Northwest Advanced Renewables Alliance

2nd Cumulative Report

April 2013 - March 2014

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A New Vista for Green Fuels, Chemicals, and Environmentally Preferred Products

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NARA

Northwest Advanced Renewables Alliance

NARA is led by Washington State University and supported by the Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30416 from the USDA National Institute of Food and Agriculture.

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Notice

The authors, their respective employers, corporate partners, affiliated universities, and government institutions prepared this annual report. The information within was obtained in the course of performing academic research supported by Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30416 from the United States Department of Agriculture National Institute of Food and Agriculture.

NARA Organizational Structure

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ORGANIZATIONAL STRUCTURE

NARA Executive Committee

The Executive Committee is responsible for leading the NARA project and communicating directly with the USDA-NIFA leadership and the Advisory Board. Specific areas of leadership include: working closely with the Project Area Team Leaders to approve the annual work plans and budgets; reviewing and administering subcontracts; approving scope of work for each affiliated individual institution; and supervising staff members.

NARA Executive Committee Members

Ralph P. Cavalieri
Executive Director and Project Director

509-335-5581
cavalieri@wsu.edu

Dr. Cavalieri is currently Associate Vice President for Alternative Energy and Professor of Biological Systems Engineering at Washington State University. He is a Registered Professional Engineer, State of Washington. He served two terms on the Department of Energy's Biomass Research and Development Technical Advisory Committee, and currently serves as the Director of the FAA Center of Excellence for Alternative Jet Fuels and Environment (ASCENT) and as the Associate Director of the Western Sun Grant Center. His research emphasis is on chemical and biochemical process kinetics and sensors.

Michael Wolcott
Project Co-Director

509-335-6392
wolcott@wsu.edu

Dr. Wolcott is a Regents Professor in Washington State University's Department of Civil and Environmental Engineering, a member of the interdisciplinary Materials Science and Engineering faculty, and director of WSU's Institute for Sustainable Design. He is an international leader in the field of natural fiber materials and biopolymers while he has led the development of advanced materials to improve durability, reduce manufacturing costs and pollution, and improve structural performance. He has previously managed nearly $20 million in funding and large research teams for numerous federal agencies, including the Office of Naval Research, the Department of Energy, the USDA, the US Forest Service, and the Federal Highway Administration.

Linda Beltz
Project Development Analyst

253-924-6638
linda.beltz@nararenewables.org

Dr. Beltz is the President and Co-Founder of Steadfast Management Inc. Founded in April 2012, Steadfast Management Inc. provides management and consulting services and is providing Phase and Gate leadership to NARA.

Outside of NARA, Linda is currently VP, Commercial Aerospace Licensing for the Boeing Intellectual Property Licensing Company. Prior to that, Linda was Director, Technology Partnerships at Weyerhaeuser for 12 years, leaving in September 2013. In this role, Linda worked with John Tao to implement Open Innovation at Weyerhaeuser. Linda was responsible for alliances and partner activities with for-profit, non-profit, university and national laboratories, and focused on emerging technology areas such as bio-fuels, bio-products and bio-power. She was also responsible for government contracts.

NARA Advisory Board

The NARA Advisory Board is composed of leaders within a variety of fields such as forestry, chemistry, and engineering. The board's role is to provide an independent overview of NARA's progress towards completing the goals articulated in the USDA NIFA competitive grant no. 2011-68005-30416. The Advisory Board meets annually with NARA and USDA-NIFA leadership, reviews NARA quarterly and annual progress reports, and provides written recommendations to NARA and to the USDA-NIFA. The board is currently composed of six members.

NARA Advisory Board Members

Brad Ack
Washington State Department of Natural Resources

Brad Ack is the Policy Director for the Washington State Department of Natural Resources. Areas of responsibility and focus include design and implementation of a climate adaptation strategy for the agency; renewable energy development including biofuels from woody biomass; retention of working forest lands; federal forest lands restoration and fire risk reduction; and development of new sustainable revenue streams derived from ecosystem services such as clean drinking water, biofuels and carbon sequestration. Prior to his position as Policy Director, Brad worked for the Marine Stewardship Council as the Director of External Affairs and Strategic Initiatives; Executive Director of the Puget Sound Action Team for Governors Gary Locke and Christine Gregoire; Conservation Director for the Grand Canyon Trust; and Senior Program Officer for World Wildlife Fund.

Terrance Cooper
Argo Group International

Dr. Terence Cooper is CEO of Argo Group International, which provides specialized consulting services in chemical and polymer science, materials technology and market and applications development in North America, Europe and Japan. Present areas of major involvement include new product, process and market development in acrylic, methacrylic, olefinic, vinylic and styrenic copolymer systems, strategic research, development and technology portfolio analysis and environmental consulting.

Katrina Cornish
Ohio State University

Dr. Katrina Cornish is the leading U.S. scientific expert, and is internationally recognized as a principal authority, on alternative natural rubber production, properties and products, and on natural rubber biosynthesis in general. As Ohio Research Scholar and Endowed Chair in Bioemergent Materials, Katrina leads a program at The Ohio State University focusing on domestic rubber production, bio-based fillers and fibers, and exploitation of opportunity feedstocks from agriculture and food processing wastes for value-added products and biofuels.

Thomas P Klin
CH2MHill

Thomas Klin serves as Principal Technologist and Director of Aviation Environmental Services for CH2M Hill. In this capacity he oversees the execution of all environmental impact statements (EIS), environmental audits, permitting, environmental compliance and related environmental projects that enable airport development and operation. Thomas specializes in the National Environmental Policy Act (NEPA) process, environmental impact assessment and creative mitigation planning for unavoidable impacts. He also specializes in education of and consensus building between agencies involved in the airport and aviation environmental regulatory process.

Michael Lakeman
Boeing

Dr. Michael Lakeman is currently the Regional Director of Biofuel Strategy for Boeing Commercial Airplanes. His focus is to build the capabilities needed to expand the scale of next-generation biofuels. He joined Boeing after holding the position of Senior Research Scientist at Imperium Renewables in Seattle. Michael serves on the Algae Foundation Board for 2013/2014 and as co-chair of the CAAFI Research and Development Team.

Jack N. Saddler
University of British Columbia

Dr. John (Jack) Saddler is the endowed Professor of Forest Products Biotechnology /Bioenergy and also the former Dean, Faculty of Forestry, at the University of British Columbia. He is a Fellow of the Royal Society of Canada, Canada's highest recognition for scientists, and he has received many other awards such as the International Union of Forest Research Organizations (IUFRO's) Scientific Achievement Award, and the Charles D. Scott award for contributions to the field of "Biotechnology for fuels and Chemicals". Recently, Dr. Saddler received the prestigious 2009 Leadership award, presented from Life Sciences British Columbia for demonstrated leadership in the industry and given to individuals who have assisted in the creation and advancement of the broader life sciences communities over time.

Member and Affiliate Organizations

NARA members and affiliates are the institutions (universities, businesses, governmental entities, and nonprofits) that are signing parties to the NARA Non-disclosure Agreement and are expected to contribute resources, personnel, time, information and other assets to NARA in support the NARA Mission. Member institutions are also signatories to the NARA Intellectual Property Agreement.

Catchlight Energy

Catchlight Energy's vision is to become a major integrated producer of biofuels derived from non-food sources and to deliver renewable transportation products produced from biomass in a manner that is scalable and sustainable—both environmentally and economically. For NARA, they participate with the Pretreatment Team.

Compañía Logística de Hidrocarburos CLH S.A.

CLH is Spain's leader for oil product transportation and storage. CLH Aviation has operated for over 85 years and is dedicated to hydrocarbon storage and logistics in Spain. CLH Aviation will provide a cross-national comparison of fuel logistics, policy, and corporate social responsibility (CSR) issues.

Cosmo Specialty Fibers, Inc.

Cosmo Specialty Fibers, Inc. (CSF) is an affiliate of The Gores Group and was created to restore, restart and operate Weyerhaeuser's former specialty cellulose mill in Cosmopolis, Washington. This facility currently produces a high-quality dissolving wood pulp. As a NARA member organization, CSF will explore available markets for the simple sugars that could be derived from their residual streams.

Facing the Future

Facing the Future is a national education nonprofit that develops and delivers K-12 sustainability curriculum resources that prepare K-12 students in all 50 U.S. states to become engaged, informed global citizens. As a member of NARA, Facing the Future will support the K-12 education efforts for the NARA project.

Gevo, Inc.

Gevo is a leading renewable chemicals and advanced biofuels company. Through the NARA project, Gevo will optimize their conversion technology to convert woody biomass hydrolysate into feedstocks for isobutanol, biojet fuel and other renewable chemicals.

Montana State University

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.

Oregon State University

Oregon State University is the state's land-grant and leading public research university. A number of NARA researchers work here and contribute primarily to the project's feedstock development and sustainability work.

Pennsylvania State University

Penn State is Pennsylvania's land-grant university. Research dedicated to the NARA project investigates the social sustainability of a wood-based biofuel industry.

Salish Kootenai College

Salish Kootenai College, a tribal university, provides research opportunities tied to biofuels and bio-products from woody biomass.

Steadfast Management

Steadfast Management provides management and consulting services and contributes Phase and Gate and pretreatment/conversion leadership to NARA.

Thomas Spink Inc.

Thomas Spink Inc. is a consulting firm specializing in biomass chemical engineering and assists NARA in co-product development and economic analyses.

University of Idaho

Faculty in the College of Natural Resources and College of Art and Architecture participate in NARA's education and outreach tasks.

University of Minnesota

Efforts from the University of Minnesota's Department of Bioproducts and Biosystems Engineering contribute to the NARA project by developing lignin-based co-products and contributing to the sustainability analyses.

University of Montana

University of Montana contributes to the NARA project by identifying and collecting primary data necessary to assess the woody biomass inventory with particular emphasis on mill and logging residue.

University of Utah

Research at the University of Utah will measure the impacts of forest residuals removal on the forest ecology. Specifically, efforts from this NARA affiliate will measure runoff, nutrient export and sediment erosion from test plots with varying levels of harvest treatments. The effects on microbial communities will also be measured.

University of Washington

Researchers at the University of Washington lead NARA's efforts to develop a complete life cycle assessment of the wood residue to biojet and co-product process. Additionally, members from this university serve as NARA liaison with regional tribal organizations to promote educational opportunities and forestry management analyses.

University of Wisconsin Extension

The University of Wisconsin Extension will contribute to NARA's goal of enhancing bioenergy literacy for students, educators and the general public.

US Forest Service-USDA, Forest Products Laboratory

The Forest Products Laboratory conducts innovative wood and fiber utilization research that contributes to the conservation and productivity of forest resources and sustainably to meet the needs of people for forest products. They contribute pretreatment conversion technology research to the NARA project.

US Forest Service, Pacific Northwest Research Station

The Pacific Northwest (PNW) Research Station is one of seven research centers that are part of the USDA Forest Service. They develop and deliver knowledge and innovative technology to improve the health and use of the Nation's forests and rangelands. They contribute to NARA's outreach tasks.

Washington State University

Washington State University is Washington's original land-grant university and the lead institution for NARA providing leadership, research and administrative services.

Western Washington University

Faculty in Western Washington University's Huxley College of the Environment, along with university's Institute for Energy Studies (IES), are involved in the education and outreach goals of the NARA project.

Weyerhaeuser

Weyerhaeuser creates sustainable solutions to the world's challenges through the development of innovative forest products that are essential to everyday lives. Weyerhaeuser NR Company continues to provide research expertise and leadership to important aspects of the NARA project, specifically with emphasis on feedstock sustainability and sourcing. Through year 3, Weyerhaeuser provided techno-economic analyses and co-product development.

NARA MANAGEMENT

NARA is an integrated project. An overarching challenge facing NARA is to provide a management framework that assists team cooperation, direction and achievement (see Figure OS-1). NARA has implemented multiple strategies to provide administrative services and management tools to the project.

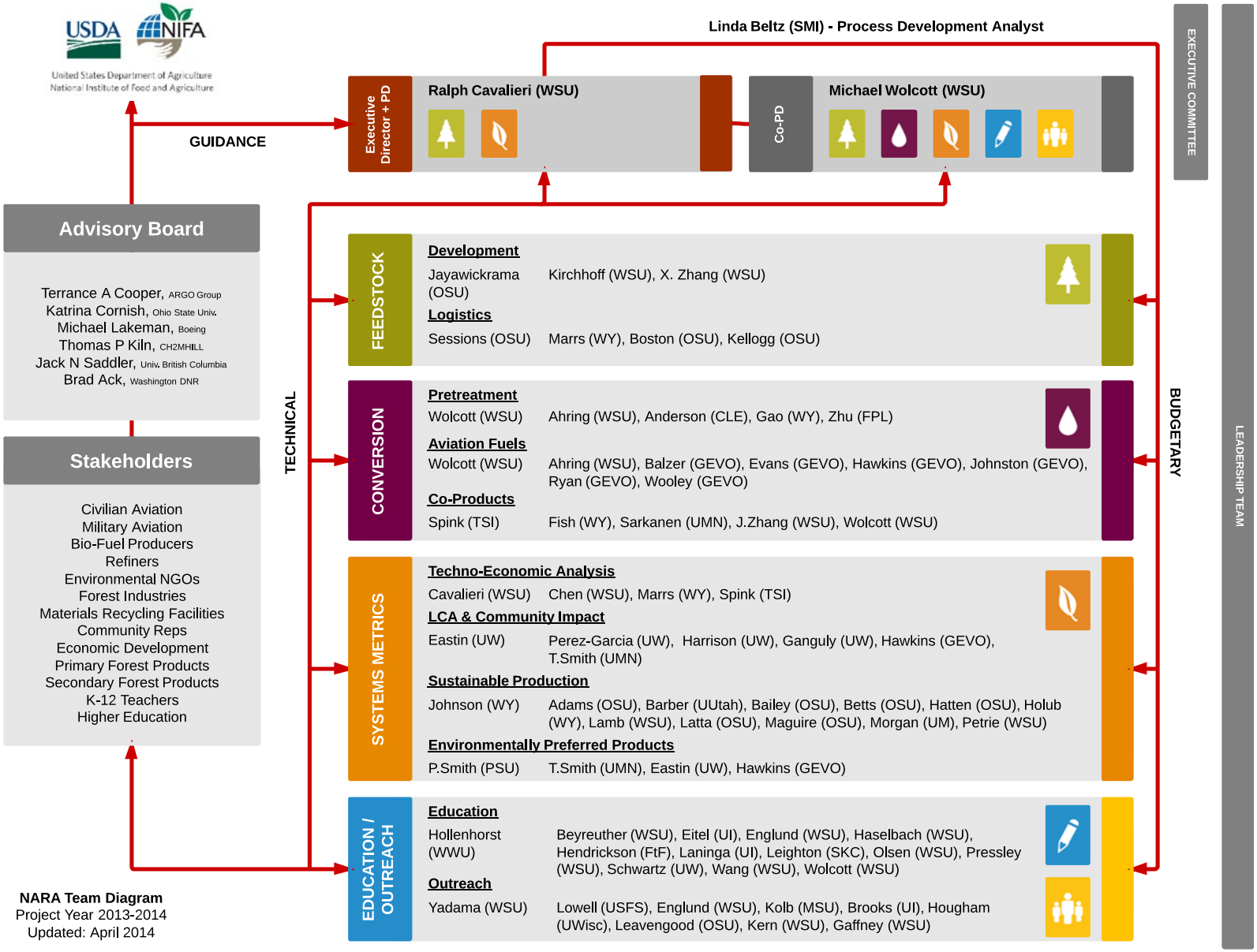

Figure OS-1. The NARA team diagram as of April 2014

NARA PHASE-GATE MODEL

Description of Phase and Gate

The Phase and Gate process is a well-known project management and decision support tool that improves project execution and promotes fact-based decision -making. Phase and Gate processes typically include "Phases", where the project work is completed and "Gates" where decisions for continuation and next Phase objectives are set. Each Phase allows progression from the idea phase to implementation, where Gates ensure that the decisions to continue are based on comprehensive information. NARA developed a customized Phase and Gate process that advances the project through the steps necessary to achieve commercial readiness of a forest residuals to aviation fuels pathway: (1) Feasibility Analysis, (2) Feasibility Validation, (3) Scale Up Readiness and (4) Commercial Options. The process is designed to be adaptable for the range of academic to commercial as well as technical to social work encompassed within the NARA project. Each phase covers key areas of: Technical, Market, Business Models / Integration, Manufacturing, Financial, Health/Safety and Intellectual Assets. Figure OS-2 shows NARA project flow diagram with desired outcomes by project area.

Objectives for NARA Phase and Gate

The Phase and Gate process is an important management element that allows NARA to:

- Coordinate team pathways and milestones in a manner that allows advancement of the project
- Identify gaps in project elements or milestones
- Realign project teams to optimize effectiveness
- Make decisions using a comprehensive fact-based gate framework

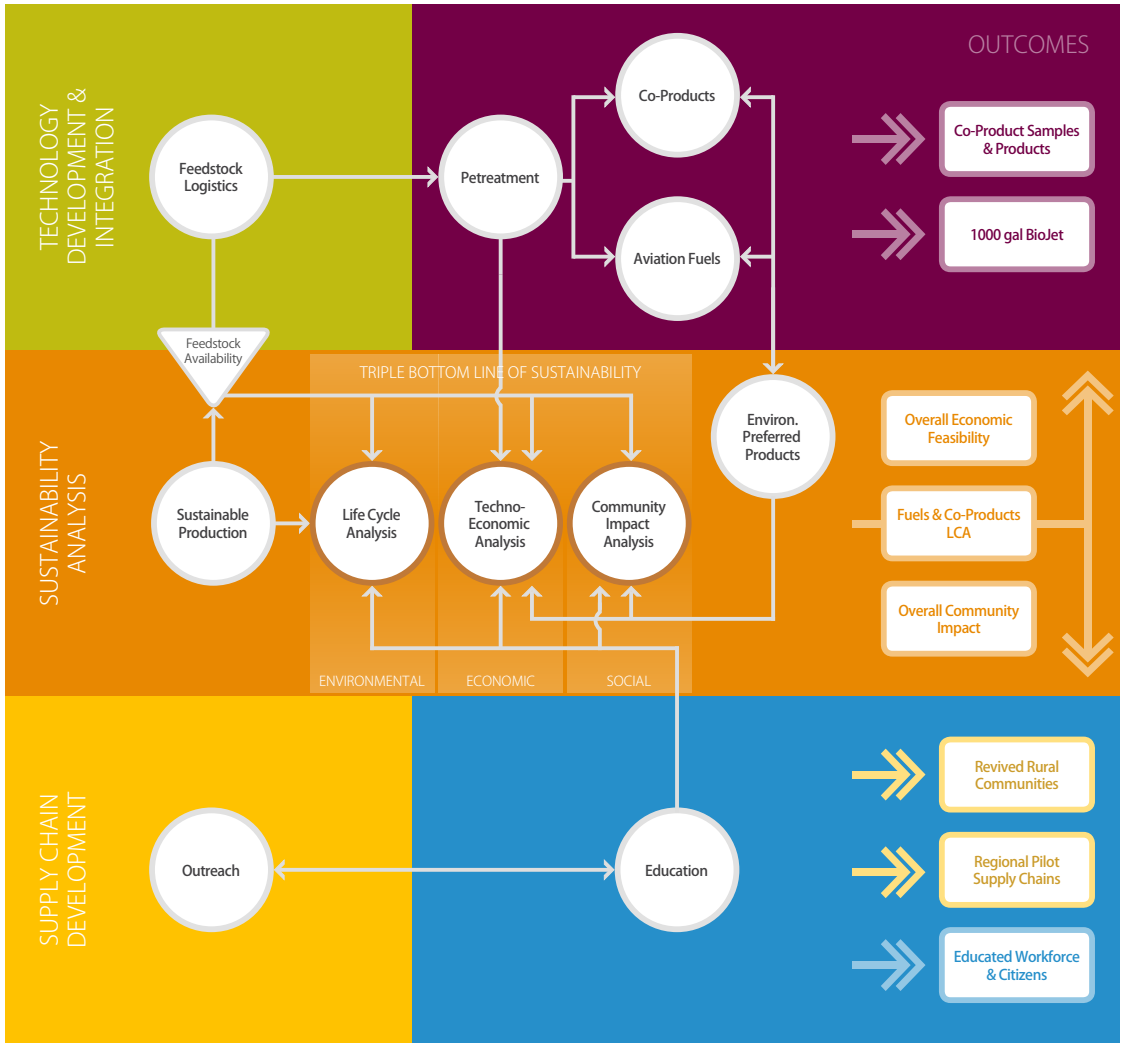

Figure OS-2. NARA project flow diagram with desired outcomes by project area

Activities and Results

A Gate packet was prepared and a Gate review completed to select the NARA-preferred pretreatment process. To accomplish this, gate metrics for comparison of the wet oxidation (WOX) and mild bisulfite (MBS) pretreatment processes were refined for each of the Gate element areas (e.g. Technical, Market, Financial, etc.). Data and observations were collected and organized from multiple NARA teams, including from the Pretreatment, Gevo Conversion, Co-Products, Techno-Economic Analysis, ASPEN (process simulation software) and Life Cycle Assessment teams. The detailed information from these teams was summarized into a Gate 1-2 Feasibility Analysis and Validation Packet. Detailed information was organized into a supplemental packet to support the conclusions and summary presented in the Gate Packet. A recommendation to select the MBS process as the NARA-preferred process was included in the packet, at the direction of Michael Wolcott who currently leads the Pretreatment team and based on the input from the other NARA team leaders. The packets were reviewed by Michael Wolcott and Ralph Cavalieri and sent to the Advisory Board one week before the Gate Review.

The Gate 1-2 Feasibility Analysis and Validation Review of the WOX and MBS pretreatments was completed with the Advisory Board on March 28, 2014. The Advisory Board provided input to Ralph Cavalieri, the Gate Keeper, and supported the selection of the MBS process as the NARA-preferred process. A Gate 1-2 Feasibility Analysis and Validation Review form documented the decision. Gate Review minutes were recorded by Jim Reid, who facilitated the Gate Review.

Intellectual Property (IP) Management Plan and Non-disclosure Agreement (NDA)

All NARA members endorse a common Intellectual Property (IP) Management Plan and Non-Disclosure Agreement. The purpose of the IP Management Plan is to ensure that the protection process for all IP developed under NARA is well defined and agreed upon in advance of IP creation. By agreeing to the terms in advance, the companies involved are more secure of the commercial prospects for licensing/using the technology, and the rights and responsibilities of the parties protecting IP are clearly defined.

The purpose of the NDA is to allow companies to talk freely and exchange ideas with the government labs and university researchers without worry that their proprietary information will be disclosed or rendered not patentable.

NARA Staff

NARA retains five staff members to assist in administrative and creative needs. All are funded by Washington State University.

Charles Burke
Communications and Publicity Director — ccburke@nararenewables.org

Janet Duncan
Project Coordinator — duncanj@nararenewables.org

Julie Semler
Project Coordinator — jsemler@nararenewables.org

Jacob Smith
Graphic Designer/Web Coordinator — jsmith@nararenewables.org

Travis Woodland
Intellectual Property Management — t_woodland@nararenewables.org

COMMUNICATIONS

NARA communicates progress to NARA members, Advisory Board, and the USDA-NIFA leadership. In addition, research and event information is provided to regional stakeholders and to the general public. To accomplish this, NARA hosts meetings, maintains communication tools and includes the communication services of outside partners.

NARA Annual Meeting

NARA holds an annual meeting in the fall. Our first annual meeting was conducted in Missoula Montana (September 13-14, 2012), followed by a meeting in Corvallis, Oregon (September 10-13, 2013). These meetings provide an opportunity for NARA researchers to present their work to the advisory board, the USDA-NIFA leadership, partners, stakeholders and the general public.

NARA Team Leadership Meetings

NARA is composed of eleven working teams grouped with the feedstock, conversion, systems metrics, education and outreach components of the project. Each month, team leaders and the executive committee meet via conference call to ensure that the process is focused on reaching solutions that achieve NARA goals.

NARA Website

The NARA website functions as the central repository for NARA information to the general public; host portals like "woodtobiofuels.org" used as a data retrieval tool for educators, professionals and the general public; and contains an intranet feature used to share project information internally among NARA researchers. As of March 31, 2014, the website experienced 39,408 visits with 142,248 page views. The NARA website is at http://nararenewables.org.

NARA Newsletter and Blog

NARA distributes a monthly newsletter and a blog written to communicate NARA's progress to the general public and to the NARA team. Past newsletters can be viewed at http://nararenewables.org/news/newsletter. The NARA blog can be viewed at http://nararenewables.org/blog/.

Forest Business Network

The focus of the Forest Business Network is to help forest product businesses grow and prosper. They work strategically with the NARA Outreach team to develop stakeholder groups and disseminate information within the forestry industry. Their website is https://www.forestbusinessnetwork.com

Ruckelshaus Center

The Center is a joint effort of Washington's two research universities and was developed in response to requests from community leaders. Building on the unique strengths of the two institutions, the Center is dedicated to assisting public, private, tribal, non-profit and other community leaders in their efforts to build consensus and resolve conflicts around difficult public policy issues. For NARA, the center assists the Outreach Team communicate with policy makers. They also help facilitate NARA's internal communications. Their website is http://ruckelshauscenter.wsu.edu/

NARA Strategic Analysis

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STRATEGIC ANALYSIS

Background

In attaining the USDA NIFA aspiration goal for the Sustainable Bioenergy AFRI CAPs to *"facilitate the establishment of regional systems for the sustainable production of bioenergy and biobased products,[1]"* NARA is envisioning an aviation biofuels industry based upon residual materials from the existing softwood supply chain in the Northwestern US. In years 1 and 2 of our project, we focused on refining management systems and team coordination while establishing the individual technical and logistical components. Two major components that were added to aid us in evaluating progress during these early stages of the project were a Techno-Economic Analysis (TEA) on our conversion pathway and a project-wide Phase and Gate Process to guide our transition from Feasibility Assessment through to Commercialization. We have used the results of the analysis to guide the strategic direction of our project towards a continued effort to realizing a *"regional system for sustainable production of bioenergy and biobased products"*. The first two years brought us to a refined vision of how this industry might successfully develop.

One pathway is that of an integrated biorefinery with a single pretreatment process at its core. Through the first three years we have considered multiple thermochemical pretreatments that included mild bisulfite, wet oxidation, and dilute acid. Regardless of the pretreatment process, the functions and assets of such a facility could closely resemble integrated pulping facilities like those that existed in Bellingham, WA. The core of NARA's conversion research is striving to improve efficiencies, yields, and the economics of feedstock sourcing for such an approach. Initially, economics of this model will necessitate retrofit of existing facilities in the region, ideally those with few existing product opportunities. Our supply chain analysis has demonstrated that a large-scale integrated facility located in the part of our region with lower biomass productivity (e.g. the NARA region east of the Cascade Range) would greatly benefit from rail-located biomass depots, to economically build the quantities of biomass needed for achieving economies of scale at the conversion site.

Our research has also indicated that a **second pathway for potential success may employ a distributed supply chain approach**. This distributed production model relies upon pretreatment and potentially saccharification processes moving upstream in the supply chains to depots. This pathway potentially benefits from additional opportunities to retrofit existing infrastructure including primary wood processing facilities and pulp mills (partial retrofit) for solid or liquid depots, ethanol plants for isobutanol production, and petroleum refining for alcohol-to-jet conversion.

The focus of our Year 3 efforts address the necessary technical research, integration, and scale-up to study feasibility of both pathways. In addition, the NARA Advisory Board specifically directed that the NARA leadership team *"should decide on a single pretreatment process to carry forward"* and *"use the Phase & Gate Analysis process to facilitate this action"*. We have followed these recommendations while continuing to develop impactful research to address our pathways as articulated above.

Approach

In response to this recommendation, the NARA Executive Team directed establishment of a coordinated evaluation of the mild bisulfite and wet oxidation pretreatment methods for a variety of technical metrics, co-products, and commercialization potentials. The process was led by NARA Process Development Analyst, Linda Beltz, and contributed to by all of the NARA Pretreatment, Co-Products, Conversion, and Sustainability Teams.

In addition, the techno-economic analysis (TEA) developed in Year 2 (see Task SM-TEA-1: Techno-Economics Analysis of the 2013 NARA Cumulative Report) was used to assess the specific role of multiple revenue streams from likely co-products developed in the process. To supplement the TEA effort, improvements were continually sought in reducing feedstock costs (Task FL-1: Feedstock Sourcing) and delineating supply chain assets (E-3: Regional Integrated Design Experience – IDX) within our NARA region. At this point, our team is focusing on a supply region spanning the Washington-Oregon border on the west-side of the Cascade Mountains (MC2P – Mid Cascade to Pacific Region). Stakeholder development was targeted by the Outreach Team to engage our new region and develop relationships focused in the states of Washington and Oregon. These groups were specifically developed to assist in supply chain development in the new MC2P region.

[1] USDA NIFA Agriculture and Food Research Initiative Competitive Grants Program.
Sustainable Bioenergy – 2010 Request for Application_http://www.grants.gov/search/synopsis.do;jsessionid=RvWPRSFJ2C2gNjyTL2K0G519XXJLCBcTTHyXT4pVH67H74WDGsYh!1654183736

Summary of Findings

TECHNO-ECONOMIC ANALYSIS

We found in Year 2, assuming a (1) complete greenfield construction of an integrated biorefinery and (2) a 20% internal rate of return, the current cost estimate for producing biojet (IPK) from forest residuals will be 2 to 3 times the current cost of petroleum jet fuel if the biorefinery is designed to produce only aviation biofuel products. With optimistic estimates for improved yields throughout the process, this value might be lowered to 1.45 times the cost of the petroleum equivalent.

In Year 3, we focused the TEA on discerning the impact of potential co-products on the revenue stream for a biorefinery. In this process we considered two commercially viable co-products: (1) lignosulfonates used for concrete additives, and (2) activated carbon to be used for mercury adsorption in coal fired power plants. Other revenues included the sale of alternative jet fuel at cost parity with petroleum, the RIN value of this fuel, and the sale of isooctane, which is a byproduct of producing biojet. After adjusting the expected capital and operating expenditures for the added co-product production, an internal rate of return (IRR) of 12.5% (Figure SA-1) is realized. This profit margin is still unlikely to be sufficient for investments of the magnitude required to build an integrated biorefinery through greenfield development. Our efforts in Year 4 will focus on assessing the value that retrofit of existing pulp mill facilities might bring to the computed IRR for a pulp-mill based, integrated biorefinery.

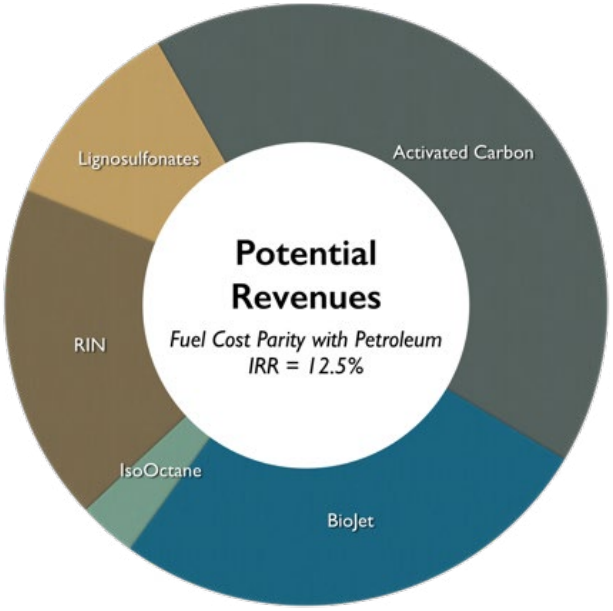

Figure SA-1. Summary of the current status of the techno-economic analysis for an integrated biorefinery producing biojet (IPK) and lignin co-products using forest residuals as a feedstock assuming a complete greenfield construction. Relative contributions of individual revenues are provided for analysis.

FEEDSTOCK COSTS

Feedstock remains the single largest cost item within the integrated biorefinery TEA. In an effort to improve our processing efficiency, NARA undertook an extensive study of feedstock preparation. In this effort, slash piles were deconstructed, the materials were categorized, moisture levels were controlled, and all the materials were processed at a controlled site with actual harvesting equipment. Processing energy was monitored carefully to assess fuel usage. By controlling biomass size, bit type, and moisture content, this effort has demonstrated pathways that will result in ca. $30/bone dry ton (BDT) savings to the feedstock production (Figure SA-2).

DISTRIBUTED SUGAR PRODUCTION

The core of a distributed production model is the ability to pretreat on a small scale in facilities where residues are readily available, e.g. sawmills. NARA has been investigating a pretreatment method that would be based solely on mechanical milling technologies (Figure SA-3). These efforts have been supported by work to design supply chain technologies and systems around this distributed production. For more information, see tasks C-P-5 (Clean Sugar and Lignin Pretreatment Technology, p-59) and E-8 (Distributed Sugar Depot, p-244) in this report.

The targeted energy consumption by the pulverized wood operations has been used for a techno-economics analysis (TEA) for clean sugar and lignin production from forest residual chips. Based on this TEA, if the targeted energy consumption of wood milling is met or achieved within the range of 0.56-0.84 kilowatt-hour/oven dried kg wood at a sugar conversion yield of about 58-65%, the economics by milling as a pretreatment technology looks plausible for clean sugar and lignin fuel pellet production. Examination of the milled wood sugar by Gevo is ongoing, but preliminary assessments indicate that organism growth and isobutanol production are excellent. Overall, the distributed production scenario demonstrates continued benefits for consideration.

OUTREACH AND EDUCATION TEAM SUPPORT

The assessment of existing regional assets to be applied to the emerging biofuels industry in regional supply chains is a key component of our Goal 3: Supply Chain Coalitions, and is carried out by our Outreach and Education Teams. This effort not only produces supply chain analysis resulting in site ranking and design, but critically links stakeholders to this effort to engage them in these efforts and involve them in the development of a future biofuels industry.

Efforts of the Outreach Team were successful at aligning State of Washington economic development programs with our fuels vision. A state grant was provided by the Washington Department of Commerce to assist a NARA member, Cosmo Specialty Fibers, in evaluating the potential to expand their operation to include biochemical and sugar products. NARA education teams worked with Cosmo and other regional stakeholders in western Washington and Oregon to envision supply chain nodes in the Mid-Cascade to Pacific (MC2P) region that spanned the Washington-Oregon border. These efforts resulted in site designs for facilities that included both solid and liquid depots for the distributed manufacturing model as well as integrated biorefinery designs. As a result of these combined Education and Outreach efforts, Cosmo announced at our 2013 stakeholder meeting in Seattle that they were pursuing a biorefinery business model.

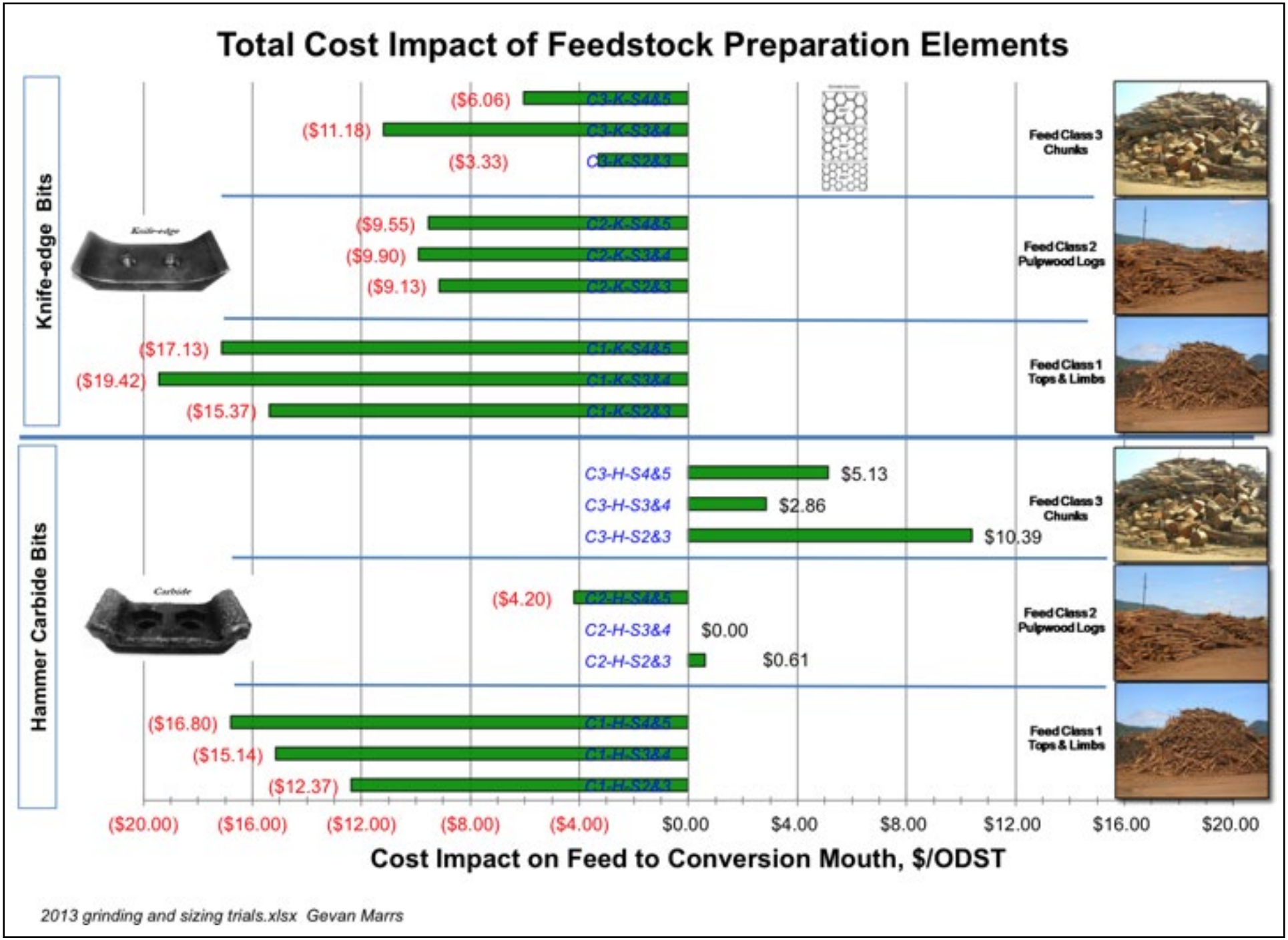

Figure SA-2. Summary of the cost impact on feedstock conversion costs for a variety of biomass and processing bit types

Figure SA-3. Milled wood powders of FS-10 chips, under various milling time, 30, 60, 80, and 100 minutes. Varying color of milled wood samples corresponds to milling temperatures. All materials were directly hydrolysable after milling with no chemical treatment.

Future Directions

Given the need to increase production efficiency by decreasing feedstock costs and reducing capital costs, we recommend the following:

- Continue seeking regional assets that might be retrofit for an emerging biofuels industry. These facilities include primary wood processing plants for depots, pulp plants for pretreatment and hydrolysis, and ethanol plants for fermentation. We will perform an analysis of the four-state NARA region.
- Specifically evaluate the potential of a retrofitted facility by providing a modified TEA around the strategy of converting a bisulfite pulp mill into biofuels, biochemical, sugar, and lignin products.
- Further assess the role of feedstock densification prior to shipping in decreasing feedstock costs.
- Produce a full simulation and TEA of a sugar depot to further evaluate the role of distributed manufacturing.
- Seek commercial partners for our carbon co-products development.
- Develop a firm commercialization strategy that will culminate in 1,000 gallons of biojet fuel produced as an initial demonstration effort.