated utilizing a pilot plant comprising two hammermills, one knife mill, and one screener in order to obtain the desired fineness for next stage pulverization. Design and operating variables are related to classification, circulating load, and circuit efficiencies. Energy requirements for milling Douglas-fir wood chips to an optimal fineness at a full-scale sugar depot are projected through a developed algorithm.

2) *Develop metrics to assess milling systems and define specifications of the ground materials.* Process metrics include specific electrical energy consumption, specific surface area increase, comminution ratio and efficiency. Product metrics include digestibility, size and size distribution, bulky density, aspect ratio, powder flow behavior, and slurry rheology. Principal breakup mechanisms (compression, tension, shear, and impact) and biomass breakage modes are investigated to provide an insight in designing innovative grinding and milling processes. Grinding performance parameters and modeling are to be learned from the comminution of the mineral ore.

3) *Design hydrolysis system and evaluate hydrolysis efficiency.* Milled wood meal and enzymes are extruded with a Cincinnati Milacron 55-mm conical twin-screw extruder; the extrudates are then enzymatic hydrolyzed in a digester. The process performance is evaluated in terms of energy requirement and sugar recovery.

4) *Separate and condense sugar stream, and define sugar specifications.* Sugar stream is processed into various product forms (granulate, powder, syrup, or separation of C5 and C6 sugars, crystalline, or amorphous) and characterized in terms of physical and chemical properties (chemical compositions, mixed sugar profile, inhibitors, fermentability etc.).

5) *Analyze sugar depot process economics.* Process economics from wood chips to sugars with respect to depot sizing and unit operations will be analyzed in a low lever techno-economical analysis. Information about comminution capital and operational costs will be collected from pulping and mining industries, literature, and through simulation based on lab experimental data.

6) *Summarize and report the findings.* The results are summarized and disseminated to the NARA leadership team and at the annual conference.

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Activities and Results

A two-stage mechanical pretreatment of Douglas-fir wood has produced 6-kg of highly digestible milled wood. The process uses an industrial scale hammer mill to reduce the biomass to 230 µm and then employs a pilot planetary ball mill to further reduce the particle size to 30 µm while simultaneously disrupting the cell wall architecture and cellulose crystalline structure. The 6-kg milled wood has been hydrolyzed and fermented using Gevo's proprietary integrated fermentation technology platform. The theoretical sugar yield is comparable with a leading chemical pretreatment. The hydrolyzed mechanically pretreated wood possessed a very low growth inhibition, demonstrated by the ability to grow isobutanol producing yeast at 100% hydrolysate. In contrast, isobutanol producing yeast propagation growth is limited to a maximum of 40% of hydrolysate produced through a thermochemical pretreatment with an admixture of mock media. The dry milling pretreatment produced excellent hydrolysate with almost no impact on isobutanol producing yeasts growth and with enhancement on isobutanol production, all without any delay in isobutanol production. This indicates that clean sugar from the milled wood can be widely used in various bioconversion processes for high value bio-based product production. The sugar yields and specific energy consumptions of the milling and cellulosic sugar production have been measured and used for the techno-economics analysis of sugar and clean fuel lignin pellet productions. Based on current market price of sugar and wood pellet co-product, the preliminary techno-economic analysis indicates that cellulosic sugar production via the dry milling pretreatment route is competitive with the National Renewable Energy Laboratory's dilute acid corn stover process model (*Humbird et al., 2011, Process design and economics for biochemical conversion of lignocellulosic biomass to ethanol*). Modeled on the dry milling corn ethanol production, we envision that dry milling could become a unique depot-size technology for biomass pretreatment and for sugar and lignin fuel production.

Several different lab-scale mills have been used to investigate the milling effects on disruption of the lignocellulosic structure and its influence on enzymatic digestibility and energy efficiency. Images produced from scanning electron microscopy showed that fiber cell walls were fragmented and the hierarchical structures of wood were disrupted with increasing milling time (Figure E-8.1). Multi-technique characterization of Douglas-fir cell wall disruption during mechanical milling was conducted using electronic microscopy (SEM, TEM), confocal laser scanning microscopy (CLSM), atomic force microscopy (AFM), and X-ray diffraction (XRD). Collectively, these techniques elucidate the evolution of cell wall changes. Coincident with the particle size reduction of the wood material during the milling process includes tissue disintegration, cell wall fragmentation, disordering of layered cell wall fragment, and aggregation of disordered cell wall fragments. As evidenced by CLSM, the constituent cell wall polymers are redistributed following the ultrastructure disruption from the mechanical milling. Micro/nano porous structures were visualized by 3D-TEM tomography. XRD results demonstrated the amorphization of the semicrystalline polymers. Cellulose crystallinity of the ball-milled samples gradually decreased with the progress of milling time and approached an amorphous state within 240-min (Figure E-8.2). Chemical compositions of the ball-milled samples did not change with milling time. Enzymatic digestibility increased with milling time and reached around 85% theoretical sugar yields under 120-min milling (Figure E-8.3). The surface and ultrastructure alternation of cell wall contribute to enhancement of enzymatic digestibility by 4-14 folds over that of untreated cell walls depending on the degree of milling pretreatment. Benefits of dry milling pretreatment without chemicals have been demonstrated by the absence of inhibitors in the sugar stream (Figure E-8.4) and an increased reactivity of the lignin residual (Figure E-8.5). Sole dry milling pretreatment led to a light-colored lignin residue (Figure E-8.5., Blank) that was hardened under heating at 103 0C (Figure E-8.5a) indicating its high reactivity and possible condensation, while other thermochemical treated residues produced a dark, loose sandy material apparently without polymerization under heating (Figure E-8.5b).

In the 2015 spring semester, four engineering major undergraduate students are participating in the research involving milling performance evaluation and characterization of feed and ground materials. A team of engineering undergraduate students is conducting process design for the dry milling pretreatment process in conjunction with a capstone project curricular requirement. The project is providing a rare opportunity for undergraduate students to solve the real world problems and acquire integrated design experience. One proposal based on preliminary results was submitted to the Manufacturing Machines and Equipment Program of the NSF Division of Civil, Mechanical and Manufacturing Innovation, titled as Advanced Knowledge That Enable a Cost-effective Dry Milling Pretreatment of Wood for Cellulosic Sugar Production. The grant has partially supported two Ph.D. dissertation projects and one M.S. thesis. Their thesis' titles are listed as follows: (1) Dry Milling Mechanical Pretreatment of Softwood for Enzymatic Hydrolysis at a Distributed Sugar Depot: Multi-Scale Assessment of Structural and Physicochemical Recalcitrance Disruption, 2) Size Reduction and Sulfite Pretreatment of Softwood for Efficient Hydrolysis and High Value Products Yield, and 3) Enhancing the Milled Wood Enzymatic Hydrolysis Through Post-Milling Kneading by a Torque Rheometer.

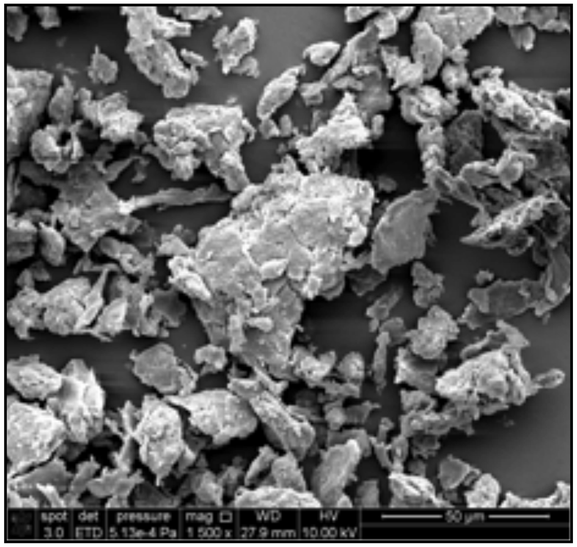


Figure E-8.1. Ball milling for 120min under ambient temperature led to the almost complete disappearance of discernible tissue structures (cell walls, lumens, pits and spiral thickenings).

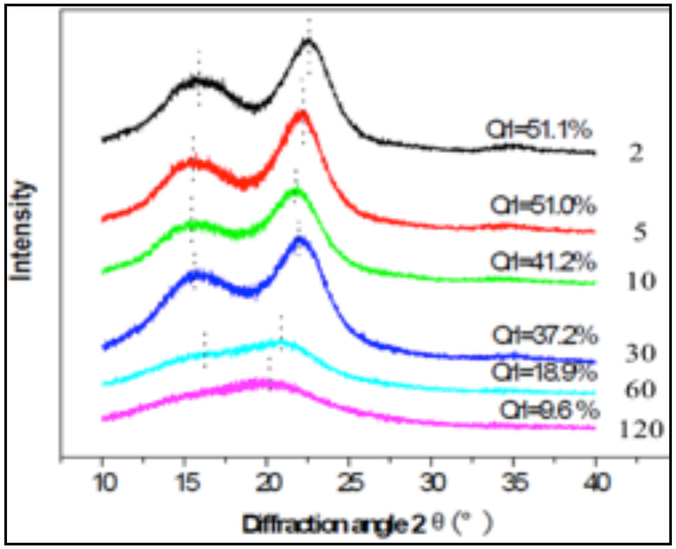


Figure E-8.2. Cellulose crystallinity index decreased with ball milling time under room temperature milling.

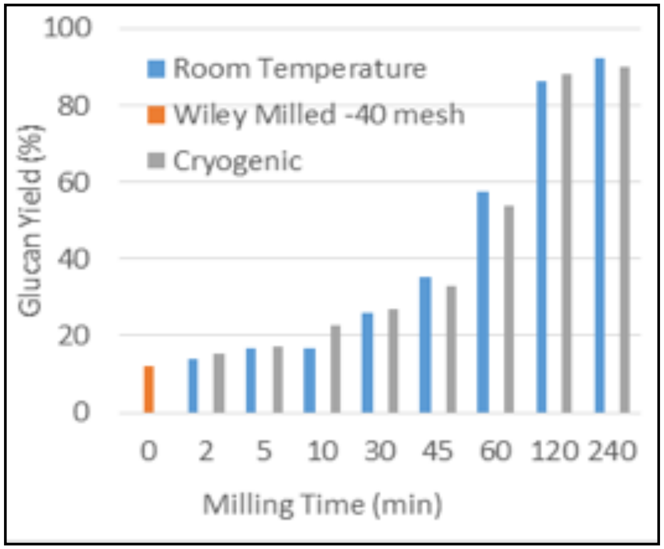


Figure E-8.3. Glucan yields of 72-hour enzymatic saccharification increased with the milling time under different milling conditions (Wiley knife milled, ball milled without controlling chamber temperature, and cryogenic milling)

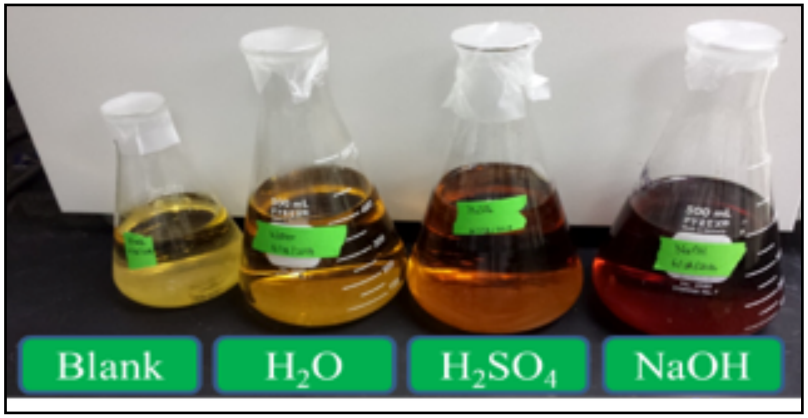


Figure E-8.4. Color difference of clarified enzymatic hydrolyzates. The light color of the hydrolyzate (Blank, mechanical pretreatment) indicated its less inhibitors, confirmed by smaller intensity at 280 nm (furfurals) and by the HPLC analysis.

Figure E-8.5. Wet lignin residues after vacuum filtration. The color of the lignin residual without chemical treatments (Blank) is lighter. After dried at 103 ^{0}C overnight, it hardened into chunks (a) while other thermochemical treated residues looked like loose sandy materials (b).

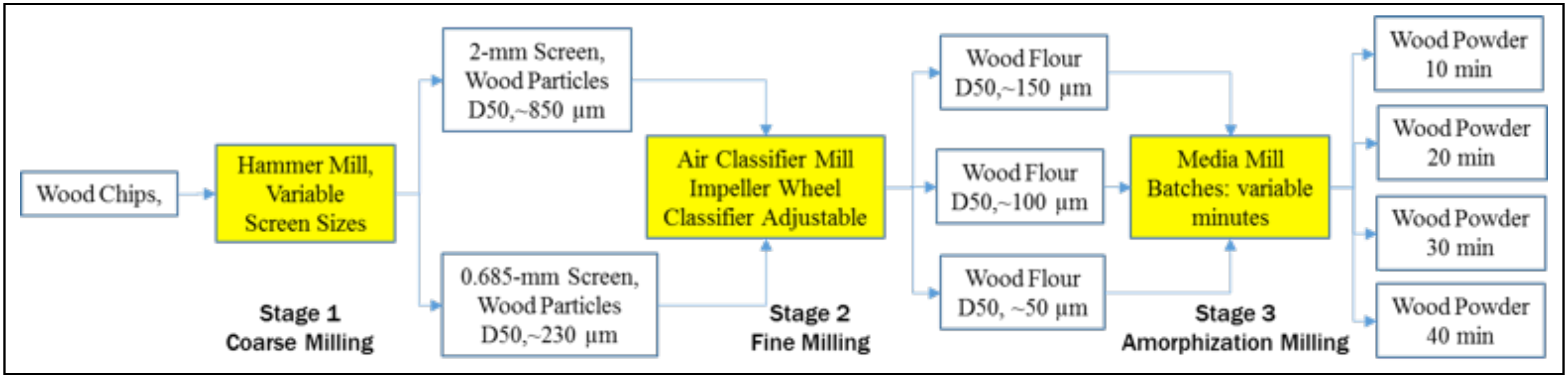


Figure E-8.6. An experimental design of the three-stage milling process for the dry milling mechanical pretreatment, D50, median particle size.

Recommendations | Conclusions

Conclusions

Several distinctive advantages of the mechanical pretreatment have been proved including generating pure and clean sugar stream with substantial less inhibitory compounds to subsequent fermentation, producing reactive lignin residues with little chemical alteration, using substantial less water, and minimizing capital and operational costs. Wood milling presents a promising alternative wood deconstruction method to produce fermentable sugar for biofuel applications and shows the potential to be deployed in a distributed sugar depot system.

Recommendation 1: Evaluate an industrial scale three-stage milling process for production of highly digestible wood.

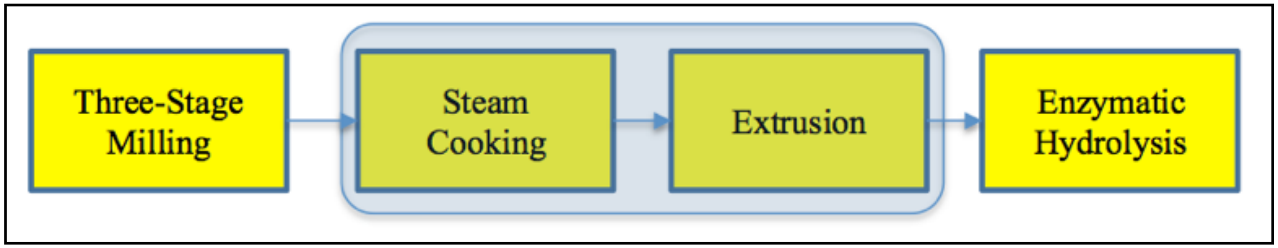


Figure E-8.7. Post-Milling Treatments

Coarse milling of wood to 400 µm typically uses a hammer mill due to its high efficiency. However, the existing wood industry does not have experience in micronizing wood to a median size of 20 µm nor does it disrupt cellulose crystalline structure on a large scale. The dry milling pretreatment has been found to be an energy intensive if accomplished by using one comminution mechanism to reduce wood chips into amorphous digestible powders. This is an area to which we are expected to bring superfine comminution technologies and innovations from mineral and chemical milling science to innovate a cost-effective solution to biomass micronization. A three-stage milling process, namely coarse, fine, and amorphization milling has been designed to take advantages of different size reduction principles to decrease milling energy and cost (Figure E-8.6). Size reduction is achieved by the hammer mill and the air classifier mill; disruption of the cell wall ultrastructure, cellulose crystalline structure, and lignocellulosic polymer assemblies are achieved by the media mill or a compression mill. The architecture and construction of a hammer mill and an air classifier mill systems are designed to break down particles with minimum friction heating, whereas an air classifier mill is more efficient than a hammer mill below 200 µm. A media mill induces the breakage across microfibril orientation due to the high amount of compressive force that disrupts the cellulose crystalline structure and reduces the recalcitrance to enzymatic hydrolysis. In NARA Year-5, a ACM 15 air classifier mill (Hosokawa Micron Powder Systems, Summit, NJ) will be used for stage 2 fine milling, and stage 3 amorphization milling will be tested with a VikroKinetic Energy Mill (Micro Grinding Systems, Inc., Little Rock, AR), a compression milling (to be identified), and an eccentric vibrating mill (TEMA Systems, Cincinnati, OH). The companies have agreed to provide services with minimum cost charges. These milling machines were identified among a large pool of comminution technologies for their great potential to be successful in the new process. The data is then analyzed, reduced, and modeled to provide a comprehensive understanding and new insights of process design and engineering of the dry milling mechanical pretreatment.

Recommendation 2: Enhance enzymatic saccharification through post-milling extrusion and steam injection cooking.

The mechanical pretreatment through the three-stage milling process is expected to render wood to be highly digestible. To reduce the requirements of the milling process, we have investigated additional post-milling physical treatments under the NARA Year 4 task (Figure E-8.7). Until now, the initial results demonstrated that post-milling extrusion treatments of the milled wood greatly unfold the structures in wood particles, dramatically increase dissolution in water, and increase viscosity of slurry. These observations show that post-milling treatments have a great potential to improve sugar yield and reduce requirements to the milling process. For the NARA Year-5 task, this study will optimize extrusion parameters such as compression ratio, screw speed, screw elements, and barrel temperature as well as water content on the sugar recovery in tandem with a digester. In addition, we have installed and commissioned the use of a direct steam injector in collaborating with an investigator in the WSU Food Science Department. Steam cooking is a unit process after hammer milling of corn in the dry milling corn ethanol production. Modeled on this process, we will also investigate the effect of post milling steam cooking of the digestible milled wood on its physiochemical properties and digestibility.

Recommendation 3: Improve milling efficiency through chemical-assisted milling.

Chemical grinding aids or additives to the mill during grinding can minimize the effects of moisture in the feed material, function as a lubricant between particles to prevent agglomeration, reduce grinding energy, and/or enhance the downstream sugar yield, or effect on powder property development.

Recommendation 4: Characterize and valorize saccharification residual solids (SRS) obtained from the enzymatic hydrolysis of the mechanical pretreated wood.

One distinctive advantage of the mechanical disruption of biomass recalcitrance over chemical pretreatments is the potential to persevere the physiochemical properties of native lignin. It is worthwhile to characterize this lignin residue and find its potential application. We are expected to fractionate SRS, extract powdered alpha-cellulose and nanocellulose and characterize and valorize the purified lignin.

Physical and Intellectual Outputs

PHYSICAL

- 6 kg hydrolysable milled wood powder was produced and characterized
- 2 kg saccharification residual lignin solids were obtained
- Industrial milling trial sites were established

RESEARCH PRESENTATIONS

1. Jiang, J.X., Wang, J.W. and Wolcott, M.P. 2014. The Development of Physical Properties and Correlation of Feed and Product Sizes and Energy Consumption During Vibratory Ring & Puck Fine Milling of Douglas-fir Wood Particles, Poster at the Annual Meeting of Northwest Advanced Renewables Alliance, Seattle, WA, Sep. 15-17, 2014

2. Liu, Y.L., Wang, J.W. and Wolcott, M.P. 2014. Size Effect on Mild bisulfite pretreatment performance on Douglas-fir, Poster at the Annual Meeting of Northwest Advanced Renewables Alliance, Seattle, WA, Sep. 15-17, 2014

3. Liu, H.N., Wang, J.W. and Wolcott, M.P. 2014. Effect of Initial Mixing on Enzymatic Hydrolysis of Ball Milled Wood, Poster at the Annual Meeting of Northwest Advanced Renewables Alliance, Seattle, WA, Sep. 15-17, 2014

4. Seals, R., Wu, E., Jiang, J.X., Liu, Y.L., Liu, H.N., Wang, J.W. and Wolcott, M.P. 2014. Testing Residual Lignin as an Binder for Wood Pellets, Poster at the Annual Meeting of Northwest Advanced Renewables Alliance, Seattle, WA, Sep. 15-17, 2014

5. Wu, E., Seals, R., Jiang, J.X., Liu, Y.L., Liu, H.N., Wang, J.W. and Wolcott, M.P. 2014. Ball Milling: Effective Pretreatment Leading to A Clean Cellulosic Sugar Conversion, Poster at the Annual Meeting of Northwest Advanced Renewables Alliance, Seattle, WA, Sep. 15-17, 2014

6. Zhou, X., J. Wang and M. Wolcott. 2014. Evaluating the Use of Ball-milling on the Douglas-fir Particles, Poster at the Annual Meeting of Northwest Advanced Renewables Alliance, Seattle, WA, Sep. 15-17, 2014
7. Eileen Wu, Rodney Seals, Jinwu Wang, Michael Wolcott, Yalan, Liu, Jinxue, Jiang, and Huinan Liu. 2014. Ball milling: effective pretreatment leading to a clean biomass to cellulosic sugar conversion, The WSU Summer 2014 Undergraduate Research Poster Symposium

8. Rodney Seals, Eileen Wu, Jinwu Wang, Michael Wolcott, Yalan, Liu, Jinxue, Jiang, and Huinan Liu. 2014. Lignin residue as wood pellet binder and energy enhancer for energy applications, The WSU Summer 2014 Undergraduate Research Poster Symposium

SUBTASK E-8: DISTRIBUTED SUGAR MODEL

Key Personnel	Affiliation
Xiao Zhang	Washington State University

Task Description

This subtask will conduct a techno-economic analysis (TEA) to determine process economics and identify the economics bottlenecks in the distributed sugar depot model based on pulverized wood. SuperPro Designer software will be used to construct TEA model of a distributed sugar depot. A schematic illustration of the main unit operations and process flow is shown in Figure SubE-8.1. SuperPro Designer has gained increasing use for applications in TEA simulation of biomass conversion processes. Several TEA models of a lignocellulosic biorefinery using SuperPro Designer have been recently developed by DOE Joint BioEnergy Institute (JBEI)1,2. SuperPro Designer incorporates several mechanical treatment unit operations (e.g. grinding, shredding, nano and high pressure milling) that are applicable to the main process steps in the distributed sugar depot process. However the default cost estimates in SuperPro associated with these unit operations are not currently based on wood as substrates. Mechanical deconstruction of woody biomass and ore comminution are common technologies used in the paper and mining industries respectively. We will identify appropriate equipment and associated cost data to be incorporated into SuperPro Designer. Dr. Zhang has a considerable amount of experience with pulping processes and biomass deconstruction methods. In this project, we will work with paper and mining companies to obtain commercial operational data in feedstock procurement, handling, transportation, storage and associated equipment as well as operational cost in pulping and cost of environmental compliances for a typical biorefinery.

In this subtask, we will first construct a SuperPro Designer model to simulate the process shown in Figure E-8.1. We will then work with Drs. Wang and Wolcott's team to import the data and metrics developed from lab studies on mechanical treatment and high consistency enzymatic hydrolysis. Several scenarios will be established to compare different size reduction technologies (grinding, shredding, milling etc.) and process configuration in order to optimize energy efficiency, substrate digestibility and process economics. A graduate student will be working on this subtask supervised by Drs. Zhang, Wang, and Wolcott.

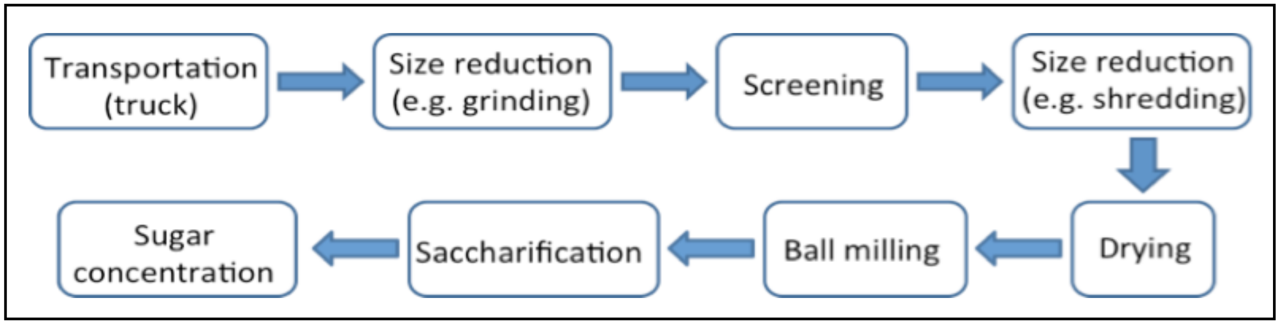


Figure SubE-8.1. A schematic illustration of main unit operations and process flow in a distributed sugar depot.

REFERENCES

1. Klein-Marcuschamer, D., Oleskowicz-Popiel, P., Simmons, B. A., Blanch, H. V. "Technoeconomic analysis of biofuels: A wiki-based platform for lignocellulosic biorefineries," Biomass and Bioenergy (2010), 34(12):1914–1921
2. Klein-Marcuschamer, D., Simmons, B. A., Blanch, H. V. "Techno-economic analysis of a lignocellulosic ethanol biorefinery with ionic liquid pre-treatment," Biofuels, Bioproducts, & Biorefining (2011); 5(5):562–569

Activities and Results

A process flow model of a distributed sugar depot was constructed in SuperPro Designer as a base case test model, sized to an operating throughput of 250,000 tons/year (Figure SubE-8.2). The appropriate primary unit operations were evaluated, and established with specifications based on industry standards and pilot scale data. Process parameters for the milling operation and hydrolysis conversion were informed by ongoing lab tests. Equipment sizing was generated by the SuperPro program, supplemented with vendor data. Combined with the calculated mass and energy balance, this allowed for preliminary evaluations of the factors contributing to the total cost as different unit operation scenarios were considered.

The initial results have shown that:

1. SuperPro is suitable for evaluating this model and is unique compared to Aspen in its built in unit operations appropriate for mechanical treatment based bioconversion process.

2. TEA analysis by SuperPro can provide insight in delineating the cost factors of the process, allowing for better optimization of the depot conversion process.

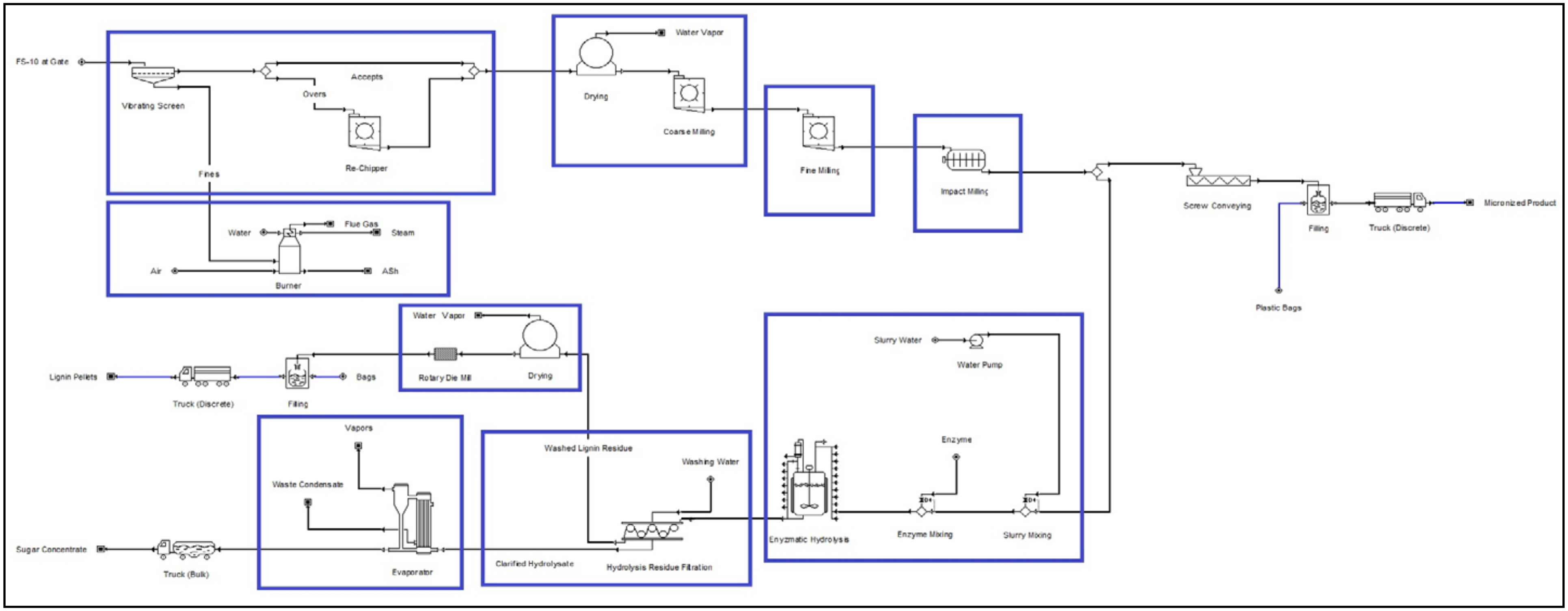


Figure SubE-8.2. A process flow model of a distributed sugar depot

Recommendations | Conclusions

Preliminary TEA analysis with SuperPro has shown that the sugar depot refinery model has several potential advantages over large-scale stand-alone biorefinery facility. The lack of chemical pretreatment not only removes the operating costs associated with chemical treatment and neutralization, it also eliminates the need for corrosive resistant reactors, greatly reducing the CAPEX associated with these processes. Evaluation of the output streams suggests that process water needs little additional processing, eliminating the need for a dedicated wastewater treatment facility. The simplified process flow allows for more flexible operability, and the compartmentalization of the primary unit operations allows for the exploration of alternative uses for the product streams.

Our work in the next year is to refine the SuperPro TEA model by improving the detail of the unit operations and completing ancillary areas such as emissions control, feed handling, and heat recovery. Furthermore, continued investigations in milling and hydrolysis technologies will update the model with more accurate energy requirements and conversion factors. We plan to survey several typical scenarios of sugar depot operations in detail, accounting for variations in feed composition, depot location, feedstock supply chain and market demands. As we fine tune our process specifications, we will construct the model in ASPEN Plus to validate the thermodynamic calculations.

Physical and Intellectual Outputs

A SuperPro based TEA model was constructed.

TASK E-7: FEEDSTOCK SUPPLY CHAIN ANALYSIS - MSW

Key Personnel Karl Englund

Affiliation Washington State University

Task Description

To inventory and assess the biomass within the municipal solid waste (MSW) and construction and demolition (C&D) supply chain throughout the NARA region. Research focus will be placed upon developing an overall and accessible inventory of the woody biomass in the Northwest (especially NARA communities), developing strategies to increase the recovery this material, establishing QC/product specifications, and identifying where these materials fit within the wood utilization supply chain.

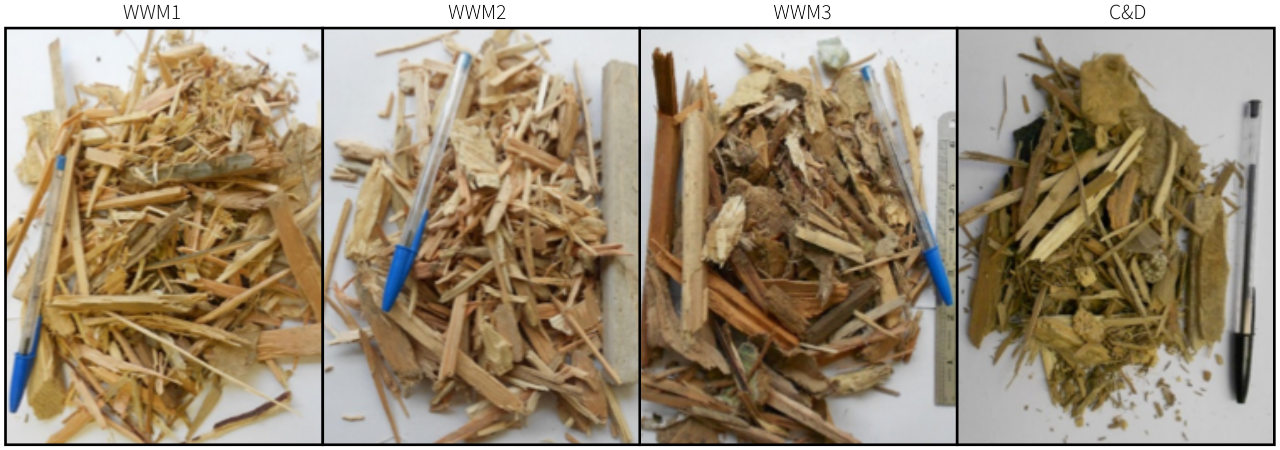


Figure E-7.1. Images of the materials (as received) used for the study.

Activities and Results

The work in the last year has been focused on characterizing waste wood residues from three material recovery facilities (MRFs) in the NARA region for their potential use as a feedstock for the production of sugars/biofuels via enzymatic hydrolysis. Four samples of the various MRFs (Figure E-7.1) have been characterized to determine ash content, presence of metals and alkalines, elemental composition, and carbohydrates content. Results showed that, when compared with "clean" wood (ponderosa pine–PPine and sugar maple–SMaple), some of the MRF wood specimens i) contained high amounts of ash (Table E-7.1), ii) possessed high amounts of alkalines and metals, including heavy metals (Figure E-7.2), and iii) showed carbohydrates content that is in the range of values reported in literature (Table E.7.1). No sulfur was detected in the samples (Table E-7.2).

For sugars production, the process consisted of acid pretreatment (SPORL process at 165°C, 75 min) followed by enzymatic hydrolysis. The materials were first classified to remove both large and relatively small particles by using two sieves with 25 and 12.5 mm holes dimensions. This process helped to remove some contaminants, especially earth and rocks, which would likely be done at a potential biorefinery. The pretreatment was performed in a 1-liter Parr reactor, using 40 g of wood for each run (in duplicate), and acid solution (9.8% H_2SO_4 and 4.6% $NaHSO_3$ (w/w, odb). The solution/wood ratio was 3:1. Since the tests showed that it takes a relatively long time to reach the set temperature for the process, the degradation that occurs during the preheating step was corrected using a time-temperature correction factor (tT). Activation energy of the feedstocks used for tT computation was 180000 kJ/mol. Yields of pretreated solids were: 78.7% for WWM1, 85.9% for WWM2, 80.3% for WWM3, and 81.6% for C&D.

After pretreatment the solids were washed with tap water and the prehydroysate was collected for sugars content determination. The washed pretreated solids were dried (70°C, 24 h), ground (40 mesh), and subjected to enzymatic hydrolysis. The enzymatic hydrolysis process was conducted at 10% (w/w) solids concentration in 250 mL flasks, using a 50 mM buffer acetate, and adjusted to pH~5. Enzyme loadings were 5% of CTec2 and 0.5% of HTec2 enzymes (dry pretreated wood basis). The process occurred at 50°C and 200 rpm, for 72 h. An aliquot of the hydrolysate of each sample was collected for analyses. Both the hydrolysate and prehydrolysate were characterized using Ion Chromatography.

Carbohydrates content of both the raw materials and the pretreated solids was determined following the NREL method. These results were used for computing the yields of sugars obtained via enzymatic hydrolysis. Although most results are available, computations for the mass balance of the sugars production are in progress. In addition, a paper showing the results is being prepared. It appears that removal of small particles, as required for the SPORL pretreatment, helps to limit the presence of alkalines and heavy metals in MRFs used for sugars production.

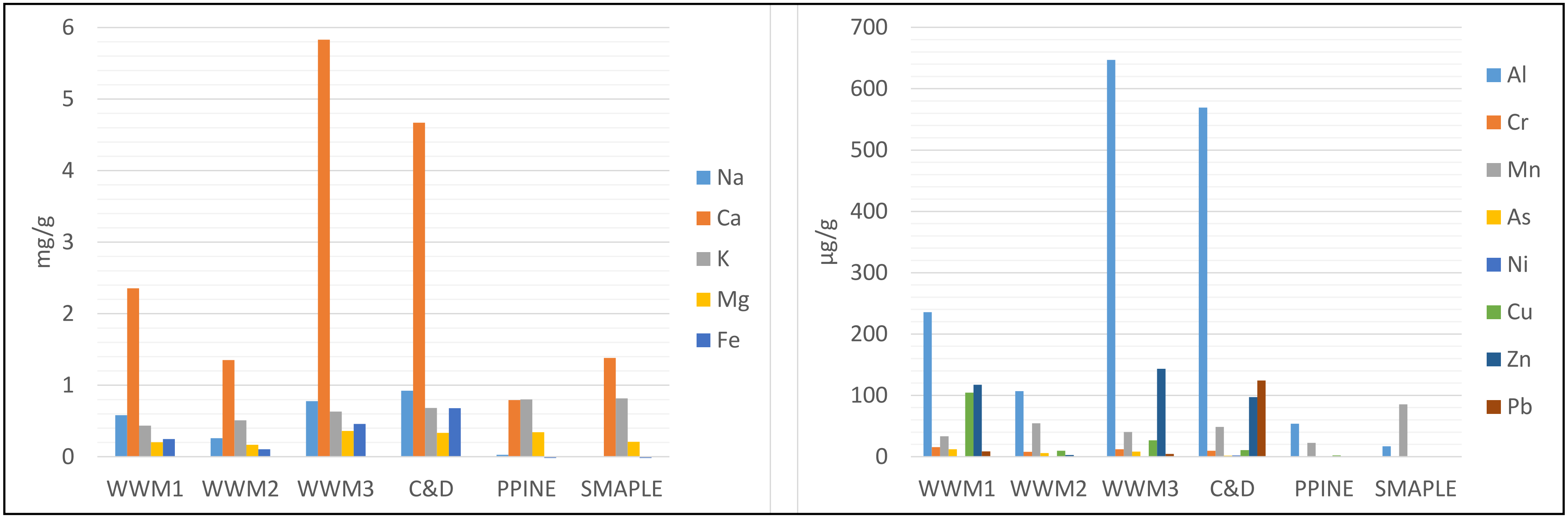


Figure E-7.2. ICP-MS results. It is observed that MRFs contain higher percentages of alkalines and metals than ponderosa pine and sugar maple (which were used for comparison). Presence of small amounts of Pb in C&D (right) could result from the presence of paints in this sample.

Table E-7.1. Feedstock carbohydrate composition and ash content (%, material as received)

Polymer sugar of biomass	WWM1	WWM2	WWM3	C&D
Arabinan (%)	0.78	0.95	0.70	0.84
Galactan (%)	2.49	2.38	1.79	2.40
Glucan (%)	43.22	45.57	43.87	41.69
Xylan/Mannan (%)	14.40	15.50	15.21	14.75
Total carbohydrates (%)	60.88	64.41	61.58	59.67
Ash (%)	1.3	0.7	3.4	2.8

Table E-7.2. Elemental composition of the samples used in this work (in ash and moisture free basis). Composition of ponderosa pine and sugar maple is provided for comparison only.

Sample	C (%)	H (%)	N (%)	O* (%)
WWM1	48.72±0.73	5.64±0.06	0.44±0.02	45.20±0.79
WWM2	46.01±0.98	5.42±0.09	0.19±0.01	48.38±1.07
WWM3	42.26±0.77	5.08±0.08	0.42±0.01	52.24±0.86
C&D	49.79±0.07	5.74±0.01	0.84±0.02	43.63±0.04
Sugar maple	48.94±0.16	5.88±0.15	0.25±0.04	44.93±0.05
Ponderosa pine	50.44±0.41	6.36±0.03	0.19±0.01	43.01±0.44
Note: No S was detected in the samples analyzed.				

* By difference.

Recommendations | Conclusions

Much of the work in the last four months will be validated with repeat runs to ensure accurate data. We will continue to provide more analysis of the feedstock and submit a referred journal article sometime this summer on the results provided. We will also identify a pathway and the logistics to identify the renewable content for RINS credits with this material.

Physical and Intellectual Outputs

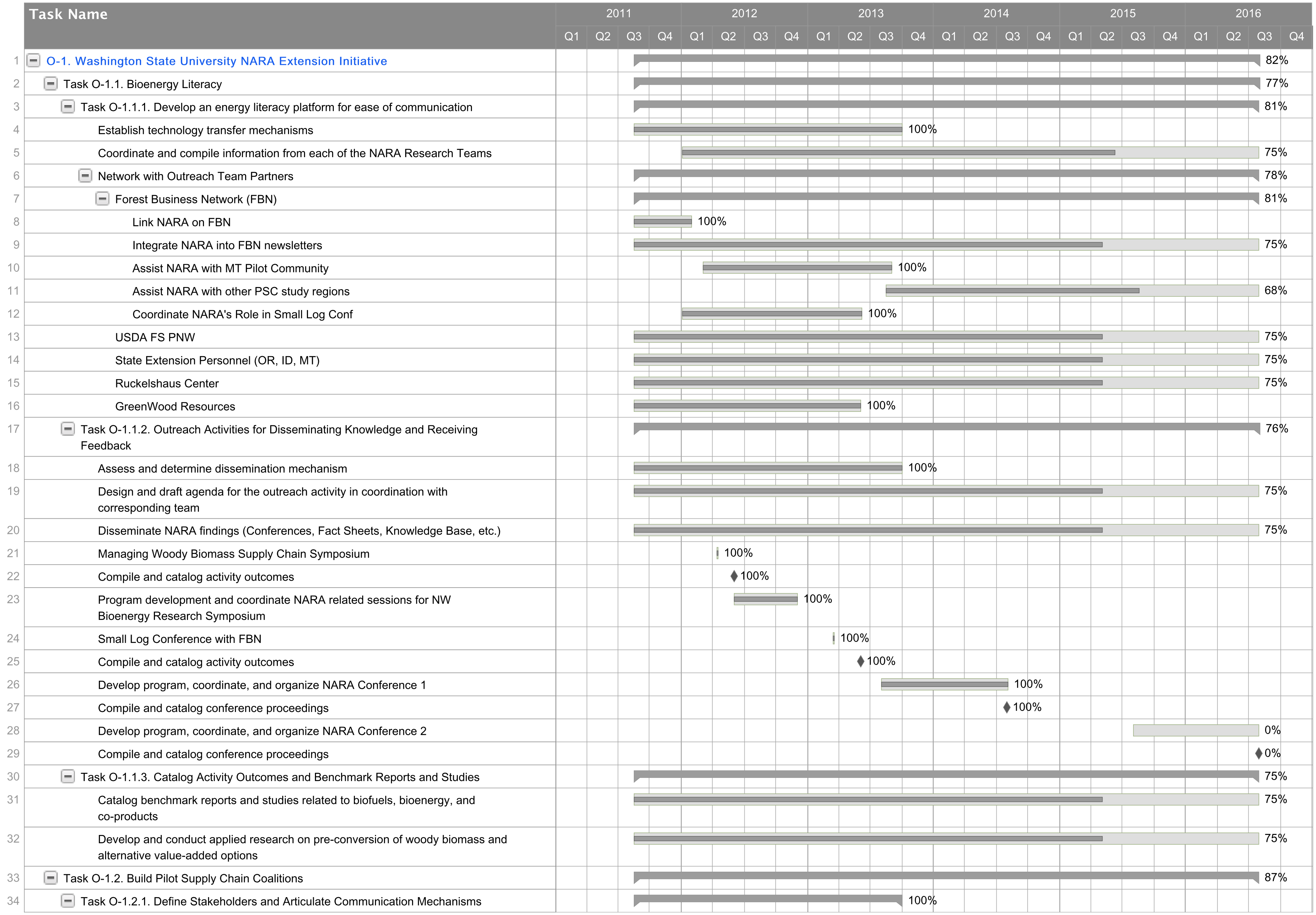
PHYSICAL

- 4 residue streams from 3 stakeholders in the NARA region are being analyzed for a potential feedstock in Biojet

RESEARCH PRESENTATIONS

Pelaez-Samaniego, M.R. and K. Englund. Characterization of waste wood materials for the production of biofuels. Poster presented at the 2014 NARA Annual Meeting, Seattle, WA, September 15-17, 2014.

Outreach_Yadama_Englund



	Task Name	
1	O-1. Washington State University NARA Extension Initiative	82%
2	Task O-1.1. Bioenergy Literacy	77%
3	Task O-1.1.1. Develop an energy literacy platform for ease of communication	81%
4	Establish technology transfer mechanisms	100%
5	Coordinate and compile information from each of the NARA Research Teams	75%
6	Network with Outreach Team Partners	78%
7	Forest Business Network (FBN)	81%
8	Link NARA on FBN	100%
9	Integrate NARA into FBN newsletters	75%
10	Assist NARA with MT Pilot Community	100%
11	Assist NARA with other PSC study regions	68%
12	Coordinate NARA's Role in Small Log Conf	100%
13	USDA FS PNW	75%
14	State Extension Personnel (OR, ID, MT)	75%
15	Ruckelshaus Center	75%
16	GreenWood Resources	100%
17	Task O-1.1.2. Outreach Activities for Disseminating Knowledge and Receiving Feedback	76%
18	Assess and determine dissemination mechanism	100%
19	Design and draft agenda for the outreach activity in coordination with corresponding team	75%
20	Disseminate NARA findings (Conferences, Fact Sheets, Knowledge Base, etc.)	75%
21	Managing Woody Biomass Supply Chain Symposium	100%
22	Compile and catalog activity outcomes	100%
23	Program development and coordinate NARA related sessions for NW Bioenergy Research Symposium	100%
24	Small Log Conference with FBN	100%
25	Compile and catalog activity outcomes	100%
26	Develop program, coordinate, and organize NARA Conference 1	100%
27	Compile and catalog conference proceedings	100%
28	Develop program, coordinate, and organize NARA Conference 2	0%
29	Compile and catalog conference proceedings	0%
30	Task O-1.1.3. Catalog Activity Outcomes and Benchmark Reports and Studies	75%
31	Catalog benchmark reports and studies related to biofuels, bioenergy, and co-products	75%
32	Develop and conduct applied research on pre-conversion of woody biomass and alternative value-added options	75%
33	Task O-1.2. Build Pilot Supply Chain Coalitions	87%
34	Task O-1.2.1. Define Stakeholders and Articulate Communication Mechanisms	100%

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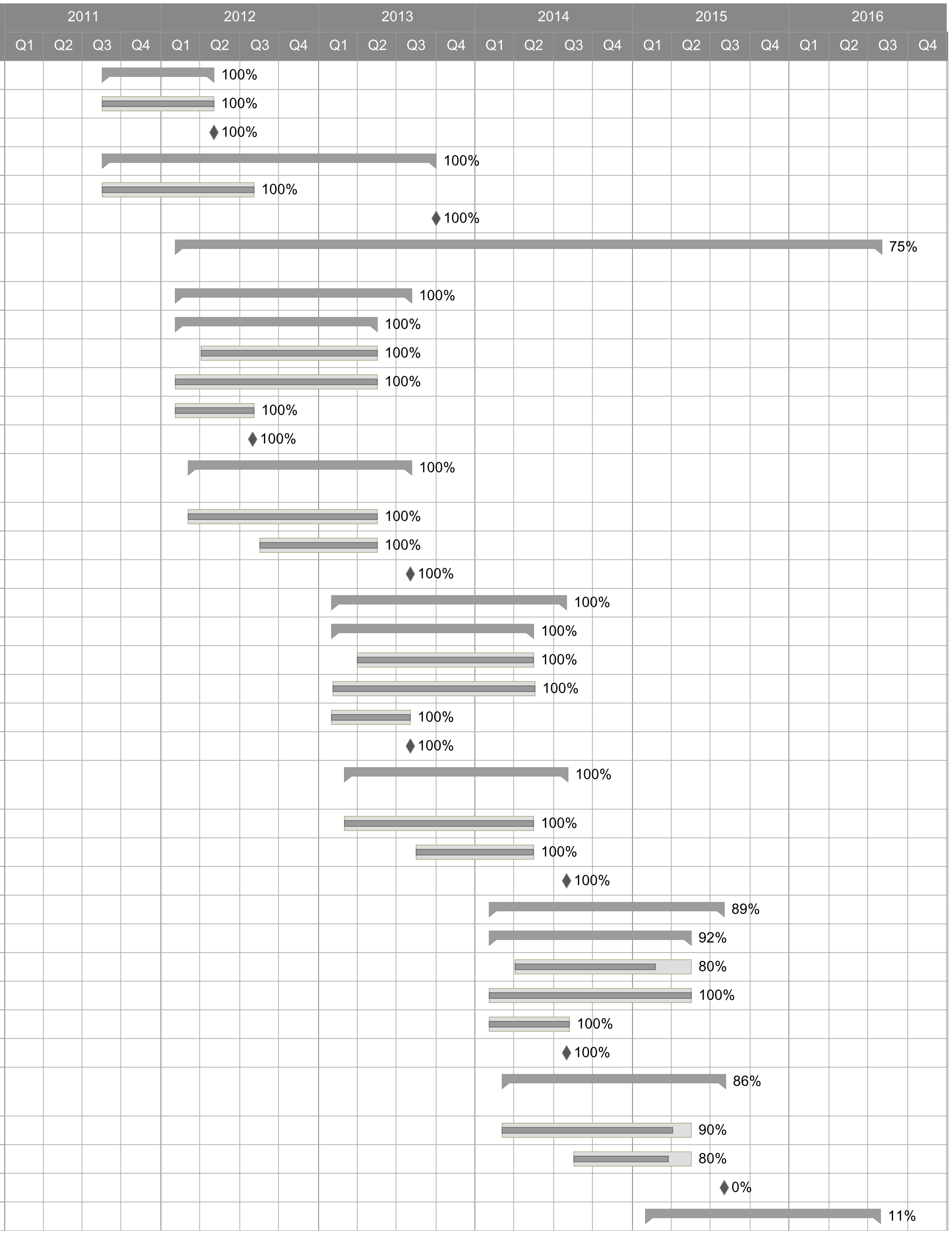
	Task Name	
35	Stakeholder (SH) Development	100%
36	Identify potential SH groups	100%
37	SH Interaction model	100%
38	SH engagement	100%
39	Plan and develop communication mechanism	100%
40	Implement communication mechanism	100%
41	Task O-1.2.2 NARA Pilot Supply Chain Study Region Establishment and Development	75%
42	1st Pilot Supply Chain Study(PSC) Region	100%
43	Coordinate with and assist Education team in the 1st PSC (WMC)	100%
44	Compile pilot community resources and assets	100%
45	Identify and engage key SHs	100%
46	Determine/develop community Leadership Team	100%
47	Leadership Team formed/identified	100%
48	Form regional coalitions and assist Education and EPP teams 1st PSC region with data collection and SH engagement	100%
49	Compile a list of regional SHs	100%
50	Disseminate PSC research findings	100%
51	Document PSC study findings Region 1	100%
52	2nd Pilot Supply Chain Study(PSC) Region	100%
53	Coordinate with and assist Education team in the 2nd PSC	100%
54	Compile pilot community resources and assets	100%
55	Identify and engage key SHs	100%
56	Determine/develop community Leadership Team	100%
57	Leadership Team formed/identified	100%
58	Form regional coalitions and assist Education and EPP teams 2nd PSC region with data collection and SH engagement	100%
59	Compile a list of regional SHs	100%
60	Disseminate PSC research findings	100%
61	Document PSC study findings Region 2	100%
62	3rd Pilot Supply Chain Study(PSC) Region	89%
63	Coordinate with and assist Education team in the 3rd PSC	92%
64	Compile pilot community resources and assets	80%
65	Identify and engage key SHs	100%
66	Determine/develop community Leadership Team	100%
67	Leadership Team formed/identified	100%
68	Form regional coalitions and assist Education and EPP teams 3rd PSC region with data collection and SH engagement	86%
69	Compile a list of regional SHs	90%
70	Disseminate PSC research findings	80%
71	Document PSC study findings Region 3	0%
72	4th Pilot Supply Chain Study(PSC) Region	11%



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	Task Name	
73	Coordinate with and assist Education team in the 4th PSC	24%
74	Compile pilot community resources and assets	0%
75	Identify and engage key SHs	50%
76	Determine/develop community Leadership Team	10%
77	Leadership Team formed/identified	0%
78	Form regional coalitions and assist Education and EPP teams 4th PSC region with data collection and SH engagement	0%
79	Compile a list of regional SHs	0%
80	Disseminate PSC research findings	0%
81	Document PSC study findings Region 4	0%
82	Task O-1.2.3. Assist EPP with PSC Selection Process and Support Index Study	95%
83	Coordinate with EPP in PSC Selection	95%
84	Develop criteria for selection	100%
85	Develop PSC selection process	100%
86	Assist compiling community resources and assets for GIS development	90%
87	Develop long-list of potential PSC regions in the region	100%
88	Develop and survey NARA Outreach members to nominate PSC regions	100%
89	Conduct and analyze the survey results	100%
90	Compile long list of PSC regions	100%
91	Assist EPP with surveys in potential PSC regions	100%
92	Assist EPP to synthesize and analyze assets of PSC regions	100%
93	Identify potential PSC regions	100%

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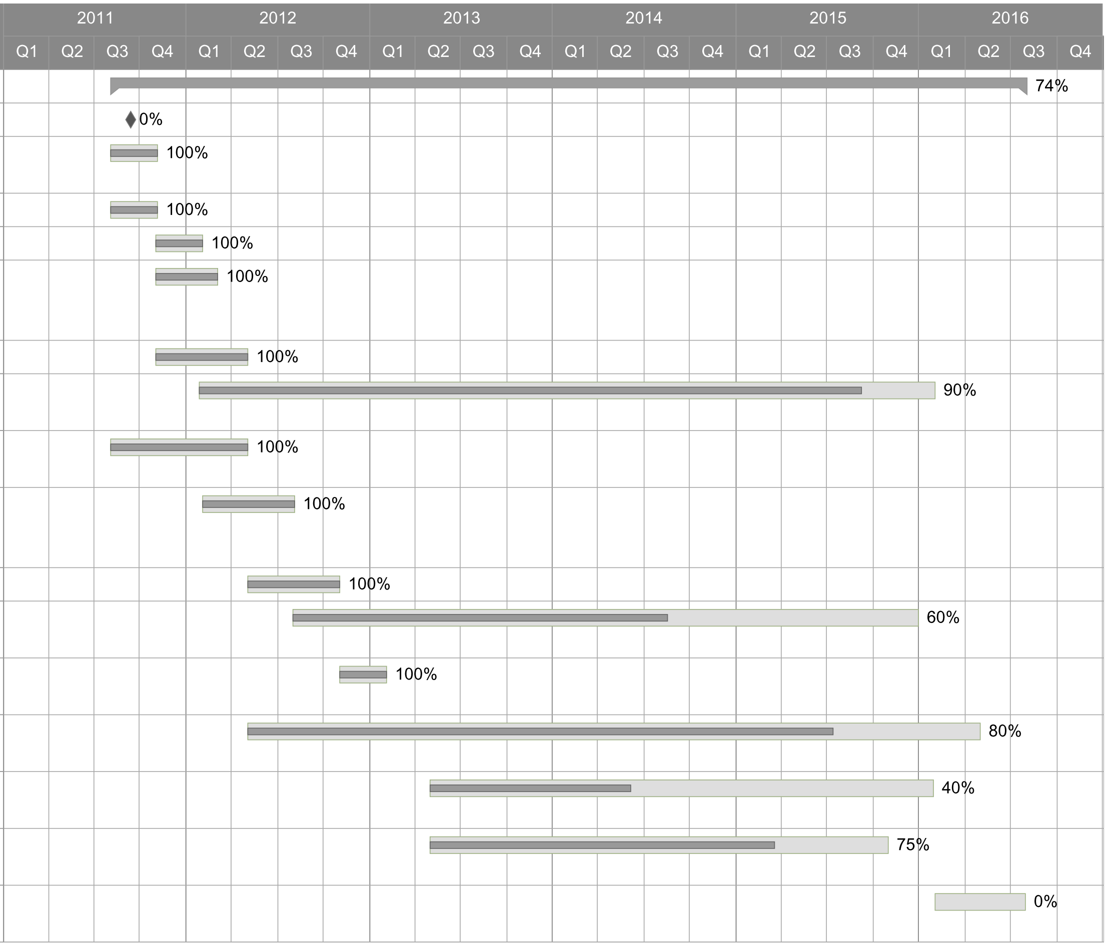
Outreach_Kolb

	Task Name
1	O-2. Montana State University NARA Extension Initiative
2	Attend kick-off meeting
3	Introduce NARA to Montana Biomass Working Group and use to develop Montana NARA advisory group
4	Introduce NARA to Montana Forest Council
5	Introduce NARA to Montana Logging Association
6	Develop article about NARA and publish on Montana Tree Farm and forest landowner newsletter, as well as send out to all Montana State county Extension Agents
7	Develop NARA web site on MSU Extension web page
8	Develop database and periodically update of potential feedstock suppliers
9	Work with entire NARA program and MT Biomass working group to develop test bed site criteria and rubric
10	Work with Montana Biomass working group to solicit and collect data and applications from landowners, industry and extension stakeholders with regard to potential test bed sites for Montana
11	Review data and rank sites for potential NARA Communities
12	Organize and conduct meetings and field trip with Montana NARA working group and potential NARA Communities
13	Summarize results from MT NARA working group and present finding to NARA regional alliance
14	Communicate updates on biomass specifications to stakeholders via web page, newsletter updates and working group updates
15	Organize meetings with selected NARA community and stakeholders to update on feedstock developments
16	Organize and conduct field trips to potential feedstock sites and harvesting practices within selected NARA community(s)
17	Write final NARA program summary and impacts for Montana Stakeholders and publish in landowner newsletter and web page



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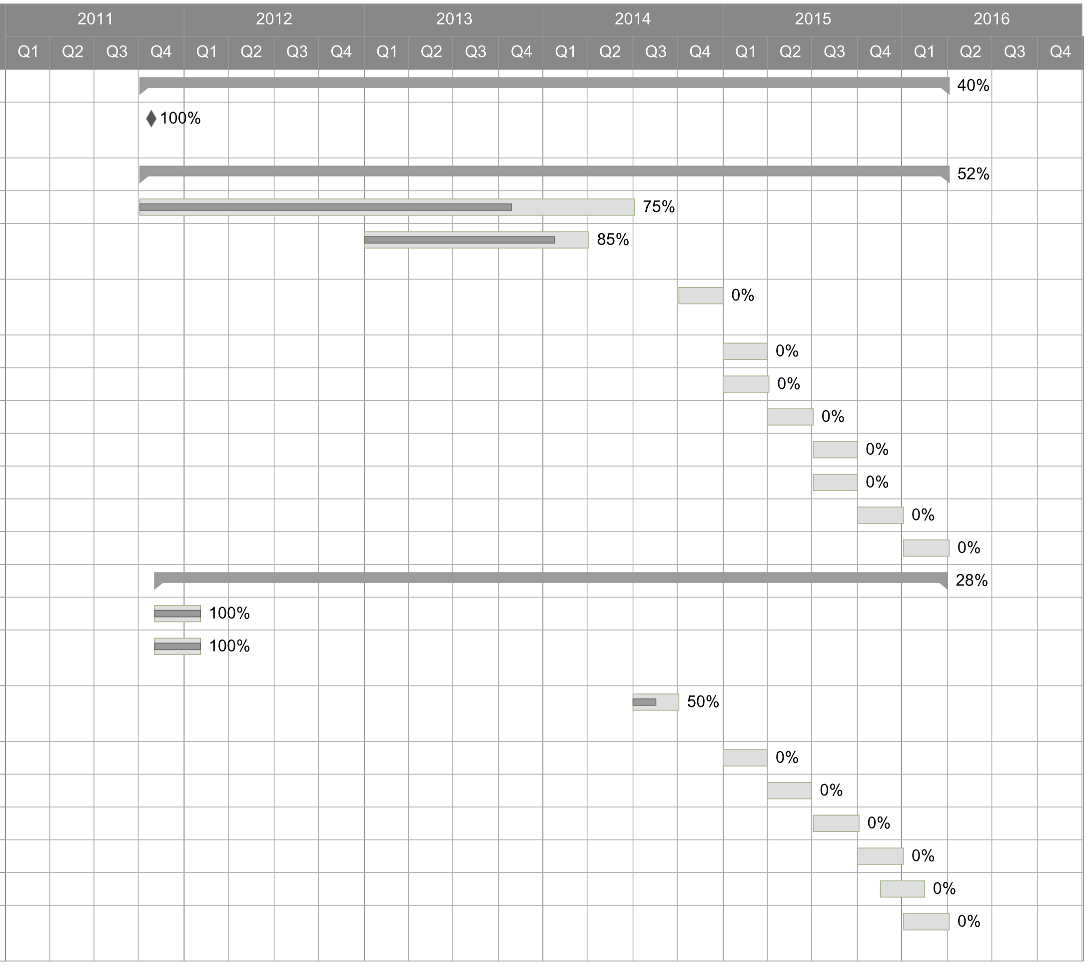
Outreach_Leavengood

NARA

	Task Name	
1	O-4. Oregon State University NARA Extension Initiative	40%
2	Introduce project to OR Forest Biomass Wrkg Grp – solicit group's involvement as advisory committee (AC)	100%
3	Task O-4.1. NARA Regional Alliances	52%
4	Review existing data & reports on potential test sites	75%
5	Convene 1-day meeting of AC to review NARA community criteria & identify 2 test sites	85%
6	Convene focus grp meeting at test site 1 – discuss feedstock specs & logistics, tech. adoptions w/existing infra., etc.	0%
7	Convene focus grp meeting at test site 2 – (same as above)	0%
8	Meet with suppliers for site 1	0%
9	Meet with industrial stakeholders for site 1	0%
10	Host community forum for site 1	0%
11	Meet with suppliers for site 2	0%
12	Meet with industrial stakeholders for site 2	0%
13	Host community forum for site 2	0%
14	Task O-4.2. NARA Extension Engine	28%
15	Develop NARA page on OSU Forestry Extension website	100%
16	Develop newsletter article on NARA project; send to OSU Extension Foresters for newsletters	100%
17	Develop briefing paper on NARA community criteria and post to project website	50%
18	Develop detailed report on each test site; post to project website	0%
19	Meet with policymakers re: project results	0%
20	Organize field trips to key supply sites & ind. facilities for site 1	0%
21	Organize field trips to key supply sites & ind. facilities for site 2	0%
22	Organize and deliver statewide conference (OR) on NARA research findings	0%
23	Develop NARA update newsletter article; send to OSU Extension Foresters for newsletters	0%



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Outreach_Brooks

	Task Name	
1	O-5. University of Idaho NARA Extension Initiative	63%
2	Network with NARA research and industry partners	85%
3	Initiate relationships with stakeholders	90%
4	Establish working relationship w/ regional cooperators	80%
5	Help identify test-bed sites	100%
6	Help develop survey w/ EPP group	60%
7	Help survey potential test-bed sites	60%
8	Help establish working relationship w/ test-bed sites	60%
9	Communicate NARA goals to test-bed sites	60%
10	Establish focus groups w/in test-bed sites	20%
11	Help plan, organize, and coordinate workshops	60%
12	Help plan, organize, and coordinate stakeholder mtgs	60%
13	Help distribute newsletters/articles/briefs to communities	60%
14	Evaluate impact of workshops	60%
15	Assist with synthesis of survey results	40%
16	Help publish impact of program	5%
17	Help organize/conduct field trips for stakeholders	60%

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Outreach_Lowell

	Task Name	
1	O-6. Forest Service - Pacific NW Research Station	66%
2	Task O-6.1. NARA Regional Alliances	75%
3	Opening meeting	100%
4	Network with other NARA teams	70%
5	Initiate relationships with regional stakeholders and partnerships	70%
6	Assist in development of decision criteria for test bed selection	95%
7	Identify candidate test bed sites near timber dependent communities	90%
8	Participate in screening of test bed communities	75%
9	Meet with clients and stakeholders at test bed communities	75%
10	Convene Focus Group at each test bed site	75%
11	Facilitate Focus Group meetings	70%
12	Identify and/or organize potential field visits and demonstrations	55%
13	Task O-6.2. NARA Extension	56%
14	Assist in organization of workshops	60%
15	Produce newsletter/one-page briefing papers	60%
16	Serve on Planning Committee for NARA First Conference	100%
17	Publish Proceedings as PNW-GTR	0%
18	Serve on Planning Committee for NARA Second Conference	0%
19	Publish Proceedings as PNW-GTR	0%

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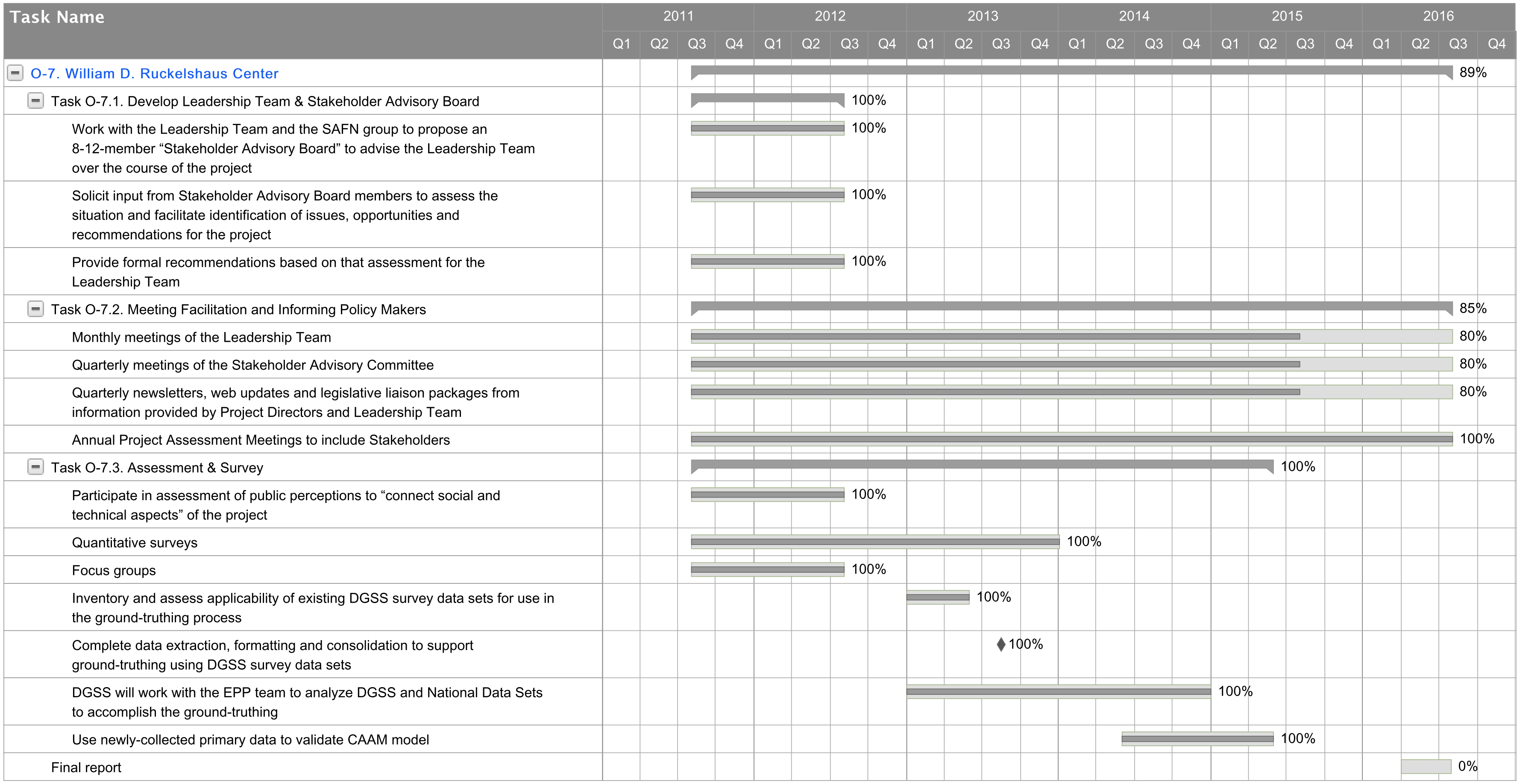
Outreach_RuckelshausCtr



	Task Name	
1	O-7. William D. Ruckelshaus Center	89%
2	Task O-7.1. Develop Leadership Team & Stakeholder Advisory Board	100%
3	Work with the Leadership Team and the SAFN group to propose an 8-12-member “Stakeholder Advisory Board” to advise the Leadership Team over the course of the project	100%
4	Solicit input from Stakeholder Advisory Board members to assess the situation and facilitate identification of issues, opportunities and recommendations for the project	100%
5	Provide formal recommendations based on that assessment for the Leadership Team	100%
6	Task O-7.2. Meeting Facilitation and Informing Policy Makers	85%
7	Monthly meetings of the Leadership Team	80%
8	Quarterly meetings of the Stakeholder Advisory Committee	80%
9	Quarterly newsletters, web updates and legislative liaison packages from information provided by Project Directors and Leadership Team	80%
10	Annual Project Assessment Meetings to include Stakeholders	100%
11	Task O-7.3. Assessment & Survey	100%
12	Participate in assessment of public perceptions to “connect social and technical aspects” of the project	100%
13	Quantitative surveys	100%
14	Focus groups	100%
15	Inventory and assess applicability of existing DGSS survey data sets for use in the ground-truthing process	100%
16	Complete data extraction, formatting and consolidation to support ground-truthing using DGSS survey data sets	◆ 100%
17	DGSS will work with the EPP team to analyze DGSS and National Data Sets to accomplish the ground-truthing	100%
18	Use newly-collected primary data to validate CAAM model	100%
19	Final report	0%

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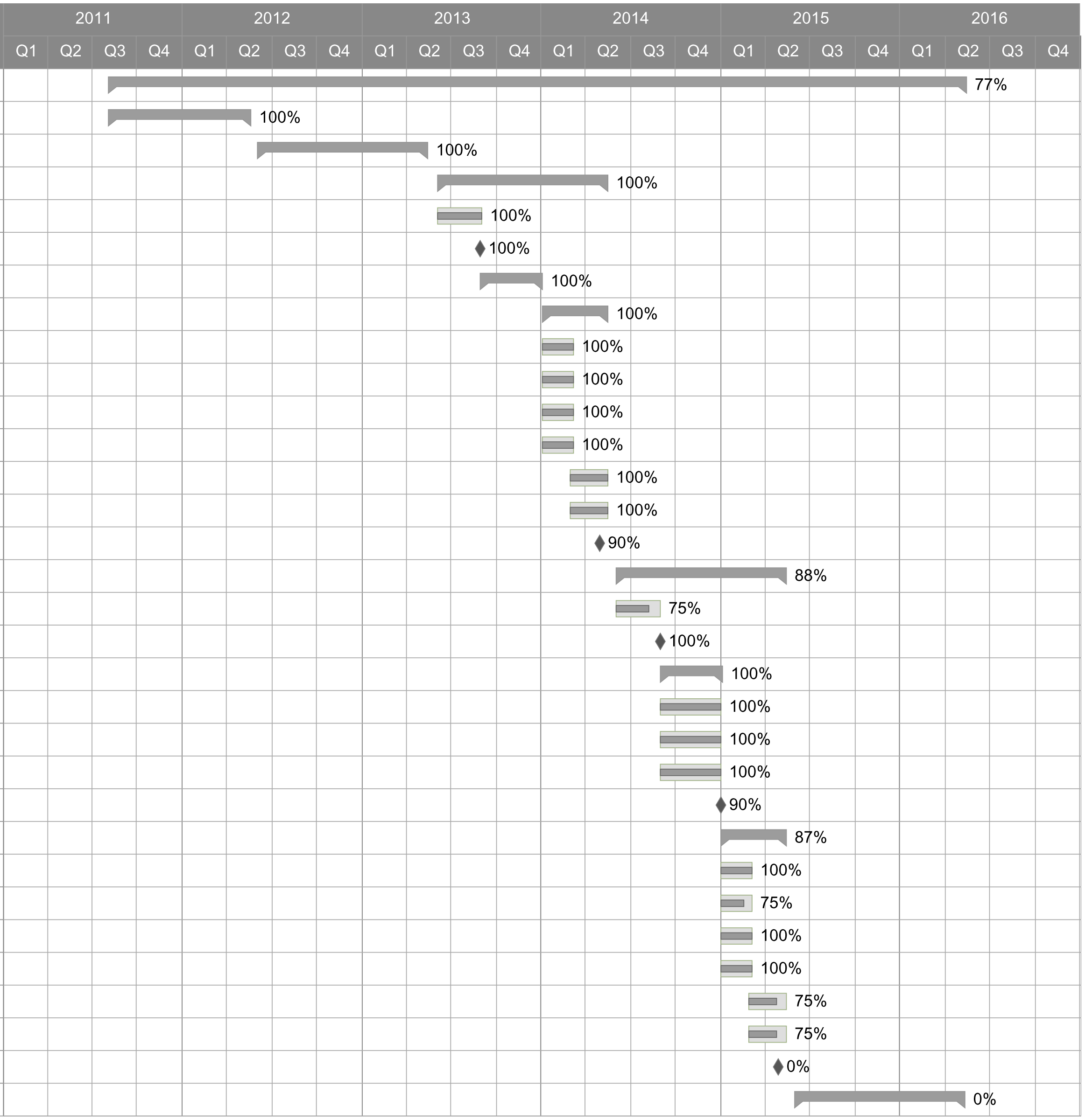
Education_Wolcott_Laninga

	Task Name
1	E-3. Bioregional Integrated Design Experience (IDX)
2	Task E-3.1. NARA Community Design #1
21	Task E-3.2. NARA Pilot Supply Chain #2
40	Task E-3.3. NARA Pilot Supply Chain #3
41	Recruit and Select Community Partners
42	Community Profile for Design Team
43	Task E-3.3.1. Community Resource Atlas Development
48	Task E-3.3.2 Community Plans and Design
49	Collect Site Attributes
50	Optimized Supply Chain Analysis
51	Supply chain site location selection
52	Resource flows and site analysis for supply chain site
53	Site case studies and design interventions
54	Design Documentation
55	Summary Document
56	Task E-3.4. NARA Pilot Supply Chain #4
57	Recruit and Select Community Partners
58	Community Profile for Design Team
59	Task E-3.4.1. Community Resource Atlas Development
60	Assess Community Resources and Assets
61	Develop analysis tool skills
62	Analyzing resource and asset data
63	Compile Analysis Document
64	Task E-3.4.2. Community Plans and Design
65	Collect Site Attributes
66	Optimized Supply Chain Analysis
67	Supply chain site location selection
68	Resource flows and site analysis for supply chain site
69	Site case studies and design interventions
70	Design Documentation
71	Summary Document
72	Task E-3.5. NARA Pilot Supply Chain #5



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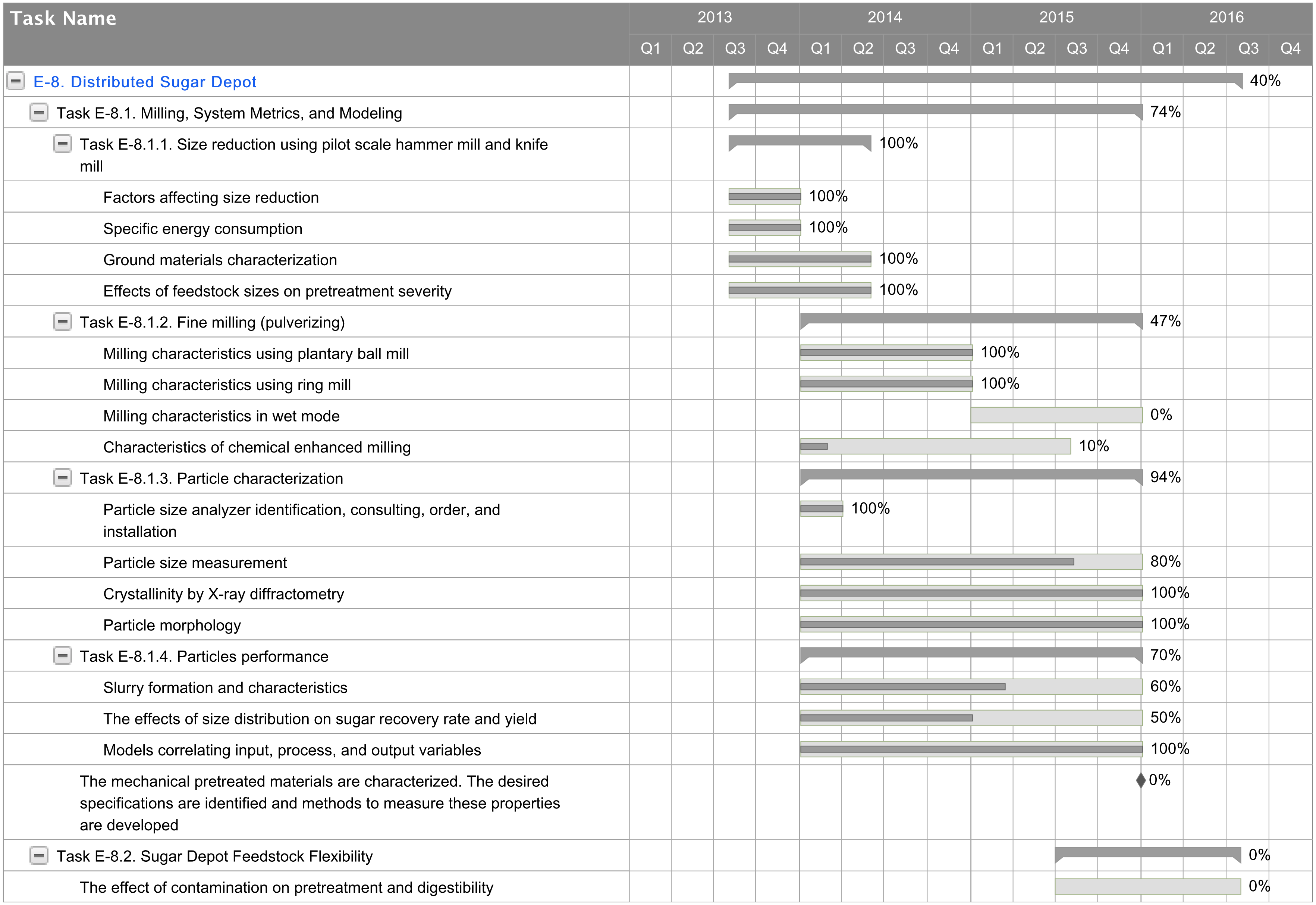
Education_Wang_Wolcott_XZhang

NARA



	Task Name	
1	E-8. Distributed Sugar Depot	40%
2	Task E-8.1. Milling, System Metrics, and Modeling	74%
3	Task E-8.1.1. Size reduction using pilot scale hammer mill and knife mill	100%
4	Factors affecting size reduction	100%
5	Specific energy consumption	100%
6	Ground materials characterization	100%
7	Effects of feedstock sizes on pretreatment severity	100%
8	Task E-8.1.2. Fine milling (pulverizing)	47%
9	Milling characteristics using plantary ball mill	100%
10	Milling characteristics using ring mill	100%
11	Milling characteristics in wet mode	0%
12	Characteristics of chemical enhanced milling	10%
13	Task E-8.1.3. Particle characterization	94%
14	Particle size analyzer identification, consulting, order, and installation	100%
15	Particle size measurement	80%
16	Crystallinity by X-ray diffractometry	100%
17	Particle morphology	100%
18	Task E-8.1.4. Particles performance	70%
19	Slurry formation and characteristics	60%
20	The effects of size distribution on sugar recovery rate and yield	50%
21	Models correlating input, process, and output variables	100%
22	The mechanical pretreated materials are characterized. The desired specifications are identified and methods to measure these properties are developed	0%
23	Task E-8.2. Sugar Depot Feedstock Flexibility	0%
24	The effect of contamination on pretreatment and digestibility	0%

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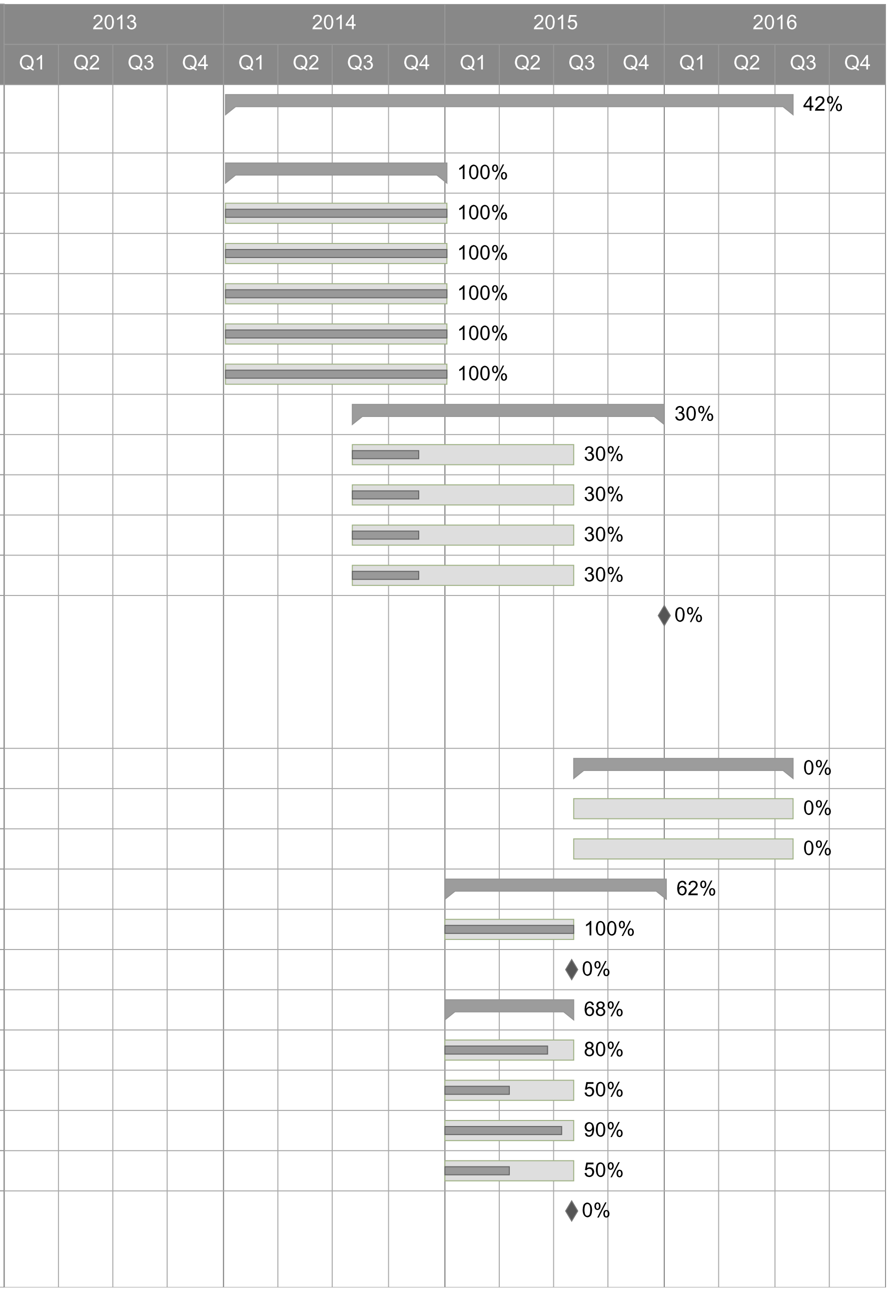
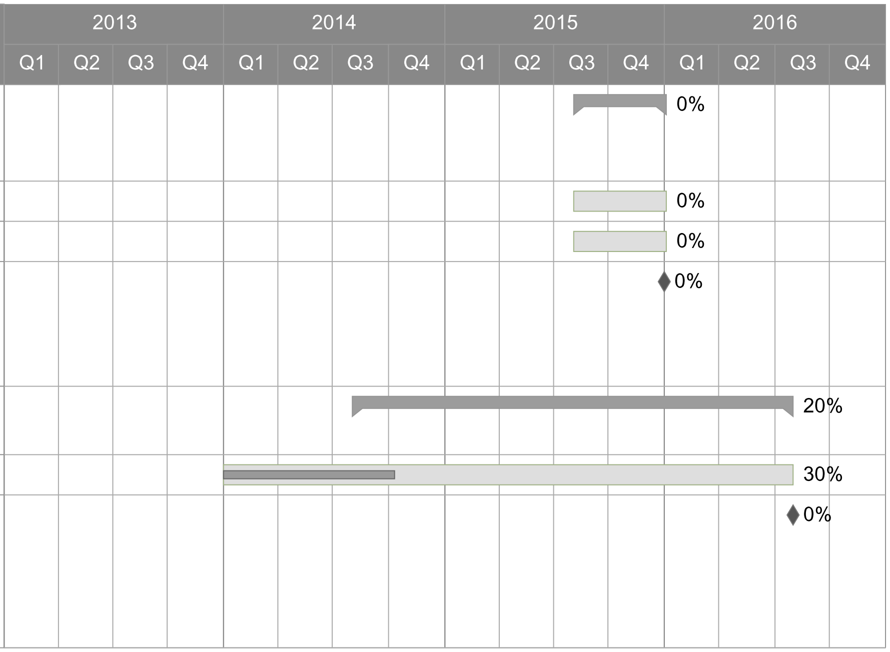
	Task Name	
25	Task E-8.3. Hydrolysis Design, Process, Metrics Development, and Sugar Specification	42%
26	Task E-8.3.1. Hydrolysis kinetics using a torque rheometer	100%
27	Effect of solid contents on rheology	100%
28	Rheology change with enzymatic hydrolysis time	100%
29	Particle size changes with enzymatic hydrolysis time	100%
30	Energy consumption	100%
31	Sugar hydrolysis rates and yield	100%
32	Task E-8.3.2. Hydrolysis with an extruder	30%
33	Pre-extrusion treatments enhancing extrusion process	30%
34	Extrusion variables optimization	30%
35	Post-extrusion treatments	30%
36	Extrudates sacharification	30%
37	Pretreated materials are enzymatic hydrolyzed via an extrusion system. Process performance such as viscosity, flowability, and energy consumption relating to handling of the mechanical pretreated materials is assessed. Conditions of enzymatic hydrolysis are optimized	0%
38	Task E-8.3.3. Sugar Specification	0%
39	Sugar streams separation and condense	0%
40	Sugar formats optimization and characterization	0%
41	Task E-8.4. Sugar Depot Process Economics	62%
42	Task E-8.4.1. Milling technology in wood and pulping industry review	100%
43	Potential industrial scale milling systems are identified	0%
44	Task E-8.4.2. Milling technologies in the mining engineering review	68%
45	Research, development, and design methodology	80%
46	Modeling, simulation, and design	50%
47	Milling equipment and case study	90%
48	Identify methods and modeling for wood milling research	50%
49	Pilot milling trials are carried out and optimal milling schemes and parameters are found. Required energy consumptions at optimum milling conditions are measured	0%

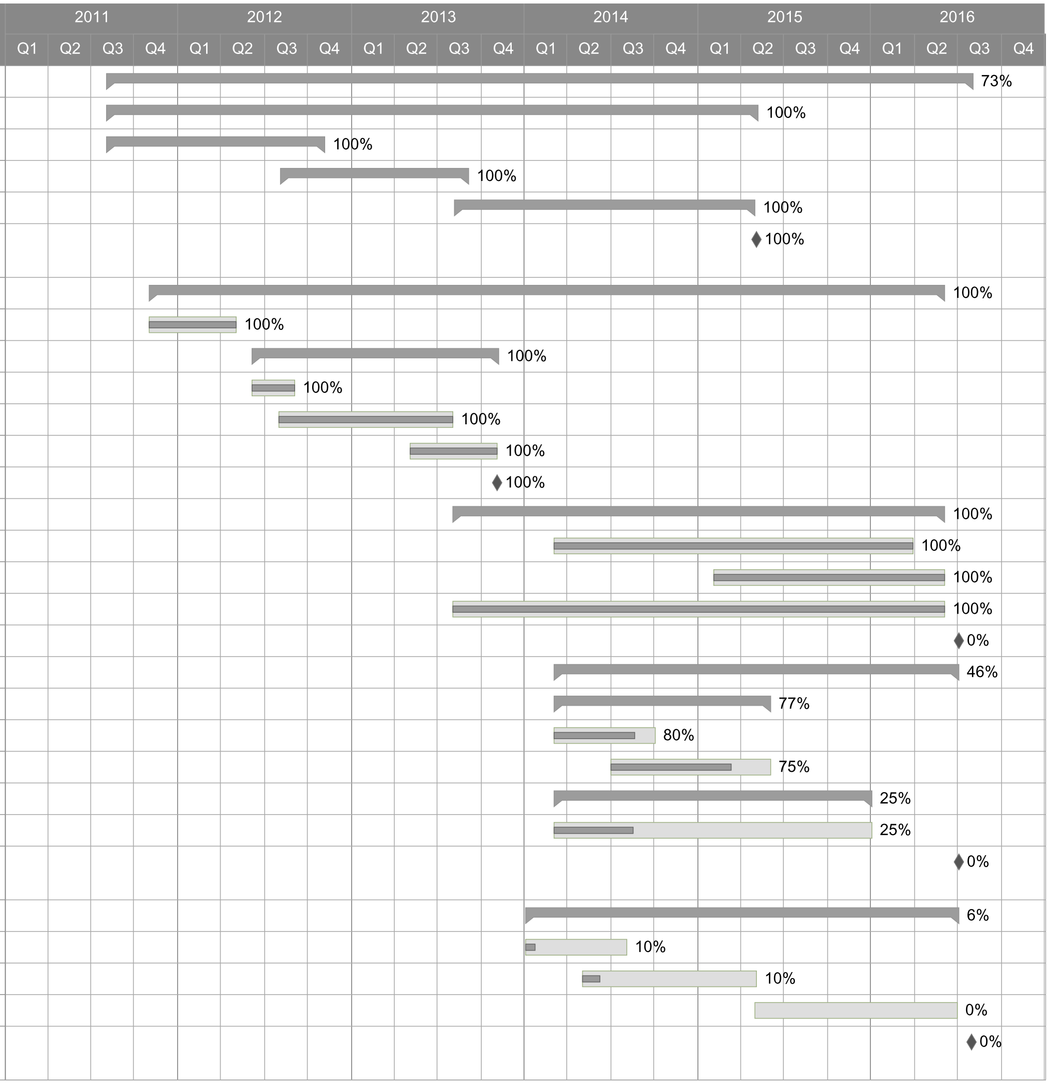


	Task Name
50	Task E-8.4.3. Development of algorithms correlating comminution features of starting materials, products, energy consumption and power requirements
51	Modeling with lab data
52	Scale modeling to large scales
53	The performance of the pretreated materials for cellulosic sugars is experimentally investigated at the bench scale. The correlation between physical characteristics and performance of the pretreated materials is established
54	Task E-8.5. Techno-economic analysis (TEA) of distributed sugar depot based on mechanical deconstruction (pretreatment) of forest residues
59	Task E-8.6. Analysis & Report (periodic & final reports)
60	Process energy requirements, costs, savings potentials, chemical composition, the presence of inhibitors, and the saccharification rate and degree are investigated to evaluate the performance of comminution. An algorithm linking data from lab tests and pilot trials and design of an industrial-scale sugar depot facility is developed



Education_Englund

	Task Name	
1	E-7. Feedstock Supply Chain Analysis - MSW	73%
2	Task E-7.1. Develop MSW/C&D woody biomass inventory in NARA region	100%
3	Task E-7.1.1. Identify and collect exisiting MSW and C&D data - by states	100%
8	Task E-7.1.2. Establish model for woody biomass inventory in NARA regions	100%
13	Task E-7.1.3. Validate model with surveys and on-site inventories	100%
17	Develop inventory of wood waste in MSW throughout NARA region based on existing data and model results	100%
18	Task E-7.2. Inventory of NARA Communities (NC)	100%
19	Work with Extension team to develop NC criteria	100%
20	Task E-7.2.1. Develop extensive inventory for 1st NC	100%
21	Identify geographical range	100%
22	Identify all sources of MSW and C&D	100%
23	Collect data and normalize for summation	100%
24	Finalized data entered into GIS database	100%
25	Task E-7.2.2. Inventory analysis of remaining NCs	100%
26	Identify all sources of MSW and C&D	100%
27	Collect data and normalize for summation	100%
28	Finalized data entered into GIS database	100%
29	Final Inventory assessment of NCs	0%
30	Task E-7.3. Develop strategies to utilize woody biomass from C&D for biofuel feedstocks	46%
31	Task E-7.3.1 Categorize incoming wood materials to select NARA-based MRFs	77%
32	Identify and categorize major contaminants for fuel production	80%
33	Determine contaminant levels in wood wastes	75%
34	Task E-7.3.2. Develop specifications for "allowable materials" for biofuel usage	25%
35	Identify procedure for providing MRF RINS credits	25%
36	Provide pathway for MRF EPA recongnized renewable woody biomass feedstock for biofuels	0%
37	Task E-7.4. Develop wood composition model	6%
38	Collect initial data/info on wood materials in MSW	10%
39	Address historical data on wood materials in building construction	10%
40	Model wood material types in the C&D stream	0%
41	Final report on quality control and specifications for using MSW and C&D wood as biofuel	0%



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