NARA Goal Three

2nd Cumulative Report

April 2013 - March 2014

Rural Economic Development

Enhance and sustain rural economic development.

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SUMMARY

Sustainability is the crucial attribute necessary for the emerging biofuels industry to develop our rural economy. The NARA project is assessing sustainability of this emerging industry using a triple bottom line approach of assessing economic viability (techno-economic analysis (TEA)), environmental impact (life cycle assessment (LCA)), and social impact (community impact analysis (CIA)). In addition to developing these three primary analytical tools, additional primary data is being collected. These data include social and market data through the Environmentally Preferred Products (EPP) team and environmental data through the Sustainable Production team. The following efforts within the Systems Metrics program are integrated to provide a sustainability analysis of the project:

ENVIRONMENTALLY PREFERRED PRODUCTS

The Environmentally Preferred Products Team (EPP) evaluates the social viability of the industry. This analysis of social sustainability investigates stakeholder needs and perceptions, community social assets, market opportunities for biojet and co-products, and governmental regulations and incentives for renewable products. To evaluate community social assets and predict bioenergy behaviors, the EPP Team completed and published a biogeophysical and social asset assessment for the western Montana corridor (WMC) region. This deliverable represents a NARA milestone and generates a two-tiered index that considers biogeophysical and social assets used to select facility site locations (Task SM-EPP-1.1.) The methodology will be applied to other regions within the NARA four-state operating area.

Work has been completed identifying co-products and intermediate products that are produced during the wood-isobutanol-biojet life cycle and describing their application. Future work will focus on identifying common bio-product attributes related to these co-products/intermediates that indicate how the market signifies environmental preference (Task SM-EPP-1.2).

To evaluate stakeholder needs and perceptions, a stakeholder survey was developed during the last reporting period. As of November 2013, the survey was distributed to 868 stakeholders targeted in the NARA four-state region with a response rate of 37% (324 responded). Non-response bias testing has been completed and survey analysis is in progress. (Tasks SM-EPP-1.4,O-7 (see supply chain coalition report)).

To provide a techno-market assessment for jet fuels, a final literature review of global biofuels policies is in progress, with an emphasis on how these legislative tools will impact the industry moving forward. A specific focus will be on the downstream portion of the biofuels supply chain in the U.S., from biorefinery to end-user. Comparisons and contrasts with EU biofuels policies will also be examined. Parallel to these efforts, managers at the Seattle (SEA) and Portland (PDX) airports were interviewed to provide insight into aviation fuel logistics and ownership. This effort lead to the development of a jet fuel logistics, policy, and social science team, that will develop and administer a stakeholder survey of key aviation fuel supply chain stakeholders in the NARA region including airport management, fuel traders/brokers, fixed-based operators, and terminal and pipeline operators. A database of all NARA region commercial airports and terminals is in progress (Task SM-EPP-1.6). A techno-market assessment for bio-products and polymers is also underway (Task SM-EPP-1.7).

An environmental assessment to using lignin-rich residuals, generated from the SPORL and wet oxidation pretreatment procedures, to produce activated carbon shows CO_2 emissions reduced by over 80% compared to a fossil fuel–based kerosene baseline. This reduction greatly exceeds the Renewable Fuel Standards emission reduction thresholds. A similar assessment compared CO_2 emissions generated from producing plastic bottles made from polyethylene terephthalate (PET) derived from forest residual feedstock and fossil-based feedstock. Preliminary results show that manufacturing bio-based bottles derived from forest residual feedstock results in CO_2 emissions decreasing by 9% relative to the fossil-based development (Task SM-EPP-1.9).

LIFE CYCLE ASSESSMENT

The Life Cycle Assessment (LCA) Team assesses the environmental and economic impacts of producing aviation biofuels with our chosen pathway and compares it to the petroleum products for which it will substitute. For this reporting period, teams were assembled to generate LCA data for co-product development (see task SM-EPP-1.9), pretreatment (SM-AM-1) and conversion processes (Task C-AF-1). A LCA on the mild bisulfite and wet oxidation pretreatment process was generated and incorporated into the data set that directed the pretreatment downselect process (see Phase and Gate segment in Organizational Structure). A preliminary “feedstock” LCA, incorporating primary data for the western Montana corridor region feedstock, has been accepted for publication and represents a significant NARA milestone. A preliminary LCA report structure following the ISO 14044 guidelines has been developed.

COMMUNITY IMPACT ASSESSMENT

A preliminary community impact assessment (CIA) has been developed for the western Montana corridor (WMC) region. A literature review and sensitivity analysis that incorporates co-product outputs will be added to the report prior to publication. A preliminary CIA was applied to the western Washington region.

This initial assessment suggests that a biorefinery could generate as many as 1,243 jobs within forestry, transportation and the refinery operations. Indirect and direct economic impact of this refinery could total $513.4 million.

A significant output for the EPP, LCA and CIA teams is:

• A biogeophysical and social asset assessment for the western Montana corridor region has been published. This work establishes a method used to quantify a region's social capability to embrace a wood to biofuel industry (Task SM-EPP-1.1). http://www.sciencedirect.com/science/article/pii/S0961953414002086

To provide more specific information regarding the influence of removing forest residuals on sites, soil, and water, the Sustainable Production Team evaluates the influence of biomass harvesting scenarios, develops potential forest management prescriptions, assesses forest residual availability from harvest of highly managed stands, and considers the impact of industry feedstock requirements on overall supply chain dynamics. In whole, this team provides a host of primary data used to verify and reduce a variety of potential impacts from this new industry. Teams evaluating the effects of forest residual removal on soil carbon and nitrogen levels at the Fall River Long Term Soil Productivity (LTSP) site found that removing forest biomass had little impact on future tree productivity. Additional, yet less intensive research, at 73 other coastal Douglas-fir plantations from northern Vancouver Island, BC, Canada to southern Oregon is being used to give the Fall River work more impact and perspective. Publications addressing the effects of vegetative control on biomass growth, deep soil carbon, and methods to calculate standing biomass were completed in this reporting period, and work to evaluate stump decomposition rates has been initiated (Task SM-LCA-1.1). At the NARA LTSP site located near Springfield Oregon, soil samples were collected pre- and post- logging and residual removal operations so that density fractions and carbon and nitrogen content can be monitored (Task SM-SP-8). In addition, lysimeters were installed to record how forest residual removal affects nitrogen and carbon cycling in the soil (Task SM-LCA-1.1).

The NARA LTSP site is structured to provide long-term analysis on the impacts of forest residual removal and soil compaction on soil and plant productivity. The site is also used to study forest residual removal impact on water effects and wildlife. For this reporting period, timber harvest was completed on the 83-acre site and 28 1-acre plots were treated with a factorial of biomass removal and soil-compaction treatments. Weather stations plus soil moisture and temperature monitoring equipment were installed. Post harvest, 5000 conifer seedlings were planted and will be monitored for productivity against various treatments. Fencing was installed to protect the seedlings (Tasks SM-SP-1, SM-SP-8). Equipment has been purchased and a study plan submitted to evaluate how forest residual removal affects stream erosion and water retention in the soil (Task SM-SP-5-water). In addition, study plans are being developed to monitor soil microbial communities (Task SM-SP-5-water) and ground-nesting bees (Task SM-SP-6) for their response to harvesting treatments. A manuscript was submitted for publication that describes the range of management practices used to harvest biomass, and the types of forest organisms known or expected to be impacted. This initial work will direct future experiments to further understand the impact of forest residual removal on wildlife (Task SM-SP-6).

To understand the impact of prescribed fires, including slash pile burning, on local-to regional-scale air quality, air pollutant emissions data related to prescribed fires was obtained and used for simulation modeling. Results show that emissions in western states vary significantly by month with most of the burning taking place in October and November. A modeled simulation comparing the emissions on an October day with or without prescribed burning showed that prescribed burning can result in significant atmospheric loading of particulate matter 2.5 micrometers or less (PM2.5). This data shows the local importance of prescribed fires and the potential air quality benefits to be gained from harvesting these fuels for the biojet supply chain as opposed to burning them (Task SM-SP-5).

Multiple efforts are being conducted to provide analysis and tools used to determine the amount of sustainable forest residual feedstock in the NARA four-state region. In order to better quantify the amount of standing residual biomass on a site, two seasons of biomass sampling has been completed. The data generated from this activity was used to develop allometric equations. The equations predict biomass quantities of live and dead branches, foliage, heartwood, sapwood, and bark for trees ranging from 10-77 cm in diameter at breast height (dbh) and 10-57 m in height and nutrient content. The biomass equations have been incorporated into ORGANON and CIPSANON growth models, enabling users to estimate biomass components of trees and stands. The work described represents a NARA milestone and should improve biomass estimates and allow managers to simulate the effect of varied harvesting options (Task SM-SP-4). Using data from the forest inventory and analysis program (FIA), a volume/biomass model based on the forest vegetative simulator (FVS) has been completed and applied to all plots in the NARA sub-regions to generate forest residual yield files. This model allows wide flexibility in specifying biomass pools. In addition, a transport cost model, based on commonly available GIS mapping functions, was completed and recognizes multiple road standards in computing both costs and diesel consumption in moving from each FIA plot to any desired set of log/biomass mill destinations. These tools were used to develop biomass cost curves for potential bio-refineries in Cosmopolis and Longview Washington and will provide simulations to study environmental, market and management impacts from forest residual removal (Task SM-SP-3). A survey of local and regional USFS silviculturists and NEPA planners was completed in order to understand the range of potential silvicultural options that are currently being implemented on agency lands. These prescriptions were incorporated into a model framework to test the impact that both prescription form and harvest intensity have on potential wood supply and fire hazard mitigation. This work satisfies a NARA milestone and will tie directly into the biomass availability model completed by NARA, allowing for a more accurate model simulation reflecting USFS decision options and the accounting of stand-level impacts of silvicultural treatments on future structural conditions and potential fire hazards (Task SM-SP-2).

The amount of forest residual feedstock is highly dependent on logging operations. Montana's Bureau of Business and Economic Research (BBER) Forest Industry Research Group established a database online that provides timber harvest data by county in CA, ID, MT, OR and WA. The BBER staff completed data sets for mill residue production in ID, MT and OR and are nearly complete with the WA data. This activity represents a NARA milestone and will be used for biomass availability modeling. The data indicates that virtually all mill residues currently produced in the region are used for either internal energy purposes or sold for a variety of industrial uses (primarily pulp and reconstituted board production). Bioenergy firms (such as NARA biomass pretreatment plants) will face competition for mill residues from current residue users. In this reporting period, BBER staff measured 700 trees at 25 sites to understand how felled logs are utilized. Since NARA inception, over 2000 trees from 81 sites have been measured. NARA teams use this data to understand the amount of residual biomass available from harvesting activities. Initial results indicate that logging residues as a fraction of mill delivered volume have continued to decline through time as land managers have progressively utilized more woody biomass on commercial logging units (Task SM-SP-7).

To understand the economic considerations and sustainability of a bio-jet fuel and co-products industry based on wood residuals, a techno-economic analysis (TEA) is underway. Analysis performed in the previous year illustrated that in order for a biorefinery to reach profitability, multiple products of high value must be produced in addition to bio-jet fuel. Adjusting the TEA to accommodate the production of multiple targeted products provided a scenario where the internal rate of return (IRR) for a multi-product integrated facility is 10.7%. In this scenario, co-products account for nearly twice the revenue compared to bio-jet fuel. The projected IRR was increased to 12.5% when efficiencies from the mild bisulfite (MBS) pretreatment process were incorporated in to TEA model. The MBS operational inputs were obtained from the NARA ASPEN modeling group. The ASPEN modeling efforts provide more accurate mass flow and operating cost estimates and is required for renewable identification number (RIN) placement and life cycle assessment (LCA) reporting. In addition, the ASPEN modeling was used to compare economic efficiencies between the MBS and wet oxidation pretreatment processes (Tasks SM-TEA-1, SM-AM-1). These comparisons contributed to the selection of a single pretreatment process (see phase and gate in the organizational structure segment of this report).

Significant outputs to date for the Sustainable Production and TEA teams are:

- The BBER Staff posted a database online that provides timber harvest data by county in CA, ID, MT, OR and WA (Task SM-SP-7). http://www.bber.umt.edu/FIR/H_Harvest.asp

- A biogeophysical and social asset assessment for the western Montana corridor region has been published. This work establishes a method used to quantify a region's social capability to embrace a wood to biofuel industry (Task SM-EPP-1.1). http://www.sciencedirect.com/science/article/pii/S0961953414002086

- Soil effects from vehicle trails made during thinning operations were assessed and published. http://www.ingentaconnect.com/content/saf/fs/pre-prints/content-forsci12525

Training

Name	Affiliation	Role	Contribution
Stephen Cline	PSU	Undergraduate student: NARA SURE (SU '14 at Weyco); wages – SP/FA '13; SP '14)	Investigating the lignin market opportunity, particularly re: activated carbon
Stephen Cline	PSU	Beginning an MS SU/ FA '14	Not yet determined
Stephen Wertz	PSU	Post doctorate	Biofuel policy, emphasis on RINs; biojet supply chains; on military obligation SP '14 +?
Wenping Shi	PSU	Post doctorate	Social Asset dataset developer, analyst, and manager
Min Chen	PSU	Post doctorate	Biopolymer value streams; biorefinery structure and analysis
Jennifer Schmitt	U Minn	Post doctorate	Exploring spatial variation aspects of supply chain structure and environmental assessment
Rylie Pelton	U Minn	Graduate student (PhD)	Environmental assessment of intermediate products and co-products, particularly re: activated carbon
Luyi Chen	U Minn	Graduate student (PhD)	Environmental assessment of intermediate products particularly re: isobutanol to paraxylene
Jillian Moroney, Ph.D.	U of Idaho	Post doctorate	Stakeholder (SH) assessment; aviation fuel SH assessment
Ibon Ibarrola, MS An industrial cooperator (CLH Aviation, Madrid, Spain)	Polytechnic Univ. of Madrid	Research and industrial cooperator	Aviation fuel logistics; aviation fuel SH assessment; cooperator on the FAA COE Techno-Market Analysis proposal
Sanne Rijkhoff, Ph.D.	WSU	Post doctorate	Social asset analysis; aviation fuel SH assessment
Natalie Martinkus, Ph.D.	WSU	Graduate Student (PhD)	Biogeophysical and social asset assessment
Yuanlong Li	U Minn	Undergraduate student; NARA SURE (SU '14 – at PSU)	Initiated background research on the SEA and PDX aviation fuel supply chains
Tait Bowers	Univ of Washington	Graduate student (PhD)	Support LCA research effort
Cody Sifford	Univ of Washington	Graduate student (MS)	Support LCA research effort
Cindy Chen	Univ of Washington	Graduate student (PhD)	Support LCA research effort
Jason James	Univ of Washington	Graduate student (MS)	Research on soil C vs productivity; several presentations; several presentations, one publication
Marcella Menegale	Univ of Washington	Graduate student (PhD)	Research on harvest vs N cycling; several presentations
Erika Knight	Univ of Washington	Graduate student (MS)	Research on nutrients and soil carbon vs harvest level; M.S. 2013; several presentations; one publication
Kim Littke	Univ of Washington	Post doctorate	Research on maximum productivity of Douglas-fir plantations, long-term sustainability, several presentations and one publication
Kristin Coons	OSU	Post doctorate	SM-SP 4.2

Micah Scudder	Univ. of Montana	Graduate student MS (note- Micah received his MS degree in December 2012- he now works as a full time research assistant at BBER).	Micah worked as a logging utilization field crew member across the 4-state NARA area in 2013. Micah has served NARA as our resident wood export specialist- his skills have been particularly useful in understanding the export and substitution effects of wood flows throughout the northwest. Micah (in collaboration with Josh Meek) developed a tool that summarizes annual timber harvest by ownership & county in Montana, Idaho, Oregon, Washington, and California. This innovative web-based application will enable users to quickly understand the spatial and temporal dynamics of timber harvest.
Josh Meek	Univ. of Montana	Graduate student (MS) received his MS degree in December 2013.	Josh worked as a logging utilization field crew member across the 4-state NARA area in 2013. Josh (in collaboration with Micah Scudder) developed a tool that summarizes annual timber harvest by ownership class and county in Montana, Idaho, Oregon, Washington, and California. This innovative web-based application will enable users to quickly understand the spatial and temporal dynamics of timber harvest. Josh finished a professional paper as a requirement for completing his MS in Forestry in December 2013. Josh's research focused on logging costs Josh left the BBER in January 2014 for a position with the Washington Dept. of Natural Resources.
Vikram Ravi	WSU, Civil Engr.	Graduate student (PhD)	Air impact analysis
Adrian Gallo	OSU	Graduate student (PhD)	Installed field monitoring equipment, initialized monitoring of soil respiration and collection of lysimeter solutions, and has begun training on density fractionation.
Raven Chavez	OSU	Undergraduate student	Assisted graduate student in field and lab, begun analyzing soil compaction data.
Mindy Crandall	OSU	Graduate student (PhD)	Developing the depot model as an extension of the basic log market model, with detailed treatment of potential local area employment and income impacts.
Mahesh Bule	WSU	Post doctorate	Served on Project until February 1st, 2014. Has since left WSU.
Allan Gao	WSU	Graduate student (PhD)	Primary Aspen modeler, wrote and submitted Aspen white papers for recommendation of pretreatment process to NARA leadership team.
Mohammad Hasan	Univ of Utah	Graduate student (PhD)	Developed sampling plan for water budget and soil microbial populations, refined 4 sampling-related hypothesis, investigated model input parameters for WEPP model. Also conducted an extensive literature review on surface sediment and water budgets.
Ross Wickham	WSU	Graduate student (PhD)	Conducted literature review on flow and sediment transport of forest streams. Reviewed numerical models to represent stream channel processes.

Resource Leveraging

Resource Type	Resource Citation	Amount	Relationship or Importance to NARA
PSU Grant-In-Aid (GIA) (tuition support)	Stephen Wertz ($16,000/semester)	$48,000 – FA ’13, FA ’14; SP ‘15	Examining biofuel policy with an emphasis on RINs.
PSU GIA	Min Chen ($16,000/semester)	$80,000 – FA ’13, SP/FA ’14, SP ’15; FA ‘15	Research on the US biorefinery structure; biopolymer market opportunity
Industrial Match from CLH Aviation, a NARA Affiliate	Ibon Ibarrola	10,000	Toward a better understanding of aviation fuel supply chains in the US and Spain
PSU Dickinson School of Law Match	Kristina Dahmann	$5,000	Contributions toward understanding biofuel policy and law
Center of Excellence (COE)	FAA COE – ASCENT program	$40,000,000 for total 10-year program	Includes Alternative Jet Fuel research and development activities to better benchmark NARA efforts.
Techno-Market Analysis of the US AJF Supply Chain project	Proposal to the FAA COE – ASCENT program (under review)	$1,000,000	Compare contrast multiple AJF supply chains – including NARA – to better understand opportunities and impediments to adoption and diffusion of Alternative Jet Fuels
PSU RA + GIA support	Stephen Cline	$72,000 – 2 year funding	Former NARA SURE student at Weyco (SU ’13); currently on PSU wages; to begin an MS at PSU SU/FA ’14
UMN RA - Funded through the Buckman endowment within BBE/CFANS	R. Pelton	$43,000	Conducting parameterized LCA of co-product (Activated Carbon) credit/debits to biojet fuel system.
UMN RA- Funded through BBE/CFANS scholarship recruitment funds	L. Chen	$43,000	Conducting parameterized LCA of co-product (bioPET) credit/debits to biojet fuel system.
NARA SURE undergraduate research	Yuanlong Li	$6,000	Background on SEA and PDX aviation fuel supply chains
NARA SURE undergraduate research	Stephen Cline	$6,000	Background on Weyco lignin research – toward the market opportunity for NARA co-product value stream outputs
Funding	AIRQUEST	$100K	The AIRPACT-4 forecast system is supported by AIRQUEST and is used in our NARA work as the modeling platform

Idaho Logging Utilization work sponsored by USDA-Forest Service-Rocky Mountain Research Station	07-JV-11221684-326		The logging residue information will be a component of woody feedstock analysis, and the reports and contacts made with landowners and land managers in Idaho will increase the awareness of the NARA project.
Pacific States Forest Industry and Timber Harvest Analysis, sponsored by USDA-Forest Service-Pacific Northwest Research Station	08-JV-11261979-355		This agreement has assisted with the gathering and reporting of data related to timber harvest volumes, mill residues, and forest industry infrastructure in Oregon and Washington, and provided various opportunities to share NARA results and discuss the NARA project with forest industry as well as private & public forest management professionals.
Timber Product Output and Forest Industry Analysis for the Interior West States, by USDA Forest Service-Rocky Mountain Research Station	11-JV-11221638-091		This agreement will assist with the gathering and reporting of data related to timber harvest volumes, mill residues, and forest industry infrastructure in Idaho and Montana, and will provide opportunities to share NARA results and discuss NARA with mill & forest owners & managers.

SYSTEMS METRICS

ENVIRONMENTALLY PREFERRED PRODUCTS TEAM

TASK SM-EPP-1: ENVIRONMENTALLY PREFERRED PRODUCTS

Key Personnel	Affiliation
Paul Smith	Pennsylvania State University
Timothy Smith	University of Minnesota

Task Description

A socio-market perspective of biorefinery value chain outputs requires an integrated, multi-faceted approach. Environmetally preferred products (EPP) activities will provide valuable insight into various aspects of the biorefinery supply chain including: (1) public stakeholder assessment via an integrated biogeophysical and social asset dataset development and analysis; (2) environmental performance assessment via review of existing life cycle assessment studies, labeling and disclosure policies and standards; (3) review regional bioenergy stakeholder perceptual issues, develop stakeholder sample frames and create preliminary protocols, constructs, and interview instruments for pre-testing; (4) operationalize the informed stakeholder data collection regarding perceptions of a regional woody biomass-to-biofuels industry; (5) refine operationalization to triangulate informed stakeholder data with biogeophysical and social asset measures into a community asset assessment model (CAAM) for subsequent refinement and use; (6) define the market opportunity for biojet including supply chain perceptions and issues; (7) develop streamlined, hotspot, life cycle-based methods for assessing environmental performance of aviation fuels for policy and private procurement; (8) define the market opportunity for select intermediate/ co-products including supply chain perceptions and issues; and (9) examine select intermediate/ co-products and allocation of methods influencing the environmental assessment and reporting of aviation fuels.

Task SM-EPP-1.1 "Public" stakeholders:

Examination of opportunities and barriers for a regional approach to bio-aviation fuels and co-product system requires an assessment of public and informed regional bioenergy stakeholders to develop a social license. The EPP group will develop multiple empirical quantitative measures for core dimensions of creative capacity and social capital to measure community-level resilience and adaptability to change. In addition, EPP will contribute to the analysis of physical asset constraints through GIS application, and explore potential NARA community concerns to better understand key supply chain community issues with regard to regional bioenergy infrastructure projects.

Task SM-EPP-1.2 –. Review sustainability approaches:

Examination of opportunities and barriers for a regional approach to bio-aviation fuels and co-product system also requires an assessment of environmental performance to ensure technologies meet policy and market requirements. The EPP group will review existing life cycle assessment studies of aviation biofuels and related technologies, public and private labeling, disclosure and certification standards, and renewable energy socio-political analyses. Specifically, EPP will examine the role of procurement and pre-commercial procurement policy in facilitating the improvement of environmental performance and market development of aviation biofuel technologies.

Task SM-EPP-1.3 – Review regional Bioenergy Stakeholder Perceptions:

While scientific, infrastructure, and community asset development are significant and important to the success of this emerging industry; key questions must also be addressed regarding the perceptions, experiences, trust and potential acceptance/rejection of this emerging industry by local informed stakeholders. This task will examine previous research to better understand salient issues, stakeholder groups, mixed methods measurement constructs and preliminary protocols for conducting relevant stakeholder research.

Task SM-EPP-1.4

This task operationalizes informed stakeholder mixed-method surveys in the Western Montana Corridor and the I-5 Corridor (West Side).

Task SM-EPP-1.5

This task is scheduled to begin Q1 – '14. One goal of tasks 1, 3 and 4 is to refine this work into a usable model for subsequent application to addition NARA region and national sites. This will be accomplished through additional community-level stakeholder interviews, as warranted. Ultimately, a refined community asset assessment model (CAAM) is envisioned that may be applied to biofuel development issues throughout the NARA region and to other U.S. regions. This model may then be re-calibrated to apply to other US regions and to additional community asset situations, such as preparedness and response to wildfire.

Task SM-EPP-1.6 – Techno-Market Assessment: Jet Fuels:

One particular area of the aviation fuels space is biojet. This research will specifically target the supply chain aspect of biojet, from biorefinery to flight. Opportunities for utilizing petroleum industry supply chain networks, and the challenges that must be overcome to bring biojet to commercial scale, will be examined.

Task SM-EPP-1.7 – Economic, Environmental & Social Assessment: Jet Fuels:

Working closely with the life cycle assessment (LCA) team, streamlined hotspot methods will be developed to estimate likely changes to CO_2 and water use performance within the isobutanol pathway and across aviation biofuel pathways likely to be available to procurers.

Task SM-EPP-1.8 - Techno-Market Assessment: BioProduct Polymers:

This task is scheduled to begin Q3 – '13; however, due to leadership requests, a Spring semester '13 graduate course at Penn State to jump-start this effort is being used.

Task SM-EPP-1.9 – Economic, Environmental & Social Assessment: BioProduct Polymers:

Given the wide variety of design configurations of a regional advanced biorefinery, pathways including intermediate product diversion and co-product production will be assessed through parameterization of the streamlined LCA tool developed in Task 7. Specifically, allocation and displacement methods will be developed to account for energy and non-energy intermediate/co-products. These approaches will inform policy and market programs seeking guidance for procurement and sourcing, as well as improved consequential approaches to LCA (changes to relevant environmental flows in response to possible decisions).

Activities and Results

Task SM-EPP-1.1. "Public" stakeholders (SHs): demographic, psychographic, and market-specific assets through dataset analysis (Leigh Stowell, Rupasingha, and Roper-Putnam). (N. Martinkus, W. Shi, N. Lovrich, J. Pierce, M. Gaffney, S. Hoard, P. Smith, M. Wolcott)

A refined biogeophysical (BGP) and social asset analysis focusing on one of the NARA supply chain sub-regions -- Western Montana Corridor, to predict bioenergy behaviors has been completed. This work has updated the retrospective analysis (RA) with paired comparison of previous collective efforts and results in the NARA region. RA demonstrates how the various NARA datasets provide predictive capacity of high and low sites. The refinement of the BGP criterion and the social asset dataset, which currently contains 542 column variables for all 3,108 U.S. counties, has been completed. Further factor analysis on the selected social asset indicators identified in RA has been conducted, which resulted in one single index -- Social Asset Factor Score -- providing an overall summary indicator of social assets that can be more efficiently employed than multiple separate indicators. This single social asset index has been incorporated into the Weighted Overlay Analysis (WAO) conducted by the biogeophysical team members. The WAO is used to solve multi-criteria problems such as site selection and suitability models.

The Western Montana Corridor (WMC) was used as a test case for integrating biogeophysical and social assets for the NARA project. The following publication has been accepted and is in-press to (the journal of) Biomass & Bioenergy:

INTEGRATING BIOGEOPHYSICAL AND SOCIAL ASSETS INTO BIOMASS–TO-BIOFUEL SUPPLY CHAIN SITING DECISIONS

Natalie Martinkus, Wenping Shi, Nicholas Lovrich, John Pierce, Paul Smith, and Michael Wolcott

Acknowledgement: This work, as part of the Northwest Advanced Renewables Alliance (NARA), was funded by the Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30416, USDA National Institute of Food and Agriculture.

ABSTRACT

Second-generation biorefineries that utilize lignocellulosic feedstocks for producing biofuels are emerging with the aim of contributing to society's need for a sustainable liquid fuel source. Decision tools are needed to aid in siting facilities based not only on biogeophysical (BGP) assets such as feedstock and infrastructure requirements but also on the social assets of communities supporting these facilities. The research presented here provides a framework for a quantitative approach for biorefinery siting and decision-making. A Social Asset Factor (SAF) score is created to assess a community's capacity for collective action and adaptation to change. This research validates the social asset measures used for facility siting at the county level through retrospective prediction analysis.

A biofuel supply chain within the Pacific Northwest region of the U.S. is examined as a test case. Interpretation of GIS analysis indicated that eleven counties in the supply chain region possess woody biomass resources and are located in proximity to key infrastructure. Eight of the eleven counties have population centers greater than 1,000 and also lie on major road and rail. From these eight counties, a top two-thirds survival analysis on the SAF score resulted in five counties that possess high BGP characteristics and varying levels of social asset characteristics. Of the five counties, only Flathead, MT and Missoula, MT have high SAF scores and are located closer to petroleum refineries than the other three counties. Thus, based on this analysis, Flathead, MT and Missoula, MT exhibit the highest potential for siting a biorefinery.

Keywords:

Social capital, creative leadership, public health status, collective action, biogeophysical assets, biomass-to-biofuels supply chain, GIS, siting decisions, social asset factor score

GO-FORWARD PLANS:

1) The biogeophysical assets methodology in the WMC region will be revised for the MC2P region and applied to the entire NARA region for direct comparisons.
2) Additional retrospective analysis with greatly expanded NARA region data sets is underway to better ascertain appropriate social asset metrics and weightings to deploy in the MC2P region – for potential use in the entire NARA region for direct comparisons.
3) The NARA Region Informed Stakeholder Assessment survey analysis is underway for potential tie-in to this task.
4) A team has been established to survey NARA-region jet fuel Stakeholders for potential tie-in to this task.

Items #2, #3 & #4 represent potential triangulated validation ("ground-truthing") of the national data using the more local data sets to further test and validate the utility of the national data with the ultimate goal of developing a predictive Community Asset Assessment Model (CAAM) to be applied elsewhere in the NARA region and across the nation for similar community assessment without the need for additional primary data collection.

Task SM-EPP-1.2. Review Sustainability Approaches: ecolabels, stds., product claims, LCA/EIO data sources & models. (R. Pelton, Luyi Chen, and T. Smith)
Work has been completed identifying co-products and intermediate products that are produced during the wood-IBA-IPK life cycle, and the type of application that these products will be used for (e.g. activated carbon). This next quarter will focus on identifying common bio-product attributes related to these co-products/intermediates that indicate how the market signifies environmental preference.

Task SM-EPP-1.3. Review Regional Bioenergy Stakeholder Perceptions: issues, influential groups, etc.; NARA site personal/focus group interviews and analysis. (J. Moroney, T. Laninga, N. Martinkus, M. Gaffney, S. Hoard, K. Gagnon, V. Yadama, P. Smith)
In recent years, there has been significant attention paid to the technology required for the creation of biofuels from various cellulosic feedstocks. In the Pacific Northwest region of the US, this focus has resulted in several alliances addressing numerous feedstocks relevant to the region (safnw.com; nararenewables.org; ahb-nw.com). This research addressed the impacts of social acceptance on biofuel project success. While scientific, infrastructure, and community physical asset development are significant and important to the success of this emerging industry, key questions must also be addressed regarding the perceptions, experiences and potential acceptance or rejection of this emerging industry by local stakeholders and communities.

The collaborative efforts between EPP, Education, and Outreach teams to develop a process for NARA Community site selection (1.3.1) was completed in 2013. Accordingly, two supply chain regions were identified – the Western Montana Corridor (WMC) and the Cascade-to-Pacific (C2P) (later becoming MC2P) (Figures SM-EPP-1.2 & SM-EPP-1.3). Information generated contributed to the identification of the WMC and the MC2P – and ultimately, to Task SM-EPP-1.4.

Task SM-EPP-1.4. "Informed" stakeholder interaction/operationalization (pop's., sampling, constructs, protocols). (J. Moroney, T. Laninga, M. Gaffney, and S. Hoard, K. Gagnon, P. Smith)
Informed Stakeholder Assessment Research Development

Prior research studies addressing salient biomass to bioenergy topics and issues were used to guide development of the research instrument (Adams et al, 2011; Becker et al 2011; Clement & Cheng, 2011; Davenport, 2007; Halder, 2011; Halder et al 2010; Mayfield et al 2007; Nelson, 2005; Plate, Monroe & Oxarart, 2010; Stidham & Simon-Brown, 2011; Tagashira & Senda (2011); Upham & Shackley, 2007). Prior research indicates that perception and acceptance are intertwined and multifaceted. Perceptions are impacted by education, experience, knowledge, values, beliefs, social background and identification with the community. Perceptions impact whether or not there is acceptance. Acceptance is also affected by communication, trust, environmental concerns, local community impact and knowledge, experience and education.

Previous studies utilized a variety of research methods that included both quantitative and qualitative measures. Some of the salient issues in prior research include regional combined heat and power plants, utilization of forest materials, facility siting, social acceptance, forest management perceptions, bioenergy perceptions, trust, communication, local community impact and environmental concerns. A mixed methods approach was employed to administer the survey which consists of open ended, multiple choice and Likert scale questions. The instrument was pilot tested using in-person interviews with 10 WMC informed stakeholders. Using pilot test feedback and in collaboration with other USDA-NIFA Agricultural and Food Research Initiative Grant researchers the instrument was refined. Those collaborators include: Dr. Stanley T. Asah, Advanced Hardwood Biofuels Northwest (AHB), University of Washington; Dr. Sudipta Dasmohapatra, Southeast Partnership for Integrated Biomass Supply Systems (IBSS), North Carolina State University; and Dr. Darin Saul and Priscilla Salant, University of Idaho Wood-Based Biofuels Project.

This study focused on potential NARA supply chain stakeholders (SH) whom are deemed to be relatively informed regarding one or more critical elements within the biomass to biojet industry supply chain concept. The supply chain has three main nodes: feedstock, pre-conversion and conversion, and marketing and distribution. This project focuses on feedstock through pre-conversion and conversion. Marketing and distribution research is being completed by other NARA EPP researchers.

Development of the SH group list began with SH groups utilized in prior research. For reference, the groups used by Mayfield et al 2007 were renewable energy, economic development, forest management, and the forest products industry. Becker et al 2011 defined the SH groups as federal, state, tribal, and local government staff; loggers; manufacturers; community leaders; and environmentalists. Lastly, the SH groups used by Stidham and Simon-Brown 2011 were community organizations, conservation organizations, elected officials (staff of), energy utilities, federal agencies, forest industry sector, informed energy participants, state agencies, and tribal organizations.

Starting from a broad perspective, 21 stakeholder groups were identified, then categorized into three overarching categories for our sample frame:
1) government/leadership
2) environmental/conservation
3) industry (feedstock, pre-conversion and conversion)

The survey was distributed to stakeholders in the Western Montana Corridor (WMC), Cascade to Pacific (C2P), and the Columbia Plateau (CP) as part of an ongoing partnership with University of Idaho's Wood-Based Biofuels Project. As of survey completion in mid-November 2013, the overall response rate for all regions was 37%. During Phase 1 of surveying, 53 out of 151 surveys were completed by stakeholder in the WMC, and 19 out of 109 surveys were completed by C2P stakeholders. During Phase 2 of surveying, 13 out of 59 surveys were completed by WMC stakeholders, 68 out of 158 surveys were completed by C2P stakeholders, and 91 out of 391 surveys were completed by C2P stakeholders. During Phase 3 of the surveying process, 610 surveys were sent out to all non-respondents from all regions. Eighty surveys were completed as a result of these mailings.

Additional efforts were made to boost response rates of environmental and tribal groups. Both of these stakeholder groups had lower response rates than other stakeholder groups. Working with Laurel James and Bob Dingethal, key contacts from the 2013 annual NARA meeting in Corvallis, allowed us to compile contact information for an additional 26 environmental non-governmental organizations (ENGOS) and 14 tribal contacts. An email with the survey link was sent to each new contact, followed by a reminder email approximately one week later. Approximately four surveys were completed as a result of these additional efforts.

Non-response bias testing has been completed and analysis of these surveys in progress. Comparisons were made between participants who completed the survey the first time they were contacted and participants who completed the survey after several contact attempts were made. Stakeholders who did not complete the survey were contacted via phone and asked to complete a short (5-10 min) version of the survey. The results generated by the phone surveys are being compared to the overall survey results to determine if there are any statistically significant differences between early and late respondents. Preliminary analysis of survey data was conducted prior to the annual NARA meeting in Corvallis and presented as a poster. Overall analysis of survey data is currently in-progress.

Task SM-EPP-1.5. Refine Operationalization – Social Hotspot Analysis. (J. Moroney, T. Laninga, M. Gaffney, and S. Hoard, N. Martinkus, W. Shi, N. Lovrich, and J. Pierce, P. Smith, M. Wolcott)

PREVIOUS RESEARCH

Task 1.5 continues from task 1.1 which developed a methodology to assess biomass-to-biofuel supply chain sites through the integration of biogeophysical (BGP) and social asset analysis. Task 1.1 addressed the NARA WMC supply chain region, resulting in the publication outlined earlier in this report. As the NARA EPP team has advanced in knowledge and experience, a refined operationalization is proposed for the NARA MC2P supply chain region in 2014. This refined approach includes both the BGP and the social assets. The social asset refinement includes several existing data sets from previous Division of Governmental Studies and Services (DGSS) community surveys in the NARA region to serve as reference comparisons for both the newly-collected data from the current stakeholder surveys (Moroney and Laninga) and national data sets already used to develop the social license measures described in Task 1.1. In addition, DGSS has substantially completed a literature review that will inform the further development of a retrospective prediction analysis of the three types of data (national, existing DGSS, new research) to develop a model for predicting community suitability for NARA/biofuel engagement.

Task SM-EPP-1.6. Techno-Market Assessment: Jet Fuels. (S. Wertz, I. Iborrola, K. Dahmann, L. Fowler, M. Gaffney, S. Hoard, S. Rijkhoff, T. Laninga, and J. Moroney, P. Smith)

PREVIOUS RESEARCH

A final literature review of global biofuels policies, with an emphasis on how these legislative tools will impact the industry moving forward is in progress. Well over 100 documents have been collected pertaining to biofuel law and policy. The information ranges from Government publications to industry reviews of the development progress. The information centers on aviation biofuel and includes documents discussing biofuel policy more generally and European Union policy documents. A specific focus will be on the downstream portion of the biofuels supply chain in the U.S., from biorefinery to retail outlet. Understanding stakeholder attitudes and perceptions with respect to biofuels policy mandates and how these affect the biofuels industry at a macro level will also be explored.

A preliminary assessment of the Renewable Fuel Standard (RFS) and Renewable Identification Numbers (RINs) has also been conducted (Wertz, 2013) and distributed for the use of select NARA team members. The report addresses issues such as RFS qualifying feedstocks, Renewable Volume Obligations (RVOs), RIN markets, and Equivalence Values (EVs). This initial work is currently on hold, but will be refined and updated when Steve Wertz, PhD student on the NARA project, returns from military obligation.

Earlier reports have identified potential biojet buyers in the NARA region including military, commercial, general, freight carriers, and foreign country segments. The main jet fuel products have also been identified. They are Jet-A, Jet A-1, and Jet B for commercial flights worldwide, while JP-5 and JP-8 are the primary jet fuel grades for the U.S. military. DLA Energy has been identified as the primary purchaser of fuels for the U.S. military. A preliminary dataset encompassing all US airports is being refined.

Exploratory visits where performed in September 2013 by Stephen Wertz and Ibon Ibarrola with key stakeholders at the Seattle-Tacoma International Airport (SEA), Portland International Airport (PDX), EUG (Eugene) and CVO (Corvallis). One important outcome was the identification of principal SH's in the jet fuel supply chain delivery systems at these airports. In addition, these exploratory interviews provided insight into aviation fuel logistics and ownership at key supply chain nodes. SH interviewees included Dean William, Fuel Facility and Hydrant Operator Manager at Swissport (SEA), Kai C. Sorenson, Commercial Sales Manager at EPIC Aviation, LLC and Jay Long, Director of the Fuel Consortium Administration at SEA and PDX. SEA and PDX consumed 55% and 21% of the NARA region's jet fuel in 2010, respectively (MacFarlane, Mazza & Allan, 2011). All jet fuel is currently delivered to SEA through the BP managed Olympic pipeline from the 3 refineries in the Anacortes area. PDX obtains aviation fuel pipeline (Olympia pipeline to Seattle and Kinder Morgan pipeline from Seattle to Portland) and barge at about a 50% - 50% ratio (MacFarlane, Mazza, & Allan, 2011; Kinder Morgan System Map, April 2013). Once the product is delivered to the airport's fuel storage sites, it is then distributed to the actual airplane via underground pipelines or truck. The management of these refueling operations can differ between airports. SEA is managed by SeaTac Fuel Facilities, LLC, who then subcontracts out the fueling operations to the fuel system operator, Swissport Fueling, Inc. who manages SEA's depot and hydrant systems (Port of Seattle, 2013).

In the Fall 2013, CLH Aviation was added as an Affiliate Member to the NARA team. CLH Aviation has been dedicated to the storage and logistics of hydrocarbons in Spain for over 85 years and is an active member of the Initiative Towards sustainable Kerosene for Aviation (ITAKA), a collaborative European Union project to support a camelina-to-biojet supply chain in Spain. Comparisons and contrasts between ITAKA and NARA may prove illuminating. In ITAKA, the neat product will be discharged from a barge and blended at the CLH Cartagena, Spain facility with conventional jet fuel for subsequent transport through a multiproduct pipeline to CLH Alicante Fuel Facility. Blended biojet will be stored and recertified (analysis done to jet fuel to assure quality before dispatching) in Alicante, Spain for final delivery through a dedicated jet fuel pipeline to the Alicante Airport Fuel Facility, also operated by CLH.

CURRENT RESEARCH

Biofuels Policy

The current emphasis is on understanding biofuels policies and the impacts of such regulations on the development of the biofuels industry. The three main global biofuels markets are the United States, Brazil, and the European Union (EU), and ethanol has largely been the sole biofuel product to-date. In 2010, the U.S. produced approx. 13.3 billion gallons of ethanol, while Brazil and the EU produced approx. 6.9 and 1.2 billion gallons, respectively, and since 2004 the U.S. has been the top global ethanol producer, surpassing Brazil at that time (RFA, 2013) (Figure SM-EPP-1.5).

Policies in each of these three primary regions have developed independently, and they have evolved in conjunction with certain political objectives in mind. Both in the U.S. and Brazil, biofuels policies had their origins in the oil disruptions of the 1970s, and energy security and stability was the initial driver of this new energy source. Brazil has had success in transforming its transportation infrastructure to accommodate its sugar-cane ethanol industry, although policy swings have still created uncertainty in the Brazilian markets, largely due to inexpensive petroleum in this region. The U.S. corn-based ethanol industry has developed with the help of tax credits that have been continuously extended over the years. Recently, however, there has been extensive debate in political circles due to the looming 'blend wall', a situation where current transportation fuel infrastructure can no longer support higher biofuels blends. There is much debate as to when this tipping point will arrive, but the EPA has already suggested lowering the biofuels mandates under RFS2 for 2014 (EPA, 2013). The EU is a newcomer to the biofuels policy arena, relative to the U.S. and Brazil, although their 'Renewables Directive' (2009/28/EC) under the 2009 Climate and Energy Package, a.k.a. 'the 20-20-20 targets', have some very ambitious goals. By 2020 the EU is looking to achieve a 20% reduction in gross energy consumption through energy efficiency improvements and a 20% share of renewable energy in gross energy consumption, and transportation fuels are also targeted for a 10% renewable energy share by the same year (EU, 2009).

The review includes the history of US Federal renewable energy fuel policy, current Federal policy affecting the industry and state policy developments. Internationally, the review includes a collection of European Union policy papers, enacted policies, and literature that assesses the effect of the newly created industry incentives. With this information, the aim is to compare and contrast across national borders as well as across the United States - as each state and/or region has developed an approach to facilitate industry development. The main focus of is on downstream production of biofuels while keeping in mind the importance of upstream development, feedstock production, and continued research.

Biofuels-to-plane logistics & Stakeholder (SH) perceptions

Fueling operations and management are still being assessed at PDX and follow up interviews at both SEA and PDX are planned for Fall 2014. The procurement piece of the jet fuel supply chain, which often involves the use of fuel consortia between airlines to contract for lower fuel prices, is also in progress.

Relevant airport operational and logistics literature was reviewed, particularly as it pertains to the implementation of the biojet in the aviation fuels supply chain. Key documents include:
1) ATA 103 (Former Air Transport Association, actually Airlines for America)
2) ACRP (Airport Cooperate Research Program) Re-

ports 46, 48, 60 and 83;
3) IATA Reports on alternative fuel (2010, 2011 and 2012);
4) IATA Guidance material for biojet fuel management;
5) SAFN Reports and key recommendations;
6) CAAFI Research & Development Team papers.

The following jet fuel logistics, policy, and social science team has been formed to develop and administer a survey of key aviation fuel supply chain stakeholders in the NARA region (in-progress):

- Lara Fowler, J.D. and Kristina Dahmann, J.D., PSU's Dickinson's School of Law;
- Michael Gaffney, J.D., Dr. Season Hoard, Christine Sanders, and Sanne Rijkhoff, WSU's DGSS;
- Dr. Tammi Laninga and Ms. Jill Moroney, U of ID;
- Mr. Ibon Ibarrola, CLH Aviation and Polytechnic Univ., Madrid, Spain; and
- Dr. Paul Smith and Min (Cathy) Chen, PSU

Primary data collection will identify populations and target key SHs in the NARA region. SHs include airport management, FBOs, fuel traders/brokers, and terminal and pipeline operators, among others.

In addition, this effort will begin to examine outputs from the Initiative Towards Sustainable Kerosene for Aviation (ITAKA) project, as available.

Secondary data:
1) Complete SH matrix from refiners to end users for each airport (populations of interest);
2) State-of-Art for the biojet industry, including ASTM approved specifications, real flight trials for performance of the biojet, and potential benefits/challenges for adoption; and
3) SH survey/ interview background data regarding concerns, perceptions and opinions.

Nearly all of the jet fuel is supplied at airports (commercial, private & military). 137 airports in the NARA regions (www.faa.org) were identified; and 39 of those do not provide Jet fuel or fuel at the airport (www.airnav.com). The following 4 categories, dividing the airports by their percent of enplanements in the 4-state NARA region, are defined in Table SM-EPP-1.1.

Airports of category 1 (SEA and PDX) have over 77% of the commercial aviation enplanements in the NARA region. In addition, SEA and PDX are the only airports in the NARA region using a hydrant system to supply fuel to aircrafts. Adding the 2 airports in category 2a (Spokane and Boise) to category 1 results in over 86% of the region's enplanements; adding the 7 airports in category 2b results in over 95% of all NARA region emplanements. Additional dataset research and management has provided key information regarding airport management, fuel consortiums, into-plane agents, fuel suppliers/traders, pipelines in the PNW and Terminal operators (www.airnav.com; airport, ITP agents, FBOs and traders webpages).

A draft questionnaire is under development to better understand jet fuel logistics SH issues relevant to the adoption and diffusion of biojet into the commercial aviation sector in the NARA region.

Task SM-EPP-1.7. Techno-Market Assessment: BioProduct Polymers. (R. Pelton, Luyi Chen, T. Smith, Min Chen, S. Cline, P. Smith)
A parameterized model of the co-products and intermediate products has been established and is based on the baseline LCA model developed by Indroneil Ganguly. Lignin used for activated carbon and isobutanol used for paraxylene production and ultimately bio-PET bottles, are the first co-products/ intermediate products from the biojet life cycle that are being investigated from an economic and environmental perspective. See section 1.9 for preliminary environmental analyses on these products.

Lignin Applications:

CHP - The combined heat and power (CHP) application is currently the primary use for lignin, and serves as a baseline with which to compare the alternative applications.

Lignin based products have been in the research pipeline since the 1930's (McCarthy, 1999). Since then scientists have yet to find an economical product to produce out of lignin; creating a stigma that "anything can be made out of lignin except money." Current US biorefineries are struggling with finding and maintaining value-added applications for lignin beyond CHP. Many products can be manufactured from lignin; however, in most cases the lignin must be purified creating an extra step where a loss of funds occurs (McCarthy, 1999).

Activated Carbon - One lignin market with large potential is activated carbon for air purification; specifically for the sequestration of mercury from flue gas streams exhausted by coal-fired electric generating units. Activated carbon injection systems have previously been discussed by Sjostrum et al. (2010). Activated carbon is a porous material that is used in the purification of various medium including water, air, food processing, and chemical processing (Norit, n.d.). Since activated carbon is versatile it has many applications as a substitute product in a wide variety of industries.

The amount of activated carbon that could be produced from the Gevo lignin by-product per year represents just 3-3.5% of the current global activated carbon market demand, reinforcing the attractiveness of the activated carbon application to serve as a 'lignin-sink'. Using the Gevo lignin for activated carbon is also attractive environmentally as it results in a more favorable environmental profile of the iso-paraffinic kerosene (IPK) jet fuel due to the emission credit that is generated by displacing activated carbon produced from coal.

Activated carbon has been recognized as a high-growth market largely because of the EPA's release of the Mercury and Air Toxic Standards in 2011. This standard will require coal-fired power plants to capture as much as 90% of mercury released into the atmosphere. In 2012 the US activated carbon market was valued at $1.9 billion, at the current compound annual growth rate (CAGR) in 2019 the activated carbon market is expected to be valued at $4.2 billion (PRWEB 2013) due largely to the new EPA emissions standards. Further, according to Transparency Market Research (2013), the powdered activated carbon CAGR is estimated at 13% (PRWeb, 2013).

Sugar Applications:

WHITE PAPER: BIO-BASED C4 AND C8 MARKETS

Paul Smith (EPP); NARA Leadership Team Meeting Brief, 1/10/14

Background:

- Global petrochemicals market = $472B in 2011; to $791B in 2018 (Transparency Research, 12/19/13).
  - China = >25% of global consumption in 2011; China + Asia/Pacific = >45%.
  - Ethylene = 28% of global consumption.
  - Largest petrochemical mfrs. = BASF, Sinopec, and Exxon Mobile = combined 20% mkt share; top 10 ~50% in 2011. Other major players = Chevron, Phillips, & Dow.
  - Biobased chemicals = $20B by 2020 (Pike Research)… at $2K/ton = 10M tons.
- Hot trend = feedstock companies make renewable sugars (Renmatix) – to sell to synthetic biology companies (Gevo) to convert to products like isobutanol. Focus on core competencies!
  - Investment trend toward intermediate companies (like Renmatix). This allows for less concern re: RFS! To date, the RFS has driven the investor focus on ethanol biorefineries.
  - Big issue = STABILITY. Renewable sugars must be carefully managed in storage & transport to ensure the chemistry doesn't evolve –to change the spec.

…From Biofuels Digest's Top 10 Biofuels & Biobased Predictions for 2014 (Jim Lane, 1/6/14): "Goodbye, stand-alone ethanol/DDGS plant!" If RFS2 pressures on the ethanol industry were not enough, think of all the technologies now available to turn ethanol plants into integrated biorefineries producing either a more significant array of co-products or a higher-value primary molecule. Whether it is corn oil extraction, algae add-ons, isobutanol or n-butanol conversion, switch to milo/biogas, or adding on a source of fermentable cellulosic sugars from crop residues or bagasse— we don't expect that there will be a sub-50 million gallon ethanol plant surviving that won't have announced a deal or being in furious negotiation to do so, to expand its product set.

C8 & C4 Markets:

1) C8s (eight-carbon molecules). PET (polyethylene teraphthalat) is the fastest growing (partially or fully) bio-based, bio-polymer. Paraxylene (PX – C8) is the platform molecule for PTA (terephthalic acid), an intermediate to PET. Coca-Cola is partnering with Gevo (and Virent) to make affordable renewable PX from biobased isobutanol for their Plant BottlesTM. Coca-cola, Ford, Heinz, NIKE, and P&G formed the Plant PET Collaborative (PPC) in 2012 to accelerate the development of 100% plant based PET. The supply chain impact on C8s is obvious.

2) C4s (four-carbon molecules). Relevance has increased due to cheap natural gas.

- Due to low cost, natural gas liquids (particularly ethane, but smaller amounts of propane and butane) are being substituted for petroleum as a chemical industry feedstock (Voegele 2010; Nexant 2012).
- Nat gas – ethane fed into crackers (split molecules under high temp.) to make ethylene; may add 12 – 17B lbs. of ethylene capacity in N. America by 2017 (Esposito 2012; Singh and Swamy 2012). Also, naphtha, a byproduct of crude oil, is cracked to ethylene. NOTE: this process results in high greenhouse gas (GHG) emissions.
- This effectively moves the petrochemical industry toward ethane and away from naphtha as a feedstock (Pan 2013). Therefore, a lot of cheap ethylene (C2s) and propylene (C3) molecules; fewer expensive butylene (C4) molecules (Voegele 2010).
- In other words, if natural gas remains cheap – lots of ethylene (C2s) but shortage of C4s. More natural gas = more ethane = less naphtha = C4 shortages (Singh and Swamy 2013; Voegele 2010). This scenario presents opportunity for renewables.

Four-carbon molecules - Butadiene and 1,4-butanediol (BDO) – (think tires, 6,6 nylon, & spandex):

1. Butadiene = $20 billion plus global market (Lane 2013):
a. Primary market = butadiene is polymerized to produce synthetic rubber - tires, hoses, seals, carpet backing, and medical latex;
b. Smaller Markets:
i. Molded plastics for consumer appliances (i.e., vacuum cleaners, kitchen appliances);
ii. Nylon 6,6 for textiles, engineered resins (i.e., auto engines);
iii. Intermediate for adhesives and specialty chemicals.
2. BDO = Half of BDO goes into (intermediate for) elastic fibers (spandex); also plastics and polyurethanes. BASF is the largest producer.

Select Key Players:

1. Gevo [corn, sugar cane (biomass?)] to Bio-paraxylene (bioPX) and Isobutanol. Their C4 molecule platform can be converted to solvents, coatings and butenes for synthetic rubber, lubricants, PMMA, propylene, xylene, and PET (http://www.gevo.com/our-markets/isobutanol).
2. Butamax (corn, sugar cane, or yeast) - JV between BP & Dupont; NOTE: Gevo and Butamax are currently in litigation, thus reinforcing the value of this space.
3. Cobalt Technologies (pulp wood & sugar beets to n-butanol; biomass-to-butadiene path competitive with petroleum-based butadiene) – partnering with two Asian chemical co's. – on-stream by 2015.
4. Zeachem (woody biomass & ag. residues)- cellulosic biorefinery for fuels and chemicals; Boardman Demo facility (250,000 gals./yr.); AHB partner w/UW and GreenWood Resources.
5. Genomatica (conventional sugars to BDO) - Joint venture with Versalis and also BASF licenses.
6. Renmatix – PlantroseTM Process = PlantroTM chemicals = intermediaries; joint venture with BASF; collaboration with Virent on biobased packaging using PX; joint venture with UPM.

Bioplastics:

According to previous NARA EPP quarterly reports, major research efforts have been focused on techno-market assessment of selected bio-based polymers, initiated January 2013. A specific emphasis was on the bioplastics industry, including the global market and growth trend for the overall bioplastics industry and comparisons between bioplastics and traditional plastics. Bio-PET30, projected to account for about 76% of total market share in 2017, is analyzed regarding value chain and market-driven factors.

In this past quarter, a literature review was conducted of biorefineries within the United States, with an emphasis on both the energy-driven biorefineries and material-driven biorefienreis (such as renewable chemicals, biopolymers, etc.). This work remains in progress and serves as a preliminary step to better understand the evolving structure of biorefineries and supply chain value propositions for competitive biopolymers emanating from biorefineries.

PREVIOUS RESEARCH

Bioplastics as an alternative to petroleum-based plastics have gained increasing recent attention due to the worldwide interest in sustainability, primarily defined as reducing energy use and related environmental impacts (Rivas & Galia, 2010). In the NARA EPP research, two kinds of bioplastics are in focus: bio-based, not biodegradable plastics, aka, durable bioplastics; and biodegradable bioplastics (Figure SM-EPP-1.6).

European Bioplastics (EB, 2013a) estimates that the annual global production of bioplastics will increase from 1.40 million tonnes in 2012 to 6.19 million tonnes by 2017 (Figure SM-EPP-1.7). And the global bioplastics market will reach US $7.7 billion by 2016 (Mind, 2012).

Growth by bioplastics types

The top three bioplastics in 2012 by production capacity were Bio-PET30 (38.8%), Bio-PE (14.3%), and PLA (13.4%) according to the results of European Bioplastics (EB, 2013b) (Figure SM-EPP-1.8). By 2017, Bio-PET30 is anticipated to lead the market, accounting for 76.4% of total bioplastics capacity (EB. 2013c). PLA is projected to rank second, with 6.9% of 2017 total production capacity (Figure SM-EPP-1.8).

Growth by Market Segments

Bioplastics are making progress into a wide variety of markets, from agricultural applications to technical application to consumer goods (EB. 2013a) (Table SM-EPP-1.2).

Recyclable Bio-PET

PET (Polyethylene Terephthalate) is commonly produced by the esterification of purified terephthalic acid (PTA) and monoethylene glycol (MEG) in an esterification reactor and then by polymerization in a polycondensation reactor (Schut, 2012). Para-xylene (PX) is a precursor of PTA production, which accounts for 70% of PET monomer component. The other 30% of PET is composed of monoethylene glycol (MEG), which already have bio-based renewable alternative (bio-MEG) in commercial market (1.7-Fig. 4) (Komula, 2011). But the aromatic PX doesn't exist except on lab scale from several companies, such as Virent's BioFromPX (www.viren.com) and Gevo from isobutanol (www.gevo.com), Anellotech from lignocellulosic biomass by high-speed pyrolysis (www.anellotech), and Honeywell UOP from agricultural waste by rapid thermal processing (www.uop.com). The challenge of cost-effectively producing 100% renewable bio-based PET is the availability of aromatic paraxylene (PX) molecule from bio-based materials.

Previous NARA EPP reports have outlined the advantages and disadvantages of Bio-PET as well as the major demand factors and leading companies. In addition, earlier reports have examined the development of 100% Bio-PET with implications regarding market potential.

CURRENT RESEARCH

Nova Institute (Baltus et al. 2013) reported that there were 247 companies at 363 locations around the world manufacturing biopolymers. Through various secondary sources, 17 bioplastics companies in N. America have been identified. Within the bioplastics industry, recyclable Bio-PET is one of the most promising applications (for bottles). A major theme in recyclable bioplastics (especially bio-PET) is strong downstream value chain partnerships between manufacturers of biochemicals/bioplastics and global consumer products companies (e.g., Pepsi, Coca-Cola).

In order to further understand supply chain partnerships, a literature review is in progress to identify and categorize biorefineries (BR) within the United States. A method for classifying U.S. biorefineries issbeing developed based on value stream outputs and feedstock inputs as follows:

- 1st generation biofuel BR (biorefinery),
- 2nd generation biofuel BR,
- 3rd generation biofuel BR, and
- 1st and 2nd generation non-fuel BR.

Additional literature reviews will address biorefinery feedstock input and product output options, the decision-making process for these practices and potential market-based implications on product mix decisions, new product development potential, competitive advantage, and social responsibility.

Task SM-EPP-1.9 Economic, Environmental and Social Assessment (R. Pelton, L. Chen, J. Schmitt, T. Smith)

Environmental Assessment: Activated Carbon

A second iteration calculating the environmental preference of using the insoluble lignin in an activated carbon application has been completed, and a comparison of using wet oxidation lignin versus SPORL lignin is made, given the differences in the quantity of insoluble lignin produced. Two major changes have been made from the first calculation, excluding the biogenic carbon from the calculation, and using the most recent lignin mass output, which is based on the Aspen model provided in early March. The ASPEN model designates that approximately 26,104 kg of lignin are generated per hour from the wet oxidation (WOX) and enzymatic hydrolysis process, whereas approximately 22,538 kg of lignin are generate per hour from the SPORL and enzymatic hydrolysis process. With approximately 8400 operating hours per year (350 days, 24 hours/day), the WOX process results in 219,276 tons of lignin solids and the SPORL process results in 189,322 tons of lignin solids. This lignin comes out of the fermentation process as fermentation residual solids (FRS) at an average of 15% solids. There are several possible ways to dry the FRS, however it was indicated through conversations with Tom Spink (NARA co-products team leader) that spray drying is a reasonable assumption since it bypasses some difficulties with mechanical pressing. Therefore, it is assume that spray drying will be used as the intermediate processing step to produce a dried lignin powder.

The amount of granular activated carbon able to be produced from the FRS lignin per year is 48,728 tons when the wet oxidation pretreatment process is used, and 42,071.6 tons per year when the SPORL pretreatment process is used (4.5 tons lignin/1 tons AC). The processing steps to produce granular activated carbon (GAC) from lignin and coal is still assumed to be the same, which means that the fossil energy required in the production steps will be equal. However, the emissions from the volatilized carbon from the coal feedstock produced during carbonization and activation must be accounted for. The CO_2 from the volatilized carbon in the lignin feedstock is excluded from the calculation because it is considered to be biogenic. Table SM-EPP-1.1 details the calculations to determine the emission credits of replacing coal-based activated carbon with lignin-based activated carbon.

The effect of diverting FRS lignin for an activated carbon application on the environmental preference of the jet fuel is determined by first, adding the additional fossil-based CHP emissions to the baseline emissions that would be generated by replacing the lignin with a natural gas substitute. The credit that is generated by displacing an equivalent amount of coal-based activated carbon with lignin-based activated carbon is then subtracted from the jet fuel emissions (see table SM-EPP-1.2). By using lignin in an activated carbon application, the IPK jet fuel CO_2e emissions decrease by about 60% and 52% from the baseline, using a wet oxidation and SPORL pretreatment process, respectively. The effect of using lignin in this particular application results in about an 85% reduction from the fossil-based kerosene baseline (for WOX) and 81.5% reduction (for SPORL), thus greatly exceeding the RFS emission reduction thresholds. Future analysis will focus on more accurately determining the differences in the activated carbon production processes between the two types of feedstock and how these differences may affect the co-product credit. Future analysis will also begin to look at alternative allocation methods.

Environmental Assessment: Bio-PET Bottles

A life cycle model of the Gevo-Coca Cola collaborative Bio-PET bottles has been established, using the default pre-treatment method of the SPORL process. A separate model of the traditional petroleum derived PET bottle has also been developed for comparison. According to Gevo Inc. and The Coca Cola Company, PET bottles are manufactured from wood-based terephthalic acid and corn-based ethylene glycol. From the Gevo isobutanol production process, isobutanol is diverted from the IPK conversion process to Silsbee, Texas to be processed into paraxylene. Paraxylene would then be transferred to Charlotte, North Carolina, the location of Coca Cola's bottle manufacturing, and be converted to pure terephthalic acid. Amorphous grade PET is formed through polymerization of purified terephthalic acid and ethylene glycol, followed by solid state polycondensation to produce bottle grade PET. The final process is injection stretch blow molding, transforming bottle grade PET to PET bottles. The production of bottle labels, packages and capsules are excluded from the system since they do not vary with bottle materials.

The preliminary results of the model indicate that 3.69 kg CO_2e is generated in the production of 1000 bio-PET bottles, compared to 4.05 kg CO_2e for manufacturing an equivalent amount of petrochemical PET bottles, resulting in approximately a 9% reduction in impact using a biobased bottle. However, this preliminary version of the bio-PET model is based on the first version of the process-flow diagram provided by Tom Spink Inc. and the life cycle inventory provided by NARA researchers Ivan Easten and Indroneil Ganguly. Future revisions will incorporate the updated version of the ASPEN models for the Gevo pretreatment process and any further life cycle inventory revisions to the isobutanol production process. Access to better data regarding the material and energy inputs for the paraxylene production process will be obtained. The economic implications of diverting a portion of isobutanol from the IPK system to paraxylene production, and ultimately, bio-PET bottles, will also be investigated, in addition to the effect that this diversion may have on the environmental preference of the IPK jet fuel.

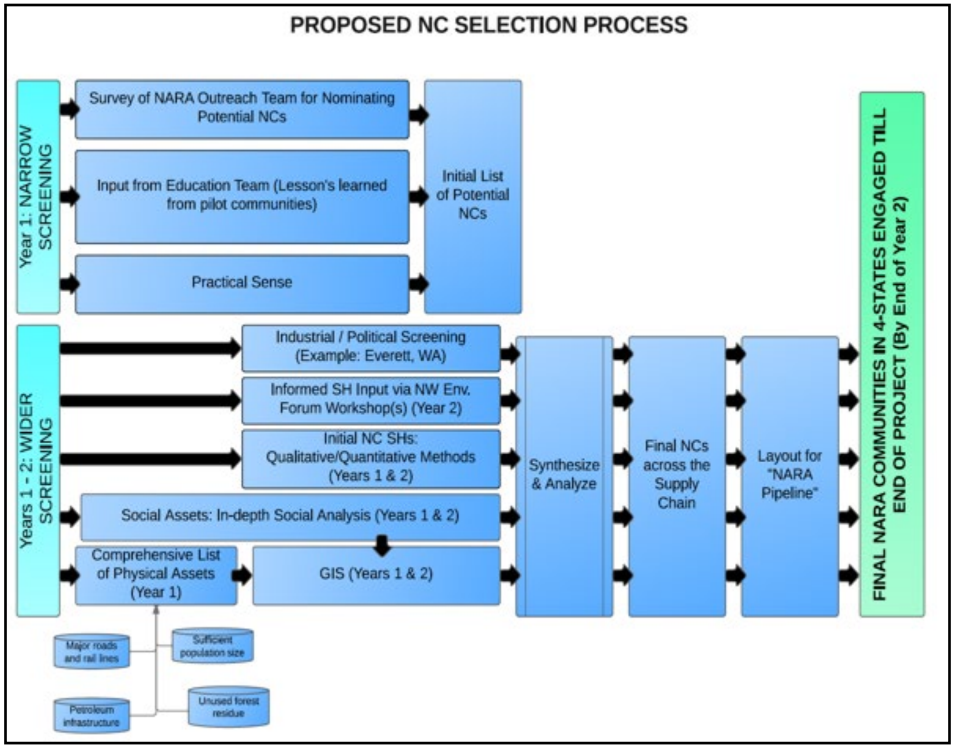

Figure SM-EPP-1.1. Proposed NARA Community Selection Process

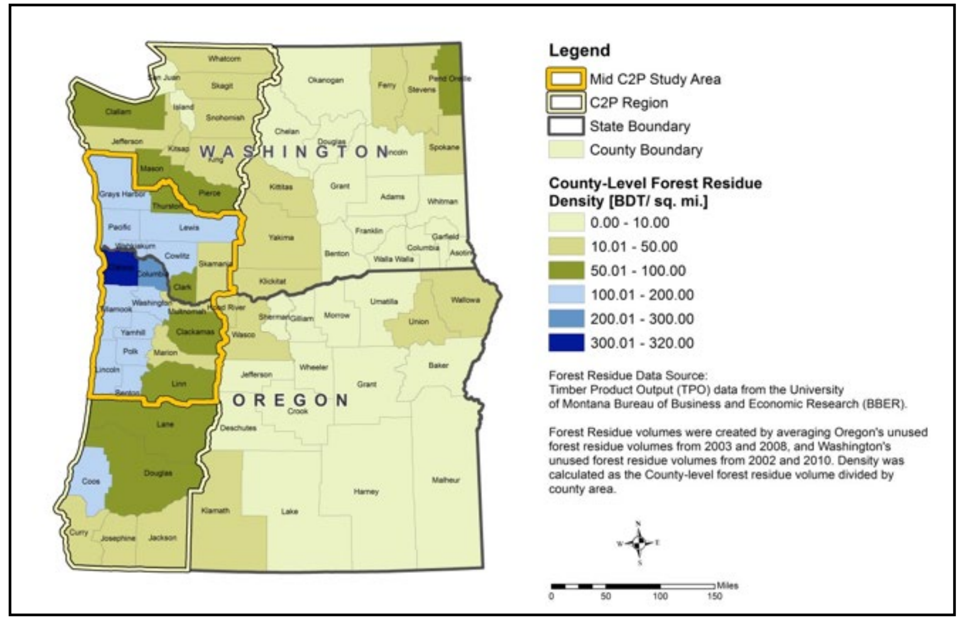

Figure SM-EPP-1.3. Tentative Cascade-to-Pacific (C2P) pilot supply chain study region in western Washington and Oregon for Year 3

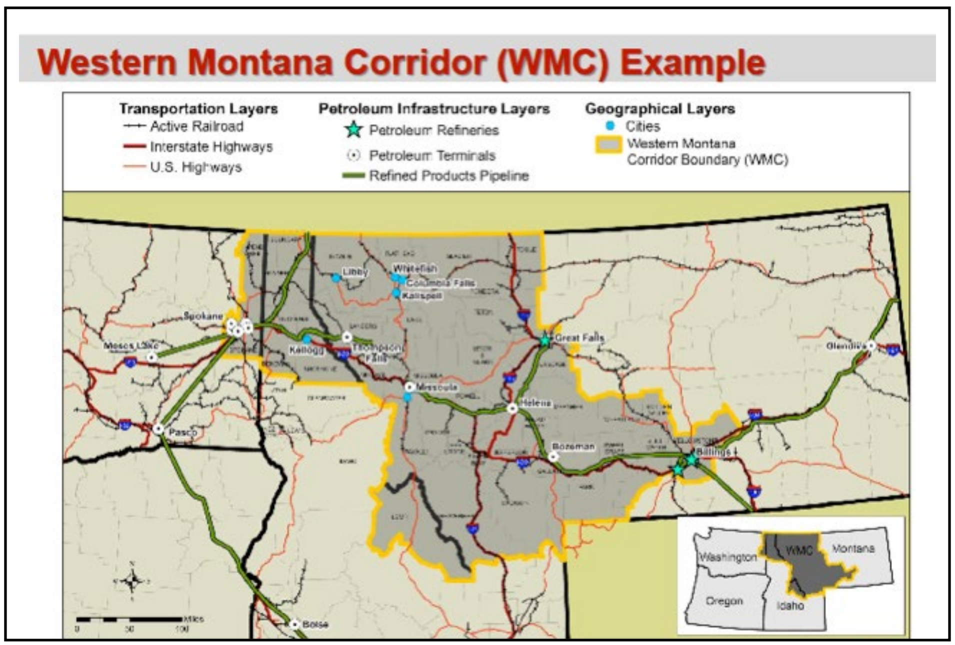

Figure SM-EPP-1.2. Tentative Western Montana Corridor (WMC) pilot supply chain study region

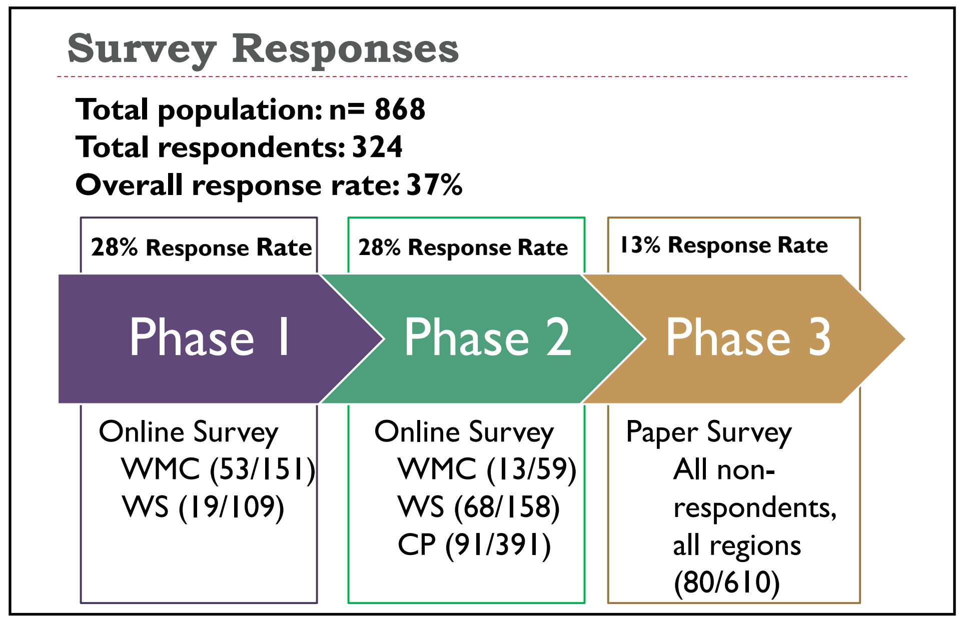

Figure SM-EPP-1.4.

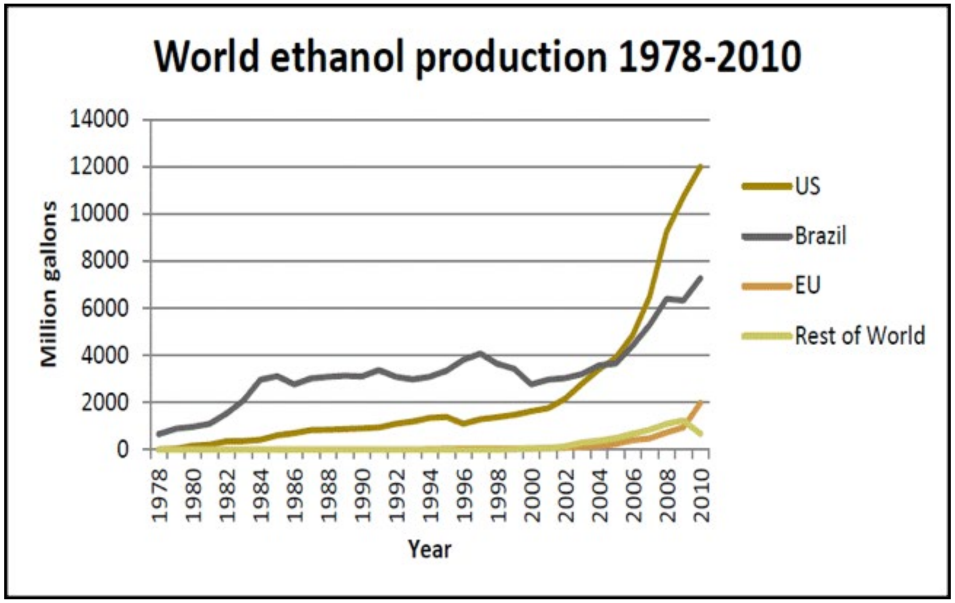

Figure SM-EPP-1.5. Global ethanol production during the years 1978 to 2010

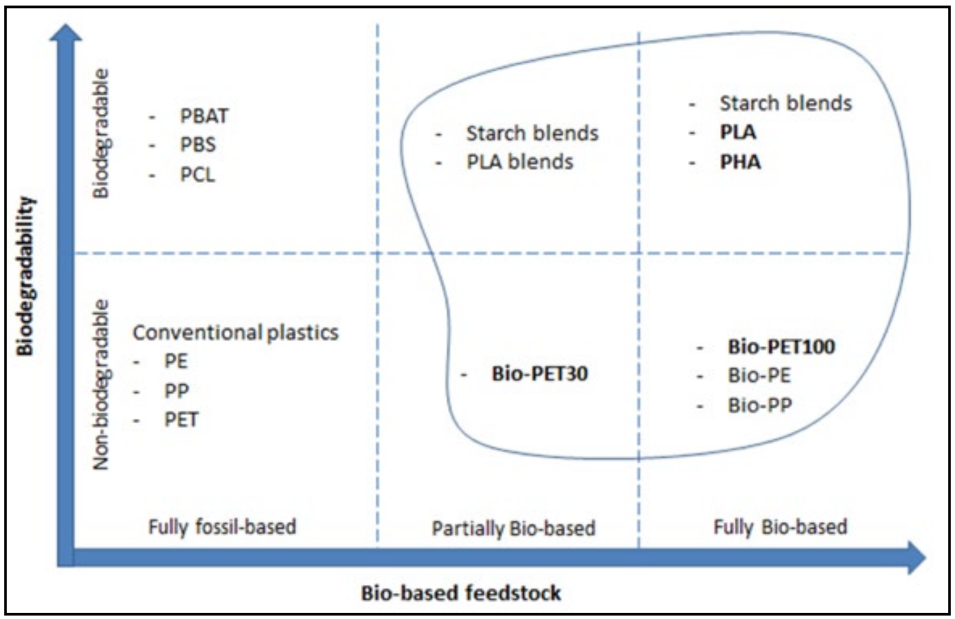

Figure SM-EPP-1.6. Bioplastics Categories (Revised from EB, 2012)

Table SM-EPP-1.1. Airport categories by percent of emplanements in the NARA region

Airport Rating	Total airports	% of total Enplanements
Category 1	2	> 20%
Category 2A	2	> 2% - 20%
Category 2B	7	> 1% - 2%
Category 3	87	> 0% - 1%
Total Airports	98	All enplanements

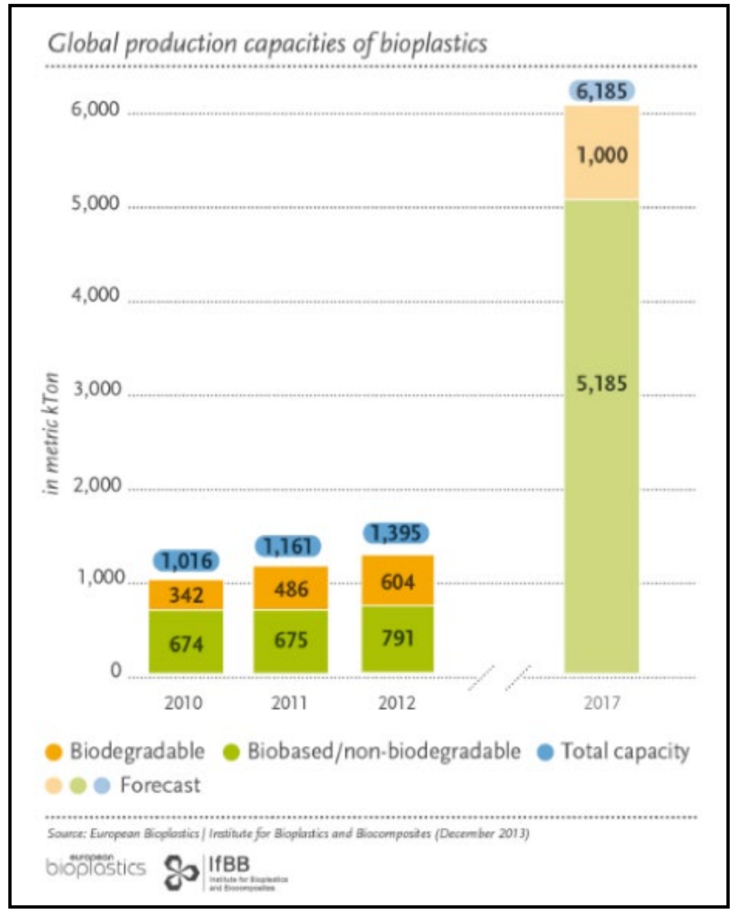

Figure SM-EPP-1.7. World Bioplastics Production Capacity (EB, 2013a)

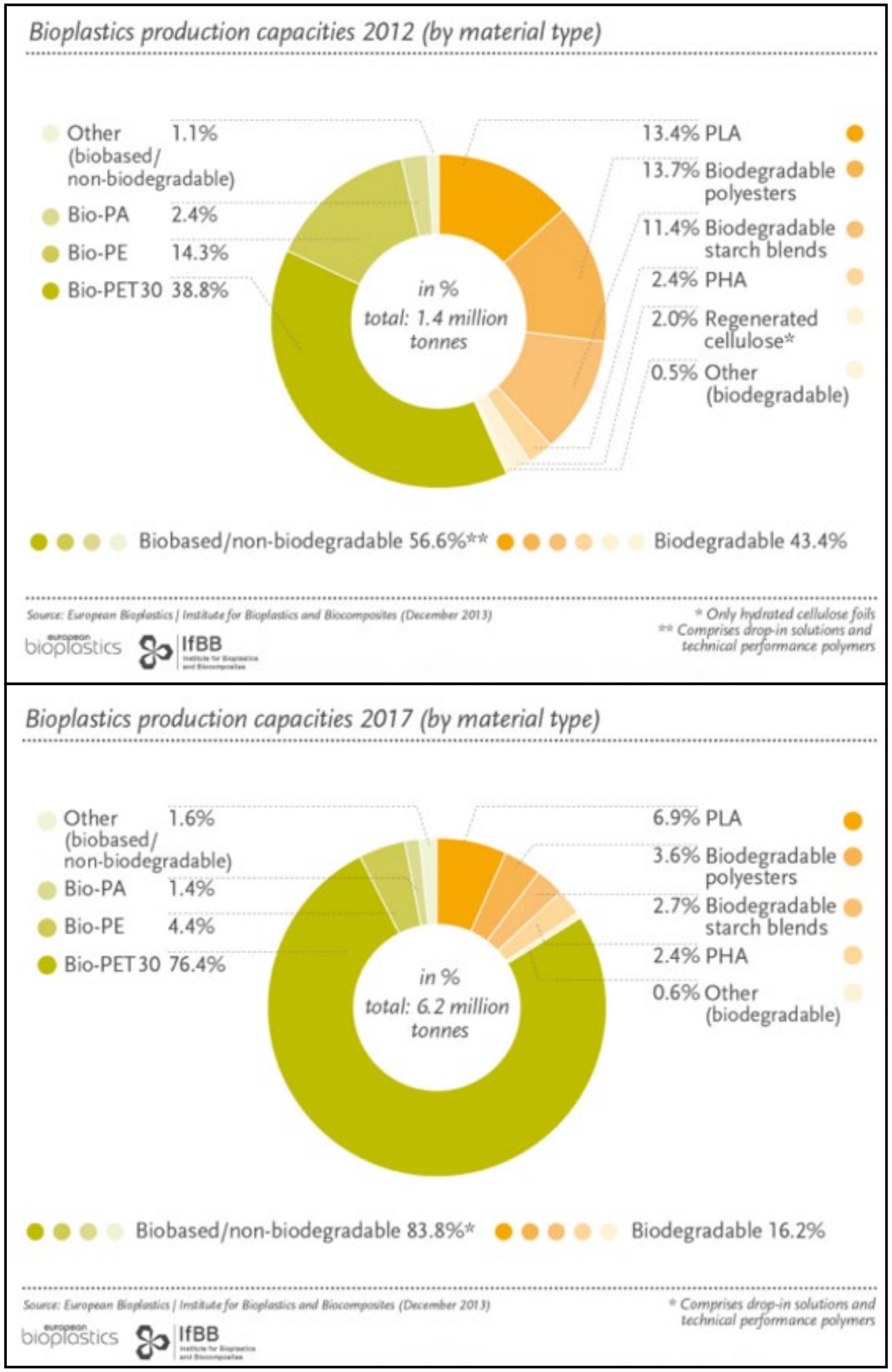

Figure SM-EPP-1.8. 2012 and Projected (2017) World Production Capacity by Polymer Type (EB, 2013b; EB, 2013c)

Table SM-EPP-1.2. Bioplastics market segments (EB. 2013a)

Market segment	Examples
Bags and agricultural applications	Can lines, leaf bags, trash bags, super-market carrier bags, mulch films,
Beverage container	Bottles
Construction	Fencing, trellis, window frames and insulation materials
Consumer goods	Appliance, consumer electronics (cam-era, cell phone), furniture
Medical and pharmaceutical	Bottles, containers, drug delivery, packaging
Technical application	Automotive including corrugated tub-ing, fluid transfer lines, fuel lines, seats materials

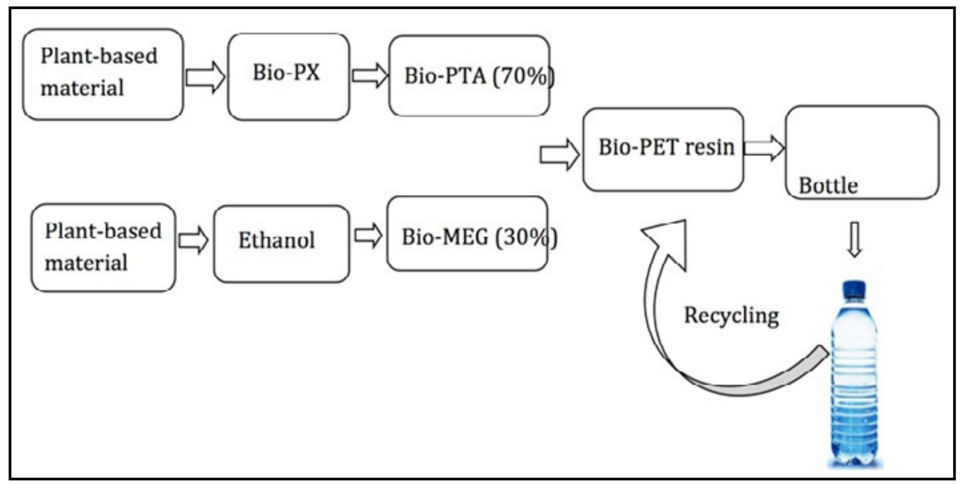

Figure SM-EPP-1.9. Production process of 100% biobased and recyclable PET bottle (Komula, 2011)

Table SM-EPP-1.3. Calculating the emission credit of displacing 48,728.1 tons (wet oxidation) and 42,071.6 (SPORL) tons of coal-based GAC with lignin-based activated carbon.

	Coal Intermediate Processing emissions	Volatilized Coal Emissions	Total Coal Emissions[A]	Lignin Intermediate Processing Emissions	Emission Credit
	Kg CO_2/yr	Kg CO_2/yr	Kg CO_2/yr	Kg CO_2/yr	Kg CO_2/yr
	(A)	(B)	(A)+(B) =(C)	(D)	(C)-(D) = (E)
Wet Oxidation	24,706,848.3	460,967,662.1	485,674,510.3	393,213,771.1	92,460,739.2
SPORL	21,331,771.2	397,997,209.9	419,328,981.1	339,498,699.2	79,830,281.8

[A] Excludes the fossil fuel emissions from the activated carbon production process because it is assumed to be equal to the lignin activated carbon fossil fuel emissions, so the net effect of these emissions are zero.

Table SM-EPP-1.4. Calculating the IPK emission using lignin for activated carbon production

	Baseline (lignin used in CHP)	CHP emissions from natural gas replacing lignin	Lignin activated carbon credit	Scenario 1: IPK emissions with lignin to activated carbon
	Kg CO_2e/yr	Kg CO_2e/yr	Kg CO_2e/yr	Kg CO_2e/yr
	(A)	(B)	(C)	(A)+(B)–(C) = (D)
Wet Oxidation	153,563,740	17,228.7	92,460,739.2	61,122,953.9
SPORL	153,563,740	19,953.1	79,830,281.8	73,750,686.9

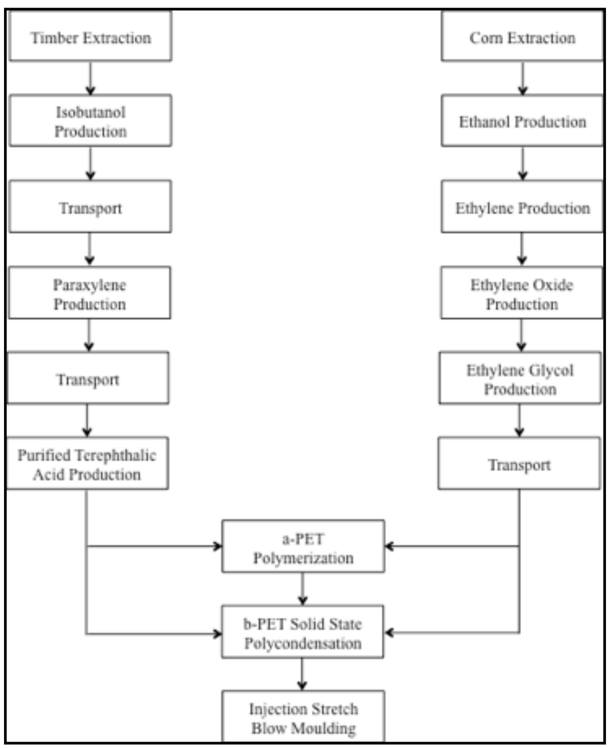

Figure SM-EPP-1.10. Life cycle model of the Gevo-Coca Cola collaborative bio-PET bottles

Recommendations | Conclusions

Task SM-EPP-1.1. "Public" stakeholders (SHs): demographic, psychographic, and market-specific assets through dataset analysis (Leigh Stowell, Rupasingha, and Roper-Putnam). (N. Martinkus, W. Shi, N. Lovrich, J. Pierce, M. Gaffney, S. Hoard, P. Smith, M. Wolcott)

A biogeophysical (BGP) and social asset analysis to predict bioenergy behaviors in the Western Montana Corridor has been completed and accepted for publication and is in-press to (the journal of) Biomass & Bioenergy. The BGP and social asset methodology and analysis deployed in the WMC region will be revised for the MC2P region and applied to the entire NARA region for direct comparisons. These revisions will include an expanded retrospective analysis and triangulation with the NARA EPP informed stakeholder data set (Tasks 3 and 4) to provide triangulated validation and refinement of social asset metrics and weightings. The ultimate goal of this research is the development of a predictive Community Asset Assessment Model (CAAM) to be applied elsewhere in the NARA region and across the nation for similar community assessment without the need for additional primary data collection.

Task SM-EPP-1.2. Review Sustainability Approaches: ecolabels, stds., product claims, LCA/EIO data sources & models. (R. Pelton, Luyi Chen, and T. Smith)

Work has been completed identifying co-products and intermediate products that are produced during the wood-IBA-IPK life cycle, and the type of application that these products will be used for (e.g. activated carbon). This next quarter will focus on identifying common bio-product attributes related to these co-products/intermediates that indicate how the market signifies environmental preference.

Task SM-EPP-1.3. Review Regional Bioenergy Stakeholder Perceptions: issues, influential groups, etc.; NARA site personal/focus group interviews and analysis. (J. Moroney, T. Laninga, N. Martinkus, M. Gaffney, S. Hoard, K. Gagnon, V. Yadama, P. Smith)

The collaborative efforts between EPP, Education, and Outreach teams completed a process for NARA Community site selection, resulting in two supply chain regions – the Western Montana Corridor (WMC) and the Mid-Cascades-to-Pacific (MC2P).

Task SM-EPP-1.4. "Informed" stakeholder interaction/operationalization (pop's., sampling, constructs, protocols). (J. Moroney, T. Laninga, M. Gaffney, and S. Hoard, K. Gagnon, P. Smith)

Prior research studies addressing salient biomass to bioenergy topics and issues were used to guide development of the research instrument. A mixed methods process was used to administer the survey, consisting of open ended, multiple choice and Likert scale questions, to potential NARA supply chain stakeholders (SH) whom are deemed to be relatively informed regarding one or more critical elements within the biomass to biojet industry supply chain concept. The survey was distributed to stakeholders in the Western Montana Corridor (WMC), Mid-Cascades to Pacific (MC2P), and the Columbia Plateau (CP) regions, resulting in an overall response rate of 37% (324/868). Analysis of survey data is in-progress.

Task SM-EPP-1.5. Refine Operationalization – Social Hotspot Analysis. (J. Moroney, T. Laninga, M. Gaffney, and S. Hoard, N. Martinkus, W. Shi, N. Lovrich, and J. Pierce, P. Smith, M. Wolcott)

As mentioned in Task 1, the NARA EPP team has advanced in knowledge and experience. Thus, a refined operationalization and triangulated validation process for the NARA MC2P supply chain region in 2014 with implications for a NARA region – and beyond – is underway. The process will include several existing data sets from previous DGSS community surveys in the NARA region to serve as reference comparisons for both the newly-collected data from the current stakeholder surveys (Moroney and Laninga) and national data sets already used to develop the social license measures described in Task 1. In addition, DGSS has substantially completed a literature review that will inform the further development of a retrospective prediction analysis of the three types of data (national, existing DGSS, new research) to develop a model for predicting community suitability for NARA/biofuel engagement.

Task SM-EPP-1.6. Techno-Market Assessment: Jet Fuels. (S. Wertz, I. Iborrola, K. Dahmann, L. Fowler, M. Gaffney, S. Hoard, S. Rijkhoff, T. Laninga, and J. Moroney, P. Smith)

A final literature review of global biofuels policies, with an emphasis on how these legislative tools will impact the industry moving forward is in progress. A specific focus will be on the downstream portion of the biofuels supply chain in the U.S., from biorefinery to end user. Comparisons and contrasts with EU biofuels policies will also be examined.

Earlier reports focused on the fuel logistics for the Seattle-Tacoma International Airport (SEA) and Portland International Airport (PDX) due to their importance in the NARA region, consuming 55% and 21% of the region's jet fuel in 2010, respectively. Exploratory interviews were conducted in September 2013 at SEA and PDX to provide insight into aviation fuel logistics and ownership. Potential biojet buyers in the NARA region include military, commercial, general, freight carriers, and foreign country segments. DLA Energy is the primary purchaser of fuels for the U.S. military. To better understanding stakeholder (SH) attitudes and perceptions with respect to biofuels logistics and policy mandates and how these affect the biofuels industry at a macro level, a database of all NARA region commercial airports and terminals is in progress. The SH database includes airport management, Fixed Base Operators (FBOs), fuel traders/brokers, and terminal and pipeline operators. A jet fuel logistics, policy, and social science team has been formed to develop and administer a SH survey. Finally, this effort will also begin to examine outputs from the Initiative Towards Sustainable Kerosene for Aviation (ITAKA) project, as available. ITAKA is a collaborative

European Union project to support a camelina-to-bio-jet supply chain in Spain which may provide illuminating comparisons and contrasts with our NARA project.

Task SM-EPP-1.7. Techno-Market Assessment: BioProduct Polymers. (R. Pelton, Luyi Chen, T. Smith, Min Chen, S. Cline, P. Smith)

The parameterized model of the co-products and intermediate products has been established and is based on the baseline LCA model developed by Indroneil Ganguly. Lignin used for activated carbon and isobutanol used for paraxylene production and ultimately bio-PET bottles, are the first co-products/intermediate products from the biojet life cycle that are being investigated from an economic and environmental perspective.

Research into potential applications for lignin-based activated carbon resulted in the identification of one market with large potential - activated carbon (AC) for air purification. Specifically, AC for the sequestration of mercury from flue gas streams exhausted by US coal-fired electric generating units. This market opportunity analysis is in progress.

C8 (eight-carbon molecule) markets include PET (polyethylene teraphthalat), the fastest growing bio-based, bio-polymer in the world. Coca-Cola is partnering with Gevo (and Virent) to make affordable renewable PX from biobased isobutanol for their Plant BottlesTM. And Coca-cola, Ford, Heinz, NIKE, and P&G formed the Plant PET Collaborative (PPC) in 2012 to accelerate the development of 100% plant based PET. C4 (four-carbon molecule) markets include butadiene and BDO. Relevance has increased due to cheap natural gas which is being substituted for petroleum as a chemical industry feedstock which moves the petrochemical industry toward ethane and away from naphtha as a feedstock. Therefore, a lot of inexpensive ethylene (C2) and propylene (C3) molecules will be produced, resulting in fewer butylene (C4) molecules. Butadiene is polymerized to produce synthetic rubber (for tires, hoses, seals, carpet backing, and medical latex), molded plastics, nylon 6,6, adhesives and specialty chemicals. BDO is used in elastic fibers (spandex), plastics and polyurethanes.

Through secondary sources, 247 biopolymer companies at 363 locations around the world have been identified with 17 North American firms. Recyclable Bio-PET is one of the most promising biopolymer applications (for bottles). A major theme in recyclable bioplastics (especially bio-PET) is strong downstream value chain partnerships between manufacturers of biochemicals/bioplastics and global consumer products companies (e.g., Pepsi, Coca-Cola). Recently, focus has been placed on the US biorefinery industry as a preliminary step to better understanding the evolving integration toward feedstock input and product output diversity. The identification and assessment of product and market-based issues related to US integrated biorefineries is in progress.

Task SM-EPP-1.9 Economic, Environmental and Social Assessment (R. Pelton, L. Chen, J. Schmitt, T. Smith)

A second iteration calculating the environmental preference of using the insoluble lignin in an activated carbon application has been completed, and a comparison of using wet oxidation lignin versus SPORL lignin is made, given the differences in the quantity of insoluble lignin produced. Two major changes have been made from the first calculation, excluding the biogenic carbon from the calculation, and using the most recent lignin mass output, which is based on the Aspen model provided in early March. The effect of using lignin in this particular application results in about an 85% reduction from the fossil-based kerosene baseline (for WOX) and 81.5% reduction (for SPORL), thus greatly exceeding the RFS emission reduction thresholds. Future analysis will focus on more accurately determining the differences in the activated carbon production processes between the two types of feedstock and how these differences may affect the co-product credit. Future analysis will also begin to look at alternative allocation methods.

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PHYSICAL AND INTELLECTUAL OUTPUTS

Database and Dataset Development:

1. A refined and weighted national social assets database to examine local, regional and national social collaborative capacity;
2. A biomass-to-biofuel stakeholder assessment dataset for the Western Montana Corridor, the Cascade to Pacific and Columbia Pleateau;
3. Coal-fired electric generating unit population – to examine the market opportunity for activated carbon for mercury and other metals emissions mitigation.
4. Data sets to classify and identify US biorefineries, including 1st generation biofuel (ethanol & biodiesel), 2nd generation, 3rd generation, and 1st and 2nd generation non-fuel biorefineries.

5. NARA region jet fuel supply chain logistics datasets of terminals, airports, and airport personnel.
6. State-by-state policy initiatives, state government actions, and the effects of these policies
7. Federal government policy collection – implementation of Federal law
8. European Policy – framework, dynamics across Europe and the relationship between multinational organizations and member countries

Model Development:
1. A preliminary Community Assets Assessment Model (CAAM) to help explain biomass-to-biojet economic development opportunities in the NARA region.
2. Isobutanol conversion to jet fuel process modeling.
3. Modeling of alternative production pathways (specifically regarding feedstock and pretreatment options).
4. Co-product use and allocation scenarios modeled – including emission credit calculations for co-product scenarios

REFEREED PUBLICATIONS (ACCEPTED OR COMPLETED)

1. Martinkus, N., W. Shi, N. Lovrich, J. Pierce, P. Smith, and M. Wolcott. 2014. Integrating Biogeophysical and Social Assets Into Biomass-to-Biofuels Supply Chain Siting Decisions. Biomass & Bioenergy. Accepted and in-press.

2. Pelton, R., T.M. Smith. 2013. Hotspot Scenario Analysis: Comparative streamlined LCA approaches for Green supply chain and procurement decision-making. Submitted to Journal of Industrial Ecology, Accepted.

Book Chapters:
1. Dahmann, K. K.S., P.M. Smith, and L.B. Fowler. 2014. An American Perspective: The Biofuel Industry and Government Policymaking – included in a Volume on "The Law and Policy of Biofuels" co-editors, Yves Le Bouthillier, Annette Cowie, Paul Martin and Heather McLeod-Kilmurray, Edward Elgar Publishing, as part of the IUCN Academy Series. Submission due date = June 30, 2014.

2. Smith, T.M., Mollina Murillo, S.A., and Anderson, B. M. 2014. Implementing sustainability in the global forest sector: Toward the convergence of public and private forest policy. In The Global Forest Sector: Changes, Practices, and Prospects. E. Hansen, R. Panwar, and R. Vlosky (eds.). Taylor & Francis, CRC press, Boca Raton, 237-260.

RESEARCH PRESENTATIONS (THIS YEAR):
Oral, Posters or Display Presentations

1. Moroney, J., and T. Laninga, 2014. Social Acceptability of a Biomass and Biofuels Supply Chain in the PNW. Abstract proposal accepted for presentation at the Pacific Northwest Wood-based Biofuels and Co-Products Conference. April 28-30, 2014. Seattle, WA.

2. Dahmann, K.S., P.M. Smith, and L.B. Fowler. 2014. Concerns Racking the Biofuel Industry's Development and Possible Solutions. Abstract proposal submitted for presentation at the TAPPI International Bioenergy & Bioproducts Conference 2014 session on Impacts of Policies and Incentives, Sept. 17-19, Seattle, WA.

3. Smith, P.M., M. Gaffney, S. Hoard, T. Laninga, S. Rijkhoff, J. Moroney, N. Martinkus, N. Lovrich, J. Pierce, and M. Wolcott. 2014. Community Asset Assessment Modeling for Informed Biofuel Location Decision-Making. Abstract proposal submitted for presentation at the TAPPI International Bioenergy & Bioproducts Conference session on Impacts of Policies and Incentives, Sept. 17-19, Seattle, WA.

POSTERS FROM PREVIOUS NARA EPP REPORTS IN PAST YEAR:

1. Li, Y., and P.M. Smith. 2013. Aviation Fuel Supply Chain Study in the NARA Region. NARA SURE Program final poster presentation. Washington State Univ., Pullman, WA. Aug. 2. http://nararenewables.org/site/media/040.pdf

2. Cline, S., Fox, C., Fish, D. 2013. Isolation of High Purity Lignin from Bio-Jet Biorefinery Hydrolysis Residue. Weyerhaeuser Cellulosic Fibers Technology. NARA SURE Program final poster presentation. Washington State Univ., Pullman, WA. Aug. 2. http://nararenewables.org/site/media/040.pdf

3. Shi, W., P. Smith, N. Martinkus, N. Lovrich, J. Pierce, M. Wolcott, and M. Gaffney. Integrating Biogeophysical and Social Assets Into Biomass-to-Biofuels Supply Chain Siting Decisions. 2013. Poster presentation at the Year 2, NARA Annual Meeting, Corvallis, OR. Sept. 10.

4. Moroney, J., K. Gagnon, T. Laninga, P. Smith, M. Gaffney, and S. Hoard. 2013. Understanding Informed Stakeholder Perceptions: Assessment Criteria for Biomass-to-Biojet Supply Chain Siting. Poster presentation at the Year 2, NARA Annual Meeting, Corvallis, OR. Sept. 10.

5. Wertz, S.M. and P.M. Smith. 2013. US Biofuels Policy: Understanding RFS2. Poster presentation at the Year 2, NARA Annual Meeting, Corvallis, OR. Sept. 10.

6. Wertz, S.M., P.M. Smith, and M.P. Wolcott. 2013. Biojet Market Prospects and US Regulatory Considerations. Poster presentation at the Year 2, NARA Annual Meeting, Corvallis, OR. Sept. 10.

7. Chen, M. and P. Smith. 2013. Preliminary Market Opportunity for Biorefinery Co-Products (BioPlastics). Poster presentation at the Year 2, NARA Annual Meeting, Corvallis, OR. Sept. 10.

8. Chen, M., S. Cline, and P. Smith. 2013. Preliminary Market Opportunity for Biorefinery Intermediates (Lignin). Poster presentation at the Year 2,

NARA Annual Meeting, Corvallis, OR. Sept. 10.

9. Pelton, R., and T. Smith. 2013. Environmental Preference of Fuel and Non-Fuel Co-Products. Poster presentation at the Year 2, NARA Annual Meeting, Corvallis, OR. Sept. 10.

PRESENTATIONS FROM PREVIOUS NARA EPP REPORTS IN PAST YEAR

1. Moroney, J., K. Gagnon, T. Laninga, P. Smith, M. Gaffney, and S. Hoard. 2013. Understanding Informed Stakeholder Perceptions: Assessment Criteria for Biomass-to-Biojet Supply Chain Siting. Poster presentation at the Washington State University Academic Showcase, Pullman, WA. Mar. 28.

2. Smith, P.M. 2013. Biorefinery Value Chain Outputs. Keynote presentation at the 56th International Convention of the Society of Wood Science & Technology, June 9, Austin, TX.

3. Wertz, S., P.M. Smith, and M.P. Wolcott. 2013. Aviation Biofuels Market Opportunities and Policy Considerations. Poster presentation at the 56th International Convention of the Society of Wood Science & Technology, June 9, Austin, TX.

4. Moroney, J., K. Gagnon, T. Laninga, P. Smith, M. Gaffney, and S. Hoard. 2013. Understanding Informend Stakeholder Perceptions: Assessment Criteria for Biomass-to-Biojet Supply Chain Siting. Poster presentation at the 56th International Convention of the Society of Wood Science & Technology, June 9, Austin, TX.

5. Shi, W., P. Smith, N. Martinkus, N. Lovrich, J. Pierce, M. Wolcott, and M. Gaffney. 2013. Integrating Biogeophysical and Social Assets Into Biomass-to-Biofuel Supply Chain Siting Decisions. Poster presentation at the 56th International Convention of the Society of Wood Science & Technology, June 9, Austin, TX.

6. Shi, W., N. Martinkus, P. Smith, N. Lovrich, J. Pierce, M. Wolcott, and M. Gaffney. 2013. An Integrated and Multidimensional Approach to Biomass-to-Biofuel Supply Chain Siting in the WMC. Presentation at the Year 2, NARA Annual Meeting, Corvallis, OR. Sept. 11.

7. Smith, T.M., M. Wolcott, R. Cavalieri. 2013. Wood to Wing: Envisioning an Aviation Biofuels Industry from Forest Residuals. Montana Jobs Summit. Montana Tech of the University of Montana, September 16, Butte, MT.

8. Smith, P.M. 2013. Biorefinery Intermediate and Co-Product Value Streams. Integrated Design Experience Seminar, Sept. 25. Washington State Univ., Pullman, WA.

9. Smith, P.M. 2013. Biorefinery Value Stream Outputs. The Business of Biomass: Next Generation Biofuels Conversion, NEWBio short course, Nov. 11-12, Malvern, PA.

10. Smith, T.M. 2013. Change-Inspired Scholarship: Applications in Green Supply Chain Management, EPSRC Centre for Innovative Manufacturing in Industrial Sustainability, University of Cambridge, Nov. 22, Cambridge, UK.

11. Smith, T.M., Pelton, R.E.O., Li, M. 2013. A parameterized supply chain sustainability tool for paper packaging. FedEx Corporate Learning Center, Memphis, TN, November 12.

12. Pelton, R., and T. Smith. 2013. Environmental Preference of Fuel and Non-Fuel Co-Products. Presentation at the Year 2, NARA Annual Meeting, Corvallis, OR. Sept. 10.

POSTERS:

1. Shi, W., P. Smith, N. Martinkus, N. Lovrich, J. Pierce, M. Wolcott, and M. Gaffney. Integrating Biogeophysical and Social Assets Into Biomass-to-Biofuels Supply Chain Siting Decisions. 2013. Poster presentation at the Year 2, NARA Annual Meeting, Corvallis, OR. Sept. 10.

2. Moroney, J., K. Gagnon, T. Laninga, P. Smith, M. Gaffney, and S. Hoard. 2013. Understanding Informed Stakeholder Perceptions: Assessment Criteria for Biomass-to-Biojet Supply Chain Siting. Poster presentation at the Year 2, NARA Annual Meeting, Corvallis, OR. Sept. 10.

3. Wertz, S.M. and P.M. Smith. 2013. US Biofuels Policy: Understanding RFS2. Poster presentation at the Year 2, NARA Annual Meeting, Corvallis, OR. Sept. 10.

4. Wertz, S.M., P.M. Smith, and M.P. Wolcott. 2013. Biojet Market Prospects and US Regulatory Considerations. Poster presentation at the Year 2, NARA Ann. Meeting, Corvallis, OR. Sept. 10.

5. Chen, M. and P. Smith. 2013. Preliminary Market Opportunity for Biorefinery Co-Products (BioPlastics). Poster presentation at the Year 2, NARA Annual Meeting, Corvallis, OR. Sept. 10.

6. Chen, M., S. Cline, and P. Smith. 2013. Preliminary Market Opportunity for Lignin (Biorefinery Intermediates). Poster presentation at the Year 2, NARA Ann. Meeting, Corvallis, OR. Sept. 10.

7. Pelton, R., and T. Smith. 2013. Environmental Preference of Fuel and Non-Fuel Co-Products. Poster presentation at the Year 2, NARA Annual Meeting, Corvallis, OR. Sept. 10.

8. Ibarrola, I. and P. Smith. 2014. CLH Aviation and Biojet Projects. CAAFI (Commercial Aviation Alternative Fuels Initiative) Bienniel General Meeting, Washington D.C., Jan. 28-30.

References

1. Advanced Biofuels, A Truly Sustainable Renewable Future. Advanced Biofuels USA, www.advanced-biofuelsusa.org.
2. Alicia Pelaez-Cid, A., M.M. Margarita Teutli-Leon. 2012. Lignocellulosic Precursors Used in the Elaboration of Activated Carbon- Characterization Techniques and Applications in the Wastewater Treatment, Dr. Virginia Hernandez Montoya (Ed.) www.intechopen.com/books/lignocellulosic-precursors-used-in-the-synthesis-of-activated-carbon-characterization-techniques-and-applications-in-the-wastewater-treatment/ no-title-specified-. Accessed May 2013.
3. Agusdinata, D. B., Zhao, F., and DeLaurentis, D. A. (2012). Sustainability of Biojet Fuels: A Multiactor Life Cycle Assessment Approach. Potentials, IEEE, 31(1), 27-33.
4. Agusdinata, D. B., Zhao, F., Ileleji, K., and DeLaurentis, D. (2011). Life Cycle Assessment of Potential Biojet Fuel Production in the United States. Environmental Science & Technology, 45(21), 9133-9143. http://pubs.acs.org/doi/abs/10.1021/es202148g
5. Ahmedna, M., Marshall, W. E., and Rao, R. M. (2000). Production of granular activated carbons from select agricultural by-products and evaluation of their physical, chemical and adsorption properties. Bioresource Technology, 71(2), 113 - 123. http://www.sciencedirect.com/science/article/pii/S096085249900070X
6. Bailis, R. E. and Baka, J. E. (2010). Greenhouse Gas Emissions and Land Use Change from Jatropha Curcas-Based Jet Fuel in Brazil. Environmental Science & Technology, 44(22), 8684-8691. http://pubs.acs.org/doi/abs/10.1021/es1019178
7. Baker, C. G. J. and McKenzie, K. A. (2005). Energy Consumption of Industrial Spray Dryers. Drying Technology, 23(1-2), 365-386. http://www.tandfonline.com/doi/abs/10.1081/DRT-200047665.
8. Baltus, W, J. Beckman, D. Carrez, M. Carus, L. Dammer, R. Essel, H. Kaeb, J Ravenstijn, A. Mirabal, L. Scholz, F. Sibilla, and S. Zepnik. 2013. Bio-Based Polymers in the World. Ed. By A.S. Mirabal, L. Scholz, and M. Carus. Nova-Institut GmbH, Huerth, Germany. 365pp.
9. Bardelline, J. (2010, October 6). Improved Standards Needed for Bioplastic Claims. Retrieved from GreenBiz.com: http://www.greenbiz.com/news/2010/10/06/improved-standards-needed-bioplastic-claims?utm_source=feedburner&utm_medium=feed&utm_campaign=-Feed%3A+Greenbuzz+%28GreenBiz+Feed%29
10. Bayer, P., Heuer, E., Karl, U., and Finkel, M. (2005). Economical and ecological comparison of granular activated carbon (GAC) adsorber refill strategies. Water Research, 39(9), 1719 - 1728. http://www.sciencedirect.com/science/article/pii/S0043135405000655
11. BCAS. (2013). Compressed Air Savings: The cost of compressed air. British Compressed Air Society.. Retrieved from BCAS: http://www.bcas.org.uk/files/pdffiles/16.pdf
12. Bioplastics, C. (2012, April). Bioplastics Industry overview guide-Executive Summary. Retrieved from The Society of the Plastics Industry Bioplastics Council: https://store.plasticsindustry.org/source/orders/index.cfm?section=unknown&task=3&CATEGORY=BPC&PRODUCT_TYPE=SALES&SKU=BPC01&DESCRIPTION=Bioplastics%20Council&FindSpec=&CFTOKEN=19244647&continue=1&SEARCH_TYPE=find&StartRow=1&PageNum=1
13. Biotechnology Industry Organization, "Timeline_Renewable Fuel Standard" - The Renewable Fuel Standard: Timeline of a Successful Policy (Biotechnology Industry Organization (BIO) Powerpoint/Brochure.
14. Bockner, G. (2011, May). Biocontent bottles can still be recycled. Retrieved from Plastics News: http://www.plasticsnews.com/article/20110506/OPINION03/305069990#
15. Bozell, J. J. (2008). Feedstocks for the Future – Biorefinery Production of Chemicals from Renewable Carbon. CLEAN – Soil, Air, Water, 36(8), 641--647. http://dx.doi.org/10.1002/clen.200800100.
16. Buchi Labortechnik AG. (2002). Training Papers-Spray Drying. Version B: 97758. Retrieved from: http://www.buchi.com/sites/default/files/downloads/Set_3_Training_Papers_Spray_Drying_EN_01.pdf
17. Cameron Carbon Incorporated. (2006). Activated Carbon Manufacture, Structure and Properties. Retrieved from: http://www.cameroncarbon.com/documents/carbon_structure.pdf
18. Chakar, F. S. and Ragauskas, A. J. (2004). Review of current and future softwood kraft lignin process chemistry. Industrial Crops and Products, 20(2), 131 - 141. http://www.sciencedirect.com/science/article/pii/S0926669004000664
19. Chiyoda Corporation. 2013. C4/C5 Fractions and Its Derivatives. Available at: http://www.chiyoda-corp.com/technology/en/chemistry/c4c5.html.
20. Cobalt. (2013). Butanols High-value markets. Retrieved from: www.cobalttech.com/biobutanol.html
21. Coca-Cola Co. (2012, January). PlantBottle: Frequently Asked Questions. Retrieved from Coca-Cola Company: http://www.coca-colacompany.com/stories/plantbottle-frequently-asked-questions
22. Colapinto, John, "Hot Grease", The New Yorker, Nov 18, 2013, 32 – 51.
23. Darby, D. (2012). Bioplastics Industry Report. BioCycle. Retrieved from: http://www.biocycle.net/2012/08/15/bioplastics-industry-report/
24. Doris, Elizabeth, Joyce McLaren, Victoria Healey, and Stephen Hockett, State of the States 2009: Renewable Energy Development and the Role of Policy, National Renewable Energy Laboratory (U.S. Dept of Energy, Office of Energy Efficiency & Renewable Energy), Technical Report NREL/TP-6A2-4667 October 2009.
25. EESI, Developing an Advanced Biofuel Industry: State Policy Options for Lean and Uncertain Times, Environmental and Energy Study Institute, February 16, 2010 – www.eesi.org.
26. Environmental Leader. 2013. Gevo, Coke, Toray Partner on Renewable PET Technology. Environmental Leader. Retrieved from: http://www.environmentalleader.com/2013/08/27/

gevo-coke-toray-partner-on-renewable-pet-technology/.
27. Erdtman, H. (1972). Lignins: Occurrence, formation, structure and reactions, K. V. Sarkanen and C. H. Ludwig, Eds., John Wiley & Sons, Inc., New York, 1971. 916 pp. $35.00. Journal of Polymer Science Part B: Polymer Letters, 10(3), 228--230. Retrieved from: http://dx.doi.org/10.1002/pol.1972.110100315.
28. Esposito, Frank. 2012. Report emphasizes importance of shale gas to plastics. Plastics News. July, http://www.plasticsnews.com/article/20120717/NEWS/307179974.
29. European Commission, 8.2.2006 "Communication from the Commission: An EU Strategy for Biofuels" Commission OF THE EC, Brussels, COM(2006) 34 final. {SEC (2006) 142} EN.
30. European Commission, Brussels, 21.1.2013, COM(2013) 18 final, 2013/0012 (COD), "Proposal for a Directive of the European Parliament and of the Council on the deployment of alternative fuels infrastructure," (Text with EEA relevance) {SWD(2013) 5 final}{SWD(2013) 6 final} EN.
31. European Commission, 24.1.2013, "Proposal for a Directive of the European Parliament and of the Council on the deployment of alternative fuels infrastructure," (Text with EEA relevance), Brussels, COM(2013) 18 final, 2013/0012 (COD) {SWD (2013) 5 final}{SWD (2013) 5 final}.
32. European Commission, 27.3.2013 Brussels, COM(2013) 175 final, Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, renewable energy progress report {SWD(2013) 102 final} EN.
33. European Commission, "2 million tons per year: A performing biofuels supply chain for EU aviation" Aug 2013 Update: Update of the version initially published June 2011. (2011 ed. team: Kyriakos Maniatis, Michael Weitz, Alexander Zschocke; contrib. Schroecker et al.).
34. European Commission, "Communication from the Commission to the Council and the European Parliament: The Renewable Energy Progress Report: Commission Report in accordance with Article 3 of Directive 2001/77/EC, Article 4(2) of Directive 2003/30/EC and on the implementation of the EU Biomass Action Plan", COM(205)628) {SEC(2009) 503 final}, EN.
35. European Commission. Future Transport Fuels: Report of the European Expert Group on Future Transport Fuels, January 2011.
36. Farm Security and Rural Investment Act of 2002. Pub. L. 107-171. 116 Stat. 134. 13 May 2002. United States Statutes at Large. Retrieved from: http://www.gpo.gov/fdsys/pkg/PLAW-107publ171/pdf/PLAW-107publ171.pdf
37. FESTO. (2010). Air is money. FESTO. Available at: http://www.festo.com/rep/en-ph_ph/assets/pdf/Air_is_Money_Tia_2.2010.pdf.
38. Food, Conservation and Energy Act of 2008. Pub. L. 110-234. 122 Stat. 923. 22 May 2008. United States Statutes at Large.
39. Freedonia. (2012). US Bioplastics Market. Freedonia.
40. Freudenberg, K. (1959, April 25). Biosynthesis and Constitution of Lignin. Nature, p. 1152.
41. Frosterud, D., M. Wahlberg, J. Sloth, M. Themens. Selected drying technologies and particle engineering for the future Biorefinery. Presented at the Nordic Wood Biorefinery, Stockholm, March 22-24.
42. Gevo. (2010). An Alternative Solution for Plant Owners. Retrieved from: www.bioenergyinstitute.com/pastevents/ethanolBankruptcies/Presentation%2010%20-%20Mark%20Smith.pdf
43. Gevo. (2011). Bio-based Isobutanol to Enable Coca-Cola to Develop Second Generation PlantBottle[a] Packaging. Retrieved from GEVO: http://gevo.com/?casestudy=bio-based-isobutanol-to-enable-coca-cola-to-develop-second-generation-plantbottle-packaging
44. Gevo. (2011). Isobutanol- A renewable solution for the Transportation Fuels Value Chain. White Paper. Retrieved from: http://www.gevo.com/assets/pdfs/GEVO-wp-iso-ftf.pdf.
45. Gevo. 2013. Markets – Isobutanol (http://www.gevo.com/our-markets/isobutanol). Accessed 1/9/14.
46. Glasser, W. G. (1999). Classification of Lignin According to Chemical and Molecular Structure. In W. Glasser, In Lignin: Historical, Biological and Materials Perspectives (p. 216). Washington, DC: American Chemical Society.
47. Glenz WW, Polyethylene terephthalate (PET). Kunststoffe (2007). Carl Hanser Verlag GmbH & Co. KG. Munich, Germany. 10/2007:76-80. Retrieved from: https://www.kunststoffe.de/en/journal/archive/article/continued-growth-trade-fair-report-k-2007-polyethylene-terephthalate-pet-586284.html
48. Gonugunta, P.(2012). Synthesis and Characterization of Biobased Carbon Nanoparticles from Lignin. University of Guelph (Thesis). Retrieved from: https://atrium.lib.uoguelph.ca/xmlui/bitstream/handle/10214/3608/Synthesis%20and%20Characterization%20of%20Biobased%20Carbon%20Nanoparticles%20from%20Lignin.pdf?sequence=1. Accessed May 2013.
49. Gosselink, R. J. A., de Jong, E., Guran, B., and Abächerli, A. (2004). Co-ordination network for lignin—standardisation, production and applications adapted to market requirements (EUROLIGNIN). Industrial Crops and Products, 20(2), 121 - 129. Retrieved from: http://www.sciencedirect.com/science/article/pii/S0926669004000652
50. Greiner, E., Kalin, T., Inoguchi, Y. (2010). Marketing Research Report: Activated Carbon. Chemical Economics Handbook. Rep no. 731.2000.
51. Highson, A., Smith, C. (2011, December 12). NNFCC Renewable Chemicals Fact sheet: lignin. Retrieved from NNFCC The Bioeconomy Consultants: http://www.nnfcc.co.uk/publications/nnfcc-renewable-chemicals-factsheet-lignin
52. Hileman, Jim. Power Point Presentation - "Alternative Jet Fuel Activities" By Dr. Jim Hileman Office of Environment and Energy, FAA, To Biomass R & D Technology Committee (Wash. D.C.), Aug 2013.
53. Holladay, J. (2007). Top Value Added Chemicals from Biomass. Retrieved from www.pnl.gov/main/publications/external/technical_reports/PNNL-16983.pdf
54. Humphreys, J. M. and Chapple, C. (2002). Rewriting the lignin roadmap. Current opinion

in plant biology, 5(3), 224--229. Retrieved from: http://www.sciencedirect.com/science/article/pii/S1369526602002571
55. Hung, J.J. (2012). The Production of Activated Carbon From Coconut Shells Using Pyrolysis and Fluidized Bed Reactors. University of Arizona (thesis). Retrieved from: http://arizona.openrepository.com/arizona/bitstream/10150/243968/1/azu_etd_mr_2012_0079_sip1_m.pdf.
56. ICCT, Measuring and Addressing Investment Risk in the Second-Generation Biofuels Industry, December 2012, The International Council on Clean Transportation – www.theicct.org.
57. ICIS. (2013). Butyl Acetate: Market Overview. ICIS. Retrieved from: www.icis.com/chemicals/butyl-acetate/?tab=tbc-tab2
58. ICIS. (2013). US gulf n-butane drops on shale production and low gasoline demand. Retrieved from: http://www.icis.com/Articles/2012/05/10/9558592/us-gulf-n--butane-drops-on-shale-production-and-low-gasoline.html
59. Imre, B. and Pukánszky, B. (2013). Compatibilization in bio-based and biodegradable polymer blends. European Polymer Journal, 49(6), 1215 - 1233. Retrieved from: http://www.sciencedirect.com/science/article/pii/S0014305713000372
60. Ioannidou, O. and Zabaniotou, A. (2007). Agricultural residues as precursors for activated carbon production—A review. Renewable and Sustainable Energy Reviews, 11(9), 1966 - 2005. http://www.sciencedirect.com/science/article/pii/S136403210600061X
61. Jebens, A., Janshekar, H., Yokose, K. (2012). Lignosulfonates. Chemical Economics Handbook Report. Retrieved from: www.sriconsulting.com/CEH/Public/Reports/671.5000
62. Johnson, L., Lippke, B., and Oneil, E. (2012). Modeling Biomass Collection and Woods Processing Life-Cycle Analysis. Forest Products Journal, 62(4), 258--272. http://dx.doi.org/10.13073/FPJ-D-12-00019.1
63. Kaeb, H. (2009, November 10-11). Bioplastics: Technology, Markets, Policies. Retrieved from Ecoembes: http://www.ecoembes.com/es/gestion-de-empresas-adheridas/prevencion/documents/haraldkaeb.pdf
64. Keller, Anne.(2012). NGL 101-The basics. Retrieved from: http://www.yumpu.com/en/document/view/10154703/ngl-101-the-basics-eia
65. Kolodzieg, R., Scheib, J. (2012) Bio-isobutanol: The Next-generation Biofuel. Hydrocarbon Processing. Retrieved from: http://www.hydrocarbonprocessing.com/Article/3081332/Bio-isobutanol-The-next-generation-biofuel.html
66. Laing, Keith. (2012, Nov.). Obama quietly signs bill shielding airlines from carbon fees in Europe. The Hill. Retrieved from: http://thehill.com/blogs/transportation-report/aviation/269603-obama-quietly-signs-airline-emission-trading-ban-.
67. Lane, Jim. 2014. Top 10 Biofuels & Biobased Predictions for 2014. Biofuels Digest (http://www.biofuelsdigest.com/bdigest/2014/01/06/top-10-biofuels-biobased-predictions-for-2014/). Jan. 6.
68. Lane, J. (2013, August 7). EPA sets final 2013 US renewable fuel mandate. Retrieved from BiofuelsDigest: http://www.biofuelsdigest.com/bdigest/2013/08/07/epa-sets-final-2013-us-renewable-fuel-mandate/
69. Lane, Jim. (2013). 4C-able future: Biobased butanol, butadiene and BDO are having a hot year. Biofuels Digest. Retrieved from: http://www.biofuelsdigest.com/bdigest/2013/08/21/4c-able-future-biobased-butanol-butadiene-and-bdo-are-having-a-hot-year/.
70. Encyclopedia Britannica. (n.d.)Lignin (Organic material). Retrieved from Encyclopedia Britannica: http://www.britannica.com/EBchecked/topic/340820/lignin
71. Lane, Jim, The Dew Drop Inn – Who's Dropping in What in Biofuels?, Jim Lane, biofuelsdigest.com.
72. Marketing Study for Biomass Treatment Technology. (n.d.). Retrieved from Report for North East Process Industry Cluster by NNFCC: www.northeastbiofuels.com/_assets/file/marketingstudynnfcc.pdf
73. MASBI Report, Fueling a Sustainable Future for Aviation 2013, Midwest Aviation Sustainable Biofuels Initiative.
74. Mato, Y., Isobe, T., Takada, H., Kanehiro, H., Ohtake, C., and Kaminuma, T. (2001). Plastic Resin Pellets as a Transport Medium for Toxic Chemicals in the Marine Environment. Environmental Science & Technology, 35(2), 318-324. Retrieved from: http://pubs.acs.org/doi/abs/10.1021/es0010498
75. McCarthy, J. L. and Islam, A. (1999). 2. In , Lignin Chemistry, Technology, and Utilization: A Brief History (pp. 2-99). Retrieved from: http://pubs.acs.org/doi/pdf/10.1021/bk-2000-0742.ch001
76. Mind, A. R. (2012, December). Bioplastics - a global market watch, 2011 - 2016. Retrieved from Research and markets: http://www.researchandmarkets.com/research/gzcgr2/bioplastics_a
77. Moller, J.T., S. Fredsted. (2009). A primer on Spray Drying. Chemical Engineering 34-40. Retrieved from: www.niro.com/niro/cmsresources.nsf/filenames/A-primer-on-Spray-Drying-Chemical-Engineering-Nov09.pdf/$file/A-primer-on-Spray-Drying-Chemical-Engineering-Nov09.pdf
78. Muñoz, I., Peral, J., Antonio Ayllón, J., Malato, S., José Martin, M., Yves Perrot, J., Vincent, M., and Domènech, X. (2007). Life-Cycle Assessment of a Coupled Advanced Oxidation-Biological Process for Wastewater Treatment: Comparison with Granular Activated Carbon Adsorption.. Environmental Engineering Science, 24(5), 638 - 651. Retrieved from: https://proxy.tamuc.edu:2048/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=25138418&site=ehost-live
79. Mussatto, S. I., Fernandes, M., Rocha, G. J., Órfão, J. J., Teixeira, J. A., and Roberto, I. C. (2010). Production, characterization and application of activated carbon from brewer's spent grain lignin. Bioresource technology, 101(7), 2450--2457.
80. National Research Counsel, Transitions to Alternative Vehicles and Fuels, The National Academies Press at http://www.nap.edu/catalog.php?record_id=18264, Committee on Transitions to Alternative Vehicles and Fuels; Board on Energy and Environmental Systems; Division of Engineering and Physical Science; National Research Counsel; 2013.

81. National Resources Defense Council. (n.d.) Mercury Contamination in Fish - Learn About Mercury and Its Effects. Retrieved from: http://www.nrdc.org/health/effects/mercury/effects.asp
82. Nexant. (2012). Biobutanol and Downstream Markets: Will you be buying bio? Retrieved from: www.chemsystems.com/reports/search/docs/prospectus/STMC12_Biobutanol_Pros.pdf.
83. Nimz, H. (1968). The Chemistry of Lignin. Von I. A. Pearl. Edward Arnold (Publishers) Ltd., London 1967. Marcel Dekker, Inc., New York 1. Aufl., XI, 339 S., 24 Abb., geb. $ 15.75. Angewandte Chemie, 80(8), 328--328. Retrieved from: http://dx.doi.org/10.1002/ange.19680800831
84. Norit. (n.d.) What is Activated Carbon? Cabot. Retrieved from: http://www.norit.com/carbon-academy/introduction/.
85. Noyes, Graham, and Sara E. Bergan, Fortifying the RPS EPA's Proposed RIN Quality Assurance Program, Stoel Rives LLP, Attorney at Law – White Paper.
86. Owen, B., Lee, D. S., and Lim, L. (2010). Flying into the Future: Aviation Emissions Scenarios to 2050. Environmental Science & Technology, 44(7), 2255-2260. Retrieved from: http://pubs.acs.org/doi/abs/10.1021/es902530z
87. Pan, Ingrid. (2013). Why ethane stopped trading like crude and started trading like nat gas (part 2). Market Realist. Retrieved from: http://marketrealist.com/2013/03/why-ethane-stopped-trading-like-crude-and-started-trading-like-nat-gas-part-ii/.
88. Panoutsou, Calliope and Ausilio Bauen, and Jim Duffield, Review: Policy regimes and funding schemes to support investment for next-generation biofuels in the USA and the EU-27 (biofpr: biofuels bioproducts & biorefining), 2013 - wileyonlinelibrary.com.
89. PepsiCo. (2011, March 15). PepsiCo develops world's first 100 percent plant-based, renewably sourced PET bottle. Retrieved from PEPSICO: www.pepsi.com/pressrelease/pepsico-develops-worlds-first-100-percent-plant-based-renewably-sourced-pet-bott03152011.html
90. Peters, M. W., et al. (2010). Integrated process to selectively convert renewable isobutanol to p-xylene, Google Patents.
91. PRWEB. (2013). Global Activated Carbon Market Industry Analysis, Size, Share, Growth, Trends and Forecast, 2013 2019. Transparency Market Research. Retrieved from: http://www.prweb.com/releases/2013/9/prweb11160954.htm
92. Ragan, S.,Megonnell, N. (2011). Activated Carbon from Renewable Resources-Lignin. Cellulose Chemistry and Technology 45(7-8): 527-531. Retrieved from: http://www.cellulosechemtechnol.ro/pdf/CCT45,7-8(2011)/p.527-531.pdf
93. Ragauskas, A. J. (2004). Lignin Overview. Retrieved from Georgia Institute pf Paper Science Tech and Technology: http://www.ipst.gatech.edu/faculty/ragauskas_art/technical_reviews/Lignin%20Overview.pdf
94. Reid, T. (2013). White Paper: Plastics vs. Bioplastics. Retrieved from awareness into action: http://www.awarenessintoaction.com/whitepapers/bioplastics-recycled-plastics.html
95. Renewable Fuel Standard. (2011). Potential Economic and Environmental Effects of U.S. Biofuel Policy. The National Academic Press, 250.
96. Rivas, S. A., Galia, M. B. (2010). Biopolymers from sunshine. In K. N. Timmis, Handbook of hydrocarbon and lipid microbiology. Springer-Verlag Berlin Heidelberg.
97. Rossi, Andrew, Ed., Good Environmental Practices in Bioenergy Feedstock Production: Making Bioenergy Work for Climate and Food Security, BEFSCI – Bioenergy and Food Security Criteria and Indicators, Bioenergy and Food Security Criteria and Indicators project (Food and Agriculture Organization of the United Nations (FAO)), 2012 – Environment and Natural Resources Management Working Paper(Environment Climate Change [Energy] Monitoring and Assessment), 49.
98. Sabourin, D. (2011, May 3). Degradable additives provide poor end-of-life option for PET packaging, says NAPCOR. Sonoma, CA: NAPCOR. Retrieved from National Association for PET Container Resources (NAPCOR).
99. SAFN, Executive Summary RE SAFN Part 1 of 1 - Regional leader group document - Sustainable Aviation Fuels Northwest: Powering the Next Generation of Flight.
100. SAFN 2011 Report Regional leader group document - Sustainable Aviation Fuels Northwest: Powering the Next Generation of Flight. 2011 Report – complete report available at www.safnw.com.
101. Schut, J. H. (2012, August 13). The race to 100% bio PET. Retrieved from Plastics Engineering Blog: http://www.plasticsengineering/blog.com/2012/08/13/the-race-to-100-bio-pet
102. Setyawan, E. (2011). Manufacturing Activated Carbon in Biomass Rich Countries. JFE Project. Retrieved from: http://www.slideshare.net/ekosbsetyawan/manufacturing-activated-carbon
103. Shen, L., Haufe, J., & Patel, M. K. (2009). Product overview and market projection of emerging bio-based plastics . The Netherlands: European Bioplastics.
104. Simon, CJ., Schnieders F. (2009). Business Data and Charts 2007. PlasticsEurope Market Research Group (PEMRG). Retrieved from: http://www.plasticseurope.org/Content/Default.asp?PageID=989.
105. Singh, B.B. and J.N. Swamy. 2012. Shale impact on C2, C3 and C4 derivitives. Chemical Market Resources, Inc., www.CMRHou.Tex.Com. (http://cmrhoutex.com/media/The%20Shale%20Gas%20Impact%20on%20C2%20C3%20and%20C4%20Downstream%20Derivatives.pdf).
106. Sjostrom, S., Durham, M., Bustard, C. J., and Martin, C. (2010). Activated carbon injection for mercury control: Overview. Fuel, 89(6), 1320 - 1322. Retrieved from: http://www.sciencedirect.com/science/article/pii/S0016236109005250
107. SPI, C. B. (2013, January). Position paper on degradable additives. Retrieved from The Society of the Plastics Industry Bioplastics Council: http://www.plasticsindustry.org/files/about/BPC/Position%20Paper%20on%20Degradable%20Additives%20-%20012113%20-%20Final.pdf
108. SPI. (2013). Development of biobased plastics independent of the future biofuels. Retrieved from: http://www.plasticsindustry.org/files/about/

BPC/Development%20of%20Biobased%20Plastics%20-%20August%2026%202013%20-%20FINAL.pdf
109. Srivastava, R. K., Hutson, N., Martin, B., Princiotta, F., and Staudt, J. (2006). Control of Mercury Emissions from Coal-Fired Electric Utility Boilers. Environmental Science & Technology, 40(5), 1385-1393. Retrieved from: http://pubs.acs.org/doi/abs/10.1021/es062639u
110. Starksy, Valarie, The Renewable Fuel Standard and Cellulosic Biofuels: Prospects and Challenges, Biomass Program, Energy Efficiency and Renewable Energy Department of Energy, Lead Platform R & D.
111. Steeman, A. (2011, July 13). PET is PET - Petro-PET or Bio-PET. Retrieved from Best in Packaging: http://www.bestpackaging.com/2011/07/13/pet-is-pet-petro-pet-or-bio-pet
112. Stevens, G. (2010, October 07). Bioplastic Standards 101. Retrieved from Green Plastics: http://green-plastics.net/news/45-science/107-bio-plastic-standards-101
113. Suhas, Carrott, P. J. M., and Carrott, M. M. L. R. (2007). Lignin – from natural adsorbent to activated carbon: A review. Bioresource Technology, 98(12), 2301 - 2312. http://www.sciencedirect.com/science/article/pii/S0960852406004056
114. The Freedonia Group. (2012). World Activated Carbon to 2016. Retrieved from: www.freedoniagroup.com/DocumentDetails.aspx?Referrerld=FG-01&studyid=2878.
115. Thielen, M. (2012, April). Bioplastics: Basics. Applications. Markets. Retrieved from bioplastics magazine: http://www.bioplasticsmagazine.com/en/books/bioplastics.php
116. Transparency Market Research. (2012). Butanediol, 1,3 Butadiene and Methyl Ethyle Ketone Market: Application, Bio-based alternatives, Downstream Potential, Market Size and Forecast. Retrieved from: http://www.transparencymarketresearch.com/butanediol-butadiene-and-mek-market.html.
117. Tsai, W. T., Chang, C. Y., Wang, S. Y., Chang, C. F., Chien, S. F., and Sun, H. F. (2001). Preparation of activated carbons from corn cob catalyzed by potassium salts and subsequent gasification with \{CO2\}. Bioresource Technology, 78(2), 203 - 208. Retrieved from: http://www.sciencedirect.com/science/article/pii/S0960852400001115
118. United States Department of Agriculture. (n.d.) Biopreferred Home. USDA. Retrieved from: http://www.biopreferred.gov/Default.aspx
119. United States, Department of Agriculture, Agriculture and Aviation: Partners in Prosperity, January 2012 – published by the U.S. Department of Agriculture in conjunction with Airlines for America (A4A, formerly the Air Transport Association of America) and the Boeing Company – USDA, Airlines for America, and Boeing.
120. United States Department of Agriculture BCAP: Biomass Crop Assistance Program – Energy Feedstocks From Farmers & Foresters, A Report by the U.S. Department of Agriculture: Farm Service Agency, October 2012.
121. United States Department of Agriculture. (2009). Public Meeting on BioPreferred Voluntary Labeling Program. Departmental Management. Office of Procurement and Property Management. Federal Register 74(240). Retrieved from: http://www.gpo.gov/fdsys/pkg/FR-2009-12-16/html/E9-29957.htm
122. United States Department of Agriculture. (2012). Guidelines for Designating Biobased Products for Federal Procurement. Office of Procurement and Property Management. Federal Register 77(84). Retrieved from: http://www.gpo.gov/fdsys/pkg/FR-2012-05-01/pdf/2012-10420.pdf
123. United States Department of Energy. (2010). Current State of the U.S. Ethanol Industry. New Castle: Cardno ENTRIX. Retrieved from: https://www1.eere.energy.gov/bioenergy/pdfs/current_state_of_the_us_ethanol_industry.pdf
124. United States, Department of Energy: U.S. Billion-ton Update; Biomass Supply for a Bioenergy and Bioproducts Industry, August 2011.
125. United States Energy Information Administration. (2010, July 8). The Ethanol Blend Wall. Retrieved from U.S. Energy Information Administration: http://www.eia.gov/oog/info/twip/twiparch/100708/twipprint.html
126. United States Energy Information Administration. (2013). Short-term Energy Outlook. EIA. Retrieved from: http://www.eia.gov/forecasts/steo/
127. United States Energy Information Administration(a). (2013). Natural gas prices. U.S. Energy Information Administration. Retrieved from: www.eia.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm.
128. United States Energy Information Administration(b). 2013. Electric Power Monthly. U.S. Energy Information Administration. Retrieved from: http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a.
129. United States Energy Information Administration(c). 2013. Short Term Energy Outlook: Coal. U.S. Energy Information Administration. Retrieved from: http://www.eia.gov/forecasts/steo/report/coal.cfm.
130. United Nations Environment Programme. (2013). Global Mercury Assessment 2013: Sources, Emissions, Releases and Environmental Transport. UNEP Chemicals Branch. Retrieved from: http://www.unep.org/PDF/PressReleases/GlobalMercuryAssessment2013.pdf
131. United State Environmental Protection Agency. (2011) Fact Sheet: Mercury and Air Toxic Standards for Power Plants. Retrieved from: http://www.epa.gov/mats/pdfs/20111221MATSsummaryfs.pdf
132. United State Environmental Protection Agency. (2013). Regulation of Fuels and Fuel Additives: Identification of Additional Qualifying Renewable Fuel Pathways Under the Renewable Fuel Standard Program. Federal Register 78(43): 14198. Retrieved from: https://www.federalregister.gov/articles/2012/03/05/2012-5256/regulation-of-fuels-and-fuel-additives-identification-of-additional-qualifying-renewable-fuel
133. United States Environmental Protection Agency. (2011) The Toxics Rule Facilities. National Electric Energy Data System Retrieved from: http://www.epa.gov/mats/pdfs/20111221facilitiesmap.pdf
134. United States Environmental Protection Agency. (n.d.) Basic Information. Retrieved from: http://www.epa.gov/hg/about.htm

135. United States Environmental Protection Agency. (n.d.) Guidance on New Fuel Pathway Approval Process. Retrieved from: http://www.epa.gov/otaq/fuels/renewablefuels/compliancehelp/rfs2-lca-pathways.htm
136. United States Environmental Protection Agency, “Regulatory Announcement: EPA Proposes 2014 Renewable Fuel Standards, 2015 Biomass-Based Diesel Volume” (U.S. Environmental Protection Agency: Office of Transportation and Air Quality), EPA-420-F-13-048, November 2013.
137. United States Environmental Protection Agency. (n.d.) Questions and Answers on Changes to the Renewable Fuel Standard Program (RFS2). Retrieved from: http://www.epa.gov/otaq/fuels/renewablefuels/compliancehelp/rfs2-aq.htm
138. Vanholme, R., Morreel, K., Ralph, J., and Boerjan, W. (2008). Lignin engineering. Current Opinion in Plant Biology, 11(3), 278 - 285. Retreived from: http://www.sciencedirect.com/science/article/pii/S1369526608000459.
139. Voegele, Erin. 2010. Filling a Void. Biomass Magazine. (http://biomassmagazine.com/articles/6544/filling-a-void). Oct. 7.
140. Washington State, Biennial Energy Report: Issues, Analysis and Updates - Department of Commerce: State of Washington. December 2012, Report to the Legislature, Rogers Weed, Director.
141. Welle, F. (2011). Twenty years of \{PET\} bottle to bottle recycling—An overview. Resources, Conservation and Recycling, 55(11), 865 - 875. Retrieved from: http://www.sciencedirect.com/science/article/pii/S0921344911000656
142. Wikipedia. (2013, August 6). Lignin. Retrieved from Wikipedia: http://en.wikipedia.org/wiki/Lignin
143. Williams, P. R. D., Inman, D., Aden, A., and Heath, G. A. (2011). Correction to Environmental and Sustainability Factors Associated With Next-Generation Biofuels in the U.S.: What Do We Really Know?. Environmental Science & Technology, 45(22), 9820-9820. Retrieved from: http://pubs.acs.org/doi/abs/10.1021/es2035043
144. Yahoo Finance. (2013). US Activated Carbon Market. PRNewswire. Retrieved from: http://finance.yahoo.com/news/us-activated-carbon-market-154600355.html
145. Yoder, J. (2010) Biofuel Economics and Policy for Washington State. WSU School of Economic Sciences. Retrieved from: http://cru.cahe.wsu.edu/CEPublications/XB1047E/XB1047E.pdf
146. Zhang, F., Johnson, D. M., and Sutherland, J. W. (2011). A GIS-based method for identifying the optimal location for a facility to convert forest biomass to biofuel. Biomass and Bioenergy, 35(9), 3951 - 3961. http://www.sciencedirect.com/science/article/pii/S0961953411003308

SYSTEMS METRICS

LCA AND COMMUNITY IMPACT TEAM

TASK SM-LCA-1: LCA ASSESSMENT OF USING FOREST BIOMASS AS A FEEDSTOCK FOR BIOFUEL

Key Personnel	Affiliation
Ivan Eastin	University of Washington
Robert Harrison	University of Washington
John Perez-Garcia	University of Washington
Elaine O-Neil	University of Washington

Task Description

This research module will provide a definitive assessment of the technical, economic, environmental, and social impacts of using woody biomass for the production of jet fuel. Understanding the consequences of this technology is necessary if forest biomass is to be widely used for jet fuel. In addition, a life cycle assessment (LCA) on greenhouse gas emissions will be necessary to qualify jet fuel made from forest based biomass under the Energy Independence and Security Act (EISA) of 2007 and the EPA guidelines promulgated to meet the new requirements of the act (EPA 2009). To meet this objective, biomass growth/yield models and life cycle assessment (LCA) models will be combined to develop life cycle environmental profiles for specific woody biomass feedstocks matched with the proposed jet fuel processing technology. The results of this analysis will be used to develop LCAs for greenhouse gases (GHG) and other environmental performance indices for comparisons between cellulosic jet fuel and fossil fuels. Alternative technologies, with their impacts on the value chain, will be compared for different forest treatments, harvesting and collection equipment and processing alternatives. Feedstock qualities will be matched with processing alternatives and regional feedstock scales of availability matched with efficient scale processing infrastructure. Alternative configurations and policy assumptions covering a range of scenarios will be used to project potential regional reductions in GHG emissions and energy dependence as well as rural economic impacts. The impacts of different policies and other alternatives will be characterized as sensitivity scenarios to better inform the adoption of appropriate policies, marketing, and investment strategies to reach energy independence goals with reduced GHG emissions while effectively managing cellulosic resources.

This revised scope of work makes several assumptions that need to be explicitly noted:

1) It is assumed that funding for Gevo's participation in the LCA analysis will be brought forward so that they can begin to participate in the LCA immediately.
2) It is assumed that the second NARA community will be identified by the end of project year #3.
3) It is assumed that the final pretreatment process will be selected by the end of project year #3.

Activities and Results

SOIL CARBON EVALUATION (TASKS 4, 5, 6, 7 AND 8)

Progress Made Thus Far

Significant productivity and accomplishments are report for the period to April 2013 - March 2014. Research completed at the Fall River site during the last year is shedding some additional light on the mechanisms behind the high productivity and resilience of the soils of the Fall River LTSP and soils in the PNW (generally associated with the most productive forests of the coastal zone). Eleven-year-old forest biomass at Fall River was sampled. It was found that the removal of additional biomass used for biofuels had little impact on future tree productivity and that regrowth was very productive. This research is published as a USFS Research paper. Resampling of soil at Fall River showed few changes in soil carbon with treatment levels, though additional tree growth associated with control of competing vegetation with herbicides seemed to show small changes in deep soil carbon associated with higher root productivity. This research is now published as part of the proceedings of the North American Forest Soils Conference in the Soil Science Society of American Journal. Other work on deep soil carbon in 22 coastal Douglas-fir plantations showed that deep soil properties may be very important in determining inherent productivity and resilience to additional biomass harvesting for bioenergy. Additional, less intensive and complete, shorter-term research at 73 other coastal Douglas-fir plantations from northern Vancouver Island, BC, Canada to southern Oregon is being used to give the Fall River work more impact and perspective and to make the work more useful as a predictive tool. Here are details on the major efforts and accomplishments for April 2013 - March 2014.

1) Fall River Tree Biomass Sampling and Journal Article

Team Members: Warren Devine, Tom Terry, Kim Littke, Scott Holub, Rob Harrison

Measurements of current tree diameters and heights at the Fall River LTSP were completed, and 26 trees were sampled for detailed analysis to provide final estimates of biomass in the bole-only harvest with and without competing vegetation control. The research showed that tree form was not highly dependent on treatments at the Fall River site and that trees sampled from the bole-only with and without vegetation control had similar form. Trees grown with and without competing vegetation control were sampled in an 11-year-old Douglas-fir (Pseudotsuga menziesii var. menziesii (Mirb.) Franco) plantation on a highly productive site in southwestern Washington to create diameter-based allometric equations for estimating individual-tree bole, branch, foliar, and total aboveground biomass. These equations were used to estimate per-hectare aboveground biomass, nitrogen (N), and carbon (C) content, and compared to (1) estimates based on biomass equations published in other studies and (2) estimates made using the mean-tree method rather than allometric equations. Component and total-tree biomass equations were not influenced by the presence of vegetation control, although per-hectare biomass, C, and N estimates were greater where vegetation control was applied. Our biomass estimates differed from estimates using previously published biomass equations by as much as 23 percent. When using the mean-tree biomass estimation approach, incorporating a previously published biomass equation improved accuracy of the mean-tree diameter calculation. The results of this work point out clearly the large impact of the vegetation control treatment on biomass production over a fairly long term of the study. Rather surprising was that the site was very resilient to high removals of additional biomass from tops, branches, foliage and woody debris. Results over a longer term will be available as this forest stand enters its rapid growth stage after age 15, where biomass will accumulate rapidly, and the soil of the site will be fully exploited. A manuscript of the research was published as a PNW station publication.

2) Fall River Soil Resampling, presentation at North American Forest Soils Conference, and Soil Science Society of America Journal Article

Team Members: Jason James, Christiana Dietzen, Marcia Ciol, Kim Littke, Scott Holub, Rob Harrison

The resampling of soils at Fall River was completed, compiled into an MS thesis, presented at the North American Forest Soils conference, and results were published in the Soil Science Society of America Journal. The thesis and journal article contain a lot of data, but perhaps the most compelling results from the research are the question's unanswered. For instance, Figure SM-LCA-1.1 shows the amount of total C in soil vs. depth in the bole-only biomass removal treatments with and without competing vegetation control. The largest changes in soil carbon due to the application of herbicides is at the deepest soil depth sampled, an unexpected result. It is generally thought that the largest impacts of any forest treatments will be in the forest floor and surface soil, which were nearly identical with and without competing vegetation control. Researchers noted the higher presence of roots in deeper soil horizons where competing vegetation was suppressed with herbicides, and the trees were allowed to growth with no competition from other species. The exploitation of the deeper soil profile by root systems of larger trees due to suppression of competing vegetation may be a key factor in high productivity sites, and may be one of the primary drivers in soil carbon changes in soil. This is not the conventional wisdom of carbon changes in soil, where lower soil horizons are considered to be relatively stable. Further research on deep soil at Fall River LTSP is being pursued by new graduate students in a resampling of Fall River LTSP soils to greater depths in new studies (detailed under item 4 below).

NARA resarcher Scott Holub published a paper detailing the ten-year growth results of the treatments at the Fall River LTSP that shows clearly the impacts of treatments on tree growth. The results of this work on differential tree growth support the findings of soil carbon (Figure SM-LCA-1.1).

3) Predicting Risk of Long-Term Nitrogen Depletion Under Whole-Tree Harvesting in the Coastal Pacific Northwest

Team Members: Austin Himes, Kim Littke, Eric Turnblom, Rob Harrison

In many forest plantation ecosystems, concerns exist regarding nutrient removal rates associated with sustained whole-tree harvesting. In the coastal North American Pacific Northwest, the depletion risk of nitrogen (N), the region's most growth-limiting nutrient, was predicted for 68 intensively managed Douglas-fir (Pseudotsuga menziesii var. menziesii [Mirb.] Franco) plantations varying widely in productivity. Stands to rotation age were projected using the individual-tree growth model ORGANON and then calculated a stability ratio for each stand, defined as the ratio of N removed during harvest to total site N store (soil and forest floor). A risk rating was assigned to each site based on its stability ratio under whole-tree and stem-only harvest scenarios. Under whole-tree harvest, 49% of sites were classified as potentially at risk of long-term N depletion (i.e., >=10% N store removed in harvest), whereas under stem-only harvest, only 24% of sites were at risk. Six percent and 1% of sites were classified as under high risk of N depletion (i.e., >=30% N store removed in harvest) under whole-tree and stem-only harvest, respectively. The simulation suggested that sites with <9.0 and<4.0 Mg/ha site N store are potentially at risk for long-term N depletion and productivity loss under repeated whole-tree and stem-only harvest, respectively. Sites with <2.2 and <0.9 Mg/ha site N store are at high risk of N depletion under whole-tree and stem-only harvest, respectively. The areas with the highest concentrations of at-risk sites were those with young, glacially derived soils on Vancouver Island, Canada, and in the Puget Sound region of Washington.

4) New NARA LTSP in Willamette Valley, Oregon " Effects of organic matter removal on Nitrogen and Carbon leaching fluxes in a Douglas-fir plantation"

Team Members: Marcella Menegale, Marcia Ciol, Kim Littke, Scott Holub, Rob Harrison

Installation of a brand new Fall River type LTSP has been completed in the Willamette Valley of Oregon. All of the treatments are done. Lysimeters have been installed and have been sampling over this winter. It is anticipated that sampling results over the next few years will provide insight into nitrogen and carbon cycling in soil similar to the insights gained at Fall River and Matlock LTSPs. The objective of this study is to determine the influence of organic matter removal during timber harvest – how does the presence/absence of harvest debris (such as chips, branches) in the area influence the accumulation of nutrients in the soil and, consequently, the final productivity of Douglas-fir forest. The latest harvest in the site occurred in April/May 2013. Three types of harvest were conducted: 1) bole only harvest, 2) total tree harvest, and 3) total tree harvest plus forest floor removal (Figures SM-LCA-1.2, SM-LCA-1.3, SM-LCA-1.4). There are 5 treatments, with 4 replications. Totally, there are 20 plots, each one acre in size. The treatments include:

A-Bole only harvest, no compacted soil
B-Total tree harvest, no compacted soil
C-Bole only harvest, compacted soil
D-Total Tree harvest, compacted soil
E-Total tree harvest + forest floor removal

Lysimeters at 20 and 100-cm depth will be used to quantify the mobilization and loss of NO_3--N, NH_4+-N, dissolved organic nitrogen (DON) and dissolved organic carbon (DOC) through the soil profile. For at least the first year, base cation leaching is being determined. Lysimeters were installed earlier: 100-cm depth lysimeters July 8-10/2013, and 20-cm depth September 26-27/2013. Soil solution samples have been collected monthly (from February 2014). Data loggers were installed in the area in order to collect soil moisture data. Thus, it will be possible to predict the movement of the water through the soil profile as well as determine the right moment for soil solution sampling. Though there is a huge amount of information being collected, Figure SM-LCA-1.5 shows the soil moisture in the treatments from October 24th 2013 to January 24th 2014.

5) Stump Decomposition Over Time For LCA Evaluation

Team Members: Matt Norton, Erin Burt, Kim Littke, Marcella Menegale, Rob Harrison

Background: Many studies have looked at decomposition rates and determined that the main factor influencing these rates within species was climate (Weedon et al, 2009), that woody debris stop losing mass from decomposition at about five years after they have been cut (Edmunds and Eglitis, 1989) and that decay rates in Douglas-fir (Pseudotsuga menziesii) are less than other species due to compounds which restrict the infestation of mycelium into the debris after death (Schafer and Cowling, 1966). However, stumps of Douglas-firs have not been studied in relation to decomposition rates, carbon (mass) retention etc. These species dominate tree farms in the Northwest, and knowing the rates of decomposition in their stumps after tree harvest could have major implications on carbon/nutrient cycling models. By assessing decomposition rates for Douglas-fir stumps on tree farms across variable climates in the region, a comprehensive model of decay can be created. This model could also contribute to a better understanding of carbon sequestration in tree farming operations.

Parameters: Examine the woody composition of tree farm stand stumps to determine total carbon and carbon to nitrogen ratios for signs of decomposition potential. Determine the loss of carbon to the atmosphere or to the soil by comparing the samples by climate type and age. Then, use the resulting data to model decomposition over time, including whether or not it has a halting point.

Methods: Samples will be taken from Pseudotsuga menziesii stumps with ages from 1 year to 60 years since cut, concentrating on trees that were grown and cut as part of the plantation but also sampling old growth stumps where possible. Sample sites will be within many of the vegetative zones in the Douglas-fir region set by Franklin and Dyrness (1988).
Using boring bits with a cordless drill and a specialized penetrating drill, woody materials from the various portions of the remaining tree trunk (bark, sapwood and heart wood) will be collected. This method should allow an increase in sample number and a decrease in individual sample size compared to the “cookie slice” method of sampling. The materials will be collected in one- or two-inch intervals to be set by changes in wood type/density. In order to reduce loss, the bark may be sampled by hand (as it is very brittle) and use the drill method to sample the inner layers. This will only be done if it increases safety and reduces material losses.

Work Timeline: The initial effort is to make sure sampling methods are safe and efficient in order to prevent any injuries related to sampling and to minimize loss of material collected.

In this first sampling, stumps with ages 15 and 60 years old were collected from the Fall River LTSP Site. Samples were brought back to the lab to test methods. Method should be finalized by the start of Winter Quarter on January 6th 2014. Sampling will be conducted over the next month and a half or so to make sure that as many representative sites in the various Douglas-fir vegetative zones are covered in the study. In the meantime, lab processing for total nitrogen and carbon will commence in addition to density measurements being taken. By February (2/3/2014), a rough idea of the results will be known and the study parameters will be re-evaluated to make certain that the potential to model decomposition is covered, as well as to make sure that considerations, such as heterotrophic interference, are not being missed by the sampling methods adopted. The idea is to have a good database and initial rates of decomposition assessed as well as an estimate of inputs and losses at the sample sites by the end of March 2014.

6) Additional Work for Fall River LTSP and other Douglas-fir Plantations

Soil represents the most important long-term sink for carbon (C) in terrestrial ecosystems because it contains more carbon than plant biomass and the atmosphere combined. Nevertheless, soil has historically been under-represented in research, especially information about subsurface (>1.0 m) layers and processes. The effects of silvicultural treatments on deep soil C and N have been particularly lacking, even in soils that are known to be many meters deep. The maximum depth of Douglas-fir rooting is often ~3 m, providing biogeochemical interactions with deep soil through uptake, root exudates, and turnover. During summer drought, drying of surface soil can drive passive upward movement of water through deep roots (called hydraulic redistribution), replenishing 28% to 40% of water depleted from the top 2 m of soil each day.

In the most recent re-sampling at the Fall River Long-term Soil Productivity Site (LTSP), differences between treatments were greatest deep in the soil profile, primarily below 0.6 m. The largest difference in soil C between bole-only harvest treatments with and without vegetation control was found in the deepest sampled layer (Figure SM-LCA-1.1). Likewise, the largest differences in soil C between the total-tree harvest plus vegetation control and bole-only harvest with vegetation control treatments were not in the surface layers, but instead at depth. This study aims to investigate whether this trend continues in layers deeper than 1.0 m at Fall River, providing valuable information about how silvicultural treatments affect soil C and N cycling in deep layers of highly productive Douglas-fir plantations in the Pacific Northwest. Jason James showed that there is a great deal of carbon and nitrogen below 100 cm depth (James et al. 2014).

Experimental Plan:
This work will build upon previous research by Erika Knight at the Fall River Long-term Soil Productivity Site located in western Washington. The Douglas-fir (Pseudotsuga menziesii) stand at Fall River was established in 1999 with four replicates of 12 treatments in a complete, randomized block design. Blocking was based on slope position and percentage of Douglas-fir and western hemlock in the original stand. This site has a deep, well-drained soil with few rocks, which developed from weathered basalt and is classified as an Andisol of the Boistfort Series. At the time of installation, soil C and N were measured both pre-harvest to a depth of 80 cm and post-harvest to a depth of 150 cm.

Our project will focus on three of the treatments implemented at the Fall River site: commercial bole only removal with vegetation control by annual herbicide application (BO+VC), commercial bole only removal without vegetation control (BO-VC), and total-tree plus removal with vegetation control (TTP+VC). In the BO+VC and BO-VC treatments, remaining tops, broken logs less than three meters in length, buttcuts, and all remnant coarse woody debris were left in place. In the TTP+VC treatment harvesting removed the entire aboveground tree including live limbs, foliage, and most dead limbs. Most remaining coarse woody debris was removed and herbicide was used to control competing vegetation. Each of four blocks contains two 30 x 85 meter plots for each treatment. Within each plot, sampling locations will be randomly selected within six subplots to estimate variation within plots.

Soil C and N concentration and bulk density will be measured to a depth of 3.5 meters using an AMS Signature Series Split-Core Sampling Kit at 9 depth intervals: 0-10 cm, 10-20 cm, 20-50 cm, 50-100 cm, 100-150 cm, 150-200 cm, 200-250 cm, 250-300 cm, and 300-350 cm, or until bedrock or an impermeable layer is reached. Sampling intervals are smaller in the top 50 cm of the soil profile to account for the higher expected rate of change of C and N concentrations with depth in the upper soil horizons. The forest floor will also be sampled at each subplot. In order to validate the bulk density measurements taken with the AMS soil corer, soil pits will be excavated in each block for bulk density measurements at the same depth intervals to 1.5 m using the more widely-used punch core method for comparison.

Samples will be analyzed to determine soil C and N concentrations. Carbon and nitrogen content on an area basis will be determined by multiplying the bulk density by concentration and sample depth interval. Samples will also be analyzed to determine cation exchange capacity (CEC), anion exchange capacity (AEC), and short-range order mineral content, which previous studies have suggested may play a role in soil C and N retention.

Depending on results and utility of sampling equipment, this analysis will be extended to additional similar studies at Matlock that have several rates of organic matter removal, and possibly to some additional studies of the Stand Management Cooperative, that have been fertilized about 30 years previously with nitrogen fertilizer to increase productivity.

The LTSP network was established in 1989 and provides one of the most valuable long-term datasets for understanding the impact of forest management on soil and site productivity. The Fall River LTSP Site was selected to represent the most productive soils in the Pacific Northwest, and results from this study can potentially be extrapolated to millions of hectares of industrial forestland. There is a large amount of previously published data from Fall River, which can be readily used to show changes over time. The effects of silvicultural treatments on deep soil nutrient cycles have not yet been investigated, making this study a pioneer in researching deep soils with robust statistical design.

LIFE CYCLE ASSESSMENT (TASKS 13, 15, 16, 19, 20, 21 AND 22)

Team Members: Ivan Eastin, Indroneil Ganguly, Tait Bowers, Ike Nwaneshiudu and Francesca Pierobon

Progress Made Thus Far

During this reporting period, April 2013 - March 2014, significant progress was made on the feedstock and pretreatment fronts of the LCA work. The research progress on the feedstock logistics aspect of the project aimed at developing a comprehensive understanding of the role of feedstock logistics on the west side of the Cascades and fine tuning aspects of the east side of the Cascades, Idaho and western Montana. With the pretreatment processes evolving during this phase, constructive discussions with the pretreatment and LCA team members created positive outlook towards the goal.

Following up on the proposed activities described in the previous quarterly report, progress was made in coordinating with NARA researcher Tim Smith to integrate the co-product LCA development task into the LCA group. A meeting was held at the University of Minnesota with Tim Smith and his research group, Ms. Rylie Olsen and Ms. Luyi Chen, which was preceded by multiple conference calls. For this meeting Dr. Ganguly and Dr. Eastin traveled to Minnesota, whereas, Mr. Tom Spink and Dr. Wolcott joined parts of the meeting via teleconference call. During the meeting, a consensus was reached on how co-products can be handled within an LCA framework.

The LCA team members were involved in organizing and attending multiple cross meetings in an attempt to integrate the pretreatment processes within an LCA framework. A meeting with the wet oxidation (WOX) pretreatment team was organized at the WSU tri-cities campus while another meeting with the mild bisulfite (MBS) pretreatment team was held on the Weyerhaeuser campus. Both of the meetings were very productive and laid the path for the ASPEN-LCA modeling. These meetings were attended by Dr. Nwaneshiudu, Ms. Pierobon and Dr. Ganguly of the LCA team.

During this reporting period, significant progress was made in the ASPEN-LCA modeling aspect of the project. Dr. Nwaneshiudu, Dr. Ganguly and Ms. Pierobon had been working closely with the ASPEN modeling team at WSU to model the pretreatment processes. Dr. Nwaneshiudu traveled twice to WSU to work with the ASPEN modeling team. While the ASPEN modeling of the pretreatment processes is still evolving, the LCA team has been able to develop initial environmental assessment models associated with each of the pretreatment processes under consideration.

During this reporting period, various aspects of the LCA work were presented at more than 20 venues by different members of the LCA team. These venues range from national level conferences to regional level stakeholder meetings and university level course lectures. During this period, multiple NARA-LCA related publications were submitted to journals and conference proceedings for publication and several manuscripts have been accepted for publication. The LCA team also worked very closely with the NARA IDX teams at WSU and the University of Idaho. The University of Washington hosted an IDX team meeting at the UW Seattle campus, headed by Dr. Karla, from the University of Idaho.

In the following section abstracts of some of the important work undertaken during this period is provided.

1) Incorporation of the carbon sequestration into the Life Cycle Assessment of woody biomass based bioenergy

The renewable characteristic of woody biomass plays an important role in evaluating the overall carbon footprint of renewable energy. However, there is no general consensus on a methodology for incorporating carbon sequestration within the life cycle assessment (LCA) framework. The objective of this study is to propose a methodology for incorporating carbon sequestration within the bioenergy LCA framework. Forest types, species mix, and silviculture techniques play an important role in the evaluation of the proposed carbon sequestration methodology. This study proposes a global warming impact assessment methodology for incorporating carbon sequestration within the life cycle assessment of wood based bioenergy. The proposed methodology considers the effects of the dynamic carbon sequestration and of the residuals decomposition on the global warming impact through the concept of radiative forcing. Greenhouse gas decay functions in the atmosphere have been utilized to evaluate the temporal impacts and benefits associated with the emission and sequestration of carbon during the forest life cycle. The preliminary results suggest that forest type, species mix and silviculture treatments influence the level of environmental benefits derived from woody biomass based bioenergy.

2) Comparative Life Cycle Assessment of Wet Oxidation and Bisulfite (SPORL) Pretreatment Methods for Converting Forest Slash Residues to Sugar

Pretreatment processes such as wet oxidation and calcium bisulfite (SPORL) are emerging as options for processing woody biomass into fermentable sugars. A comparative assessment of both wet oxidation and mild bisulfite processes will be used to assess their environmental impacts. The assessment will be built from full-scale models of both processes using the Aspen Plus® Software package. A techno-economic assessment is used to augment the data set developed in the process model. Based on the LCA results, pretreatment options will be determined that best fit a conceptual depot scale facility based in the Pacific Northwest. it would be beneficial to know which units in the pretreatment process have the greatest impact on global warming, eutrophication, and carcinogens.

3) Environmental Implications of Advanced Biofuels in the Pacific Northwest: An LCA Approach

This paper presents the preliminary results of a framework 'cradle-to-grave' life-cycle of woody biomass based bio-jet fuel. In this paper 'cradle' is defined as beginning with the natural regeneration of young trees within the forest and 'grave' is defined as the burning of bio-jet fuel in an intercontinental passenger aircraft. To evaluate the various logistical/procedural pathways, this paper explores a range of biomass transportation scenarios and incorporates the avoided environmental costs associated with piling and burning the woody biomass within the forest into the LCA calculations. For this paper, the primary LCA assumes a 'greenfield model' (similar to the NREL process), where the biomass collection, pretreatment and fuel conversion processes are all undertaken at the same location. However, the environmental implications of a depot model for local collection and pretreatment sites are also explored in this paper. The environmental burdens for each of these scenarios are assessed in terms of global warming, acidification, smog, and ozone depleting potentials. Preliminary results suggest that there is a 61.6% reduction in the global warming potential and a 60.7% reduction in fossil fuel depletion potential by substituting NARA bio-jet fuel for fossil fuel-based jet fuel.

4) Environmental Assessments of Woody Biomass Feedstock for Bio-jet Fuel Production

This paper presents the results of a 'cradle-to-gate' life-cycle of woody biomass feedstock to be used for bio-jet fuel production. In this paper 'cradle' is defined as beginning with the natural regeneration of young trees within the forest and 'gate' is defined as residual woody feedstock delivered to the pre-treatment facility. To evaluate the various logistical/procedural pathways, this paper explores a range of biomass transportation scenarios and incorporates the avoided environmental costs associated with piling and burning the woody biomass within the forest into the LCA calculations. The environmental burdens for each of these scenarios are assessed in terms of global warming, acidification, smog, and ozone depleting potentials. Results obtained indicate that transportation of loose residue in forest road contributes significantly to the overall carbon footprint of woody feedstock. Forest road conditions that limit the access of trucks with high load carrying capacity to the primary landing increases the carbon intensity of the feedstock logistics. The avoided environmental impact associated with recovering forest residues (rather than burning them in slash piles) proves to be substantial. The results of the avoided impacts analysis show that, under certain scenarios, residual biomass recovery operations can be conducted with no or minimal adverse global warming impact.

5) Transportation Logistics of Forest Residue Collection (Class project by Cindy Chen)

The goal of this project is to assess and compare the environmental impacts of the transportation logistics that transport forest residues to treatment facilities, and to identify transportation options that reduce environmental impacts while maintaining efficiency. The long-term objective is to reduce the negative environmental impacts of energy production process. This LCA provides a framework of the residue transportation processes for forest owners/managers and policy makers, and the results of this LCA can be applied in practice to reduce the economic and environmental burden of residue removal and to make the future of the entire "biomass to energy" process more sustainable. This research focuses on the domestic transportation and uses the scenarios developed by the OSU logistics team, headed by Dr. John Sessions. The approximate distance between the pretreatment facility and the study site is calculated based on a range of distances described in previous works, which includes steep roads, paved roads, and interstate highways (Johnson et al., 2012; Zamora-Cristales et al., 2013). Thus, the functional unit of this study is to efficiently transport one bone dried metric ton BDmT of forest residues to a treatment facility located 80 miles the biomass collection site.

Reference Flow

2 cases:

1. Grind the woody residues at the primary landing and transport to the pretreatment facility
   a. One large loader (diesel consumption 0.82 L/BDmt)
   b. Dump truck to transport to centralized landing for processing
   c. One horizontal grinder at primary landing to process residues (fuel consumption 3.01 L/BDmt)
   d. Transport to treatment facility using large capacity chip-van (120 cy capacity)

2. Bundle the residues at a centralized landing and transport to the pretreatment facility where the residues are ground on-site (electric grinder at facility)
   a. Dump truck to transport residue piles to centralized landing (30 cubic yard capacity)
   b. One diesel-engine bundler to bundle residues into bundles
   c. Load onto the short log trucks (120 cubic yard capacity)
   d. Transport to treatment facilities
   e. Residues are griound using electric powered grinder at the facility

In these two cases, the product is the woody residues that are collected and transported to the treatment facility while the co-product is the avoided emissions associated with the slash pile burns. Although it may require more work to collect residues from the forest to a secondary, or centralized, landing for easier accessibility, emissions could be reduced substantially by using an electric grinder rather a diesel powered grinder.

COMMUNITY ECONOMIC IMPACT ASSESSMENT (TASKS 36 AND 39)

Team Member: John Perez-Garcia

Progress Made Thus Far

Comments on the draft report with initial results: ECONOMIC IMPACTS OF NEW BIOREFINERY PRODUCTION IN THE WESTERN MONTANA CORRIDOR has been received and incorporated into a final version. A literature review on existing economic analysis was begun, and upon completion, will be inserted into the report. Once done, the report will be converted into a journal article for publication.

Among the comments received is the need to complete a sensitivity analysis. Spreadsheet models to produce a sensitivity analysis with respects to commodity versus industry assumptions have been created. Commodity versus industry production refers to make and use tables and the differences in the technology assumptions and types of questions answered by the input-output models. The above report uses industry-based technology assumption to conduct the analysis. A commodity use model allows the analysis to include secondary products (co-products), whereas the industry make model, assigns secondary products the industry with the secondary product as its primary output. The distinction is relevant to the project since the biorefinery will produce jet-fuel in addition to important co-products. The analysis will include a section describing the relationships between a commodity by commodity total requirements matrix, a commodity by industry total requirements matrix, an industry by commodity total requirements matrix, and the industry by industry total requirements matrix used in the above mentioned report. The results will be appended to the western Montana corridor (WMC) economic impact report when completed.

A preliminary conversion of the WMC spreadsheet model was successfully adapted to the western Washington region in response to a request to quantify the potential economic impacts of a biorefinery located in western Washington. A summary of the analysis is presented in Table SM-LCA-1.1.

SECTOR IMPACTS are commonly referred to as direct and indirect effects

VALUE ADDED are commonly referred to as induced effects

SECTOR IMPACTS, VALUED ADDED AND TOTAL Impacts are in $millions

EMPLOYMENT is measured in persons

FEEDSTOCK refers to feedstock purchases by the facility. The effect is decomposed into forestry activity and transportation activity. Trucking is the transportation activity used (versus ships, rail, etc.) to deliver feedstock.

Interpretation

An estimated $41.4 million annually (valued at $65/ bone dried tons (BDT) delivered) spend by a hypothetical biojet fuel refinery on forest residue feedstock creates a direct and indirect economic impact of $73.1 million ($25.5 + $47.6). Six hundred fifty-one (651 = 253 + 398) new jobs are created with nearly $39 million ($15.9 + $22.9) in value added, i.e., the induced effect. The sum of these direct, indirect and induced economic effects totals $112 million ($41.4 + $70.5) annually. This impact measures only the expenditure associated with feedstock purchases. The transportation sector impact is larger than the forestry sector impact.

An estimated $203 million annually spend by a hypothetical biofuel refinery on variable inputs (as estimated by Spinks and Marrs), such as labor and materials, creates a direct and indirect economic impact of $315 million.

The combined effect of $244 million ($41 (feedstock) + $203 (labor and other materials)) expenses results in $388 million dollars in direct and indirect economic impact with 1,243 new workers and $125 million in value added. The sum of these direct, indirect and induced economic effects totals $513 million annually.

Additional Assumptions:

- 636,766 tons of market biomass produced (~83% of planned facility usage) (used biomass calculator for WA to estimate the biomass supply)
- New facility located in Aberdeen, WA
- Harvest levels are expanded to allow the biomass production to be in addition to existing consumption.
- New facility competes with existing facilities to acquire biomass volumes.

RECOMMENDATIONS/CONCLUSIONS

Framework LCA using multiple logistical scenarios is completed for the WMC region and is just beginning for the west side. A combination of primary and secondary data was used to conduct the analysis. The primary data was collected through a series of surveys and field visits in both the regions. The 'Feedstock LCA' report incorporating primary data for WMC and preliminary west side feedstock LCA is available now. Multiple residual transportation and harvesting scenario-based analyses have been conducted and will be expanded over time. A preliminary LCA report structure following the ISO 14044 has been developed.

SUMMARY COMPARISON COMMENTS OF PRETREATMENT PROCESSES:

SUGAR

The LCA indicator criterions were developed based on incomplete information. The numbers used to make these determinations may change significantly as the ASPEN modeling progresses. Also note that the results of the various ASPEN models have been quite different over time, sometimes significantly different, which means these results must be viewed with extreme caution.

A mass balance approach has been adopted to distribute the environmental burdens between the co-products. Two products are considered in this analysis, sugar and insoluble lignin. Table SM-LCA-1.2 presents a comparative assessment of the environmental outputs resulting from the production of 1 kg. of sugar obtained from the two pretreatment processes.

Results based on the March 3rd, 2014 version of the ASPEN models show that the global warming potential results, based on the available data, reveal that mild bisulfite pretreatment (MBS) has a marginally lower (better) global warming potential (GWP) as compared to wet oxidation (WOX) pretreatment, although the difference between the two numbers is less than 10%. Given the uncertainties associated with the pretreatment processes and the ASPEN results, the differences between the GWP values for the two pretreatment processes is well within the margin of error and the two pretreatment processes may be considered to have similar global warming potential.

Results based on the March 3rd, 2014 version of the ASPEN models show that in terms of eutrophication, the WOX process has a significantly higher eutrophication potential compared to MBS. This is primarily because of the greater water intensity of the process. Once the waste water treatment is modeled, some of this eutrophication may be addressed. However, it is likely that even after developing a waste water management plan, the WOX will still have a higher eutrophication potential relative to MBS. In terms of ecotoxicity, no conclusion can be drawn without understanding how the red liquor will be utilized, and the LCA team cannot make a determination of the potential of reducing the ecotoxicity index of the MBS pretreatment process.

A mass balanced approach has been adopted to model the LCA indicators associated with lignin obtained from the two pretreatment processes. Our results show that the lignin follows exactly the same trend associated with the three LCA criterions identified in the sugar section. On the global warming potential indicator the lignin global warming potential (GWP) numbers are within 5% of each other with MBS lignin showing a marginally more favorable number. Given the data available, the LCA team feels that WOX lignin and MBS lignin have a similar GWP impact, and may be considered indistinguishable on this measure.

The results obtained from the preliminary LCA, using the NREL dilute acid pretreatment as surrogate, suggests that the overall greenhouse gas (GHG) impact of the bio-jet fuel is at approximately 65%. This preliminary result is significant in that it exceeds the mandated 60% emission reduction criterion specified in the US Energy Independence Act guidelines.

Proposed Activities:

It should be noted that the ASPEN modeling has multiple gaps that need to be filled in. Following is a list of the knowledge gaps and resulting risk factors that need to be addressed.

Knowledge gaps: O_2 generation is not modeled; significant mass balance gap exists; steam generation is not modeled; enzyme production and usage for hydrolysis may change; waste water treatment is not modeled; and vent streams are not measured.

Risk Factor: The knowledge gaps identified in the previous section are significant from an LCA perspective, and this makes the results presented susceptible to change. Moreover, the current ASPEN model does not deal with the extraction of soluble lignin from the red liquor stream. However, if the soluble lignin from red liquor can be extracted with limited (economically viable) energy inputs, this may give MBS an advantage in the co-products' LCA metric. This is only a possibility and can only be determined after developing the actual model.

Coordination

The LCA team needs cooperation from Gevo to to move forward. The meeting planned in January, 2014 did not materialize. It needs to be conducted sooner rather than later.

Employment coefficients calculated from IMPLAN employment numbers seem high. Forestry is often thought of as a capital intensive industry since the time value is so high. Whether further disaggregation from fisheries affects the results presented here will be investigated. A literature review has been initiated of economic impact studies for a biorefinery, and the employment impacts when reported will be noted.

Imports play a role in determining the multipliers since they affect purchase coefficients. it is assumed that purchases outside the county and region reflected in the current purchase coefficients are adequate. Regional purchase coefficients and their methods of calculation by IMPLAN procedures will be further explored. In addition, a multiregional modelling framework is being pursued to help identify interregional relationships.

One time purchases for the biorefinery plant are not included in the analysis and will be completed in a future update.

An investigation has been initiated of the industry by commodity, and commodity by commodity accounts, to describe how sales of products including the co-products leads to added economic activity.

Table SM-LCA-1.1. Summary analysis of the economic impacts of a biorefinery located in western Washington

	Feedstock		Facility	Total
	Forestry	Transportation		
SECTOR IMPACTS	$25.5	$47.6	$315.0	$388.1
VALUE ADDED	$15.9	$22.9	$86.5	$125.3
TOTAL IMPACTS	$41.4	$70.5	$401.5	$513.4
EMPLOYMENT	253	398	592	1,243

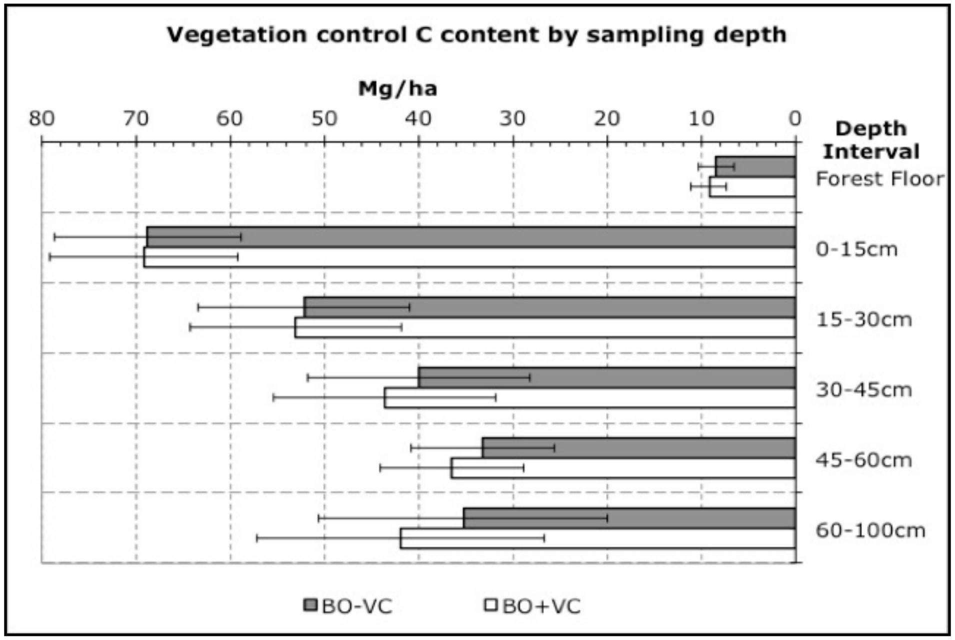

Figure SM-LCA-1.1. Cumulative soil C content by depth to 100 cm for a bole-only harvest with and without 5 yr of annual herbicide application (+VC and −VC, respectively). Each point represents the cumulative content to that depth. Reported forest floor depth is the average of measurements in both treatments. Bars indicate standard errors. There was no significant difference in total C content to 100 cm between treatments (a = 0.10).

Figure SM-LCA-1.3. Bole-only harvest treatment

Figure SM-LCA-1.2. 100-cm installed in the field

Figure SM-LCA-1.4. Total tree harvest + forest floor removal treatment

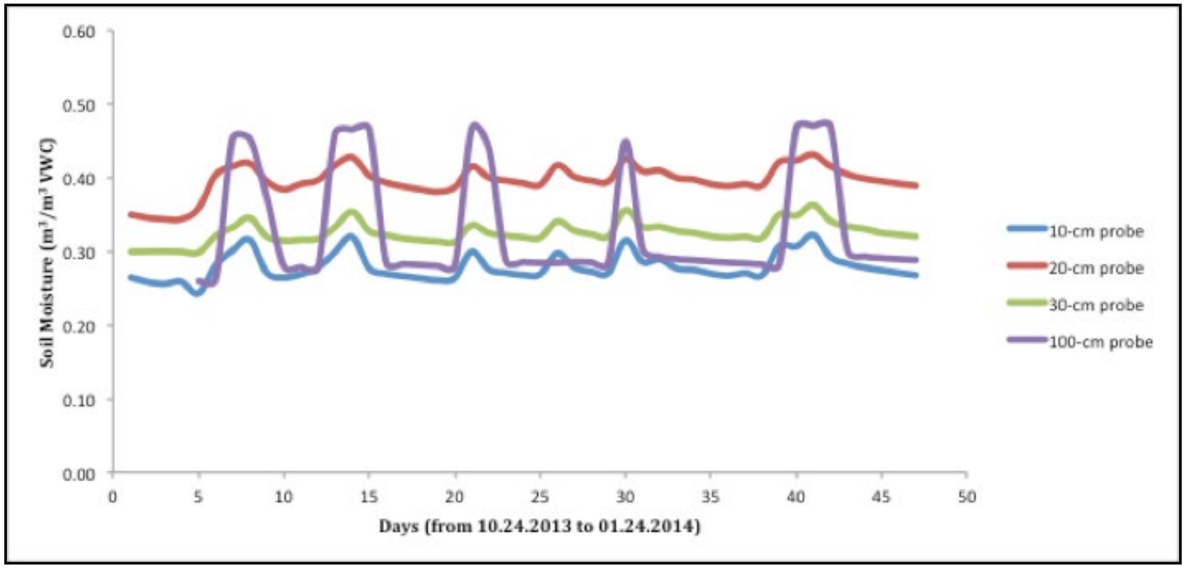

Figure SM-LCA-1.5. Soil moisture curve in “Bole only harvest, no compacted soil” treatments.

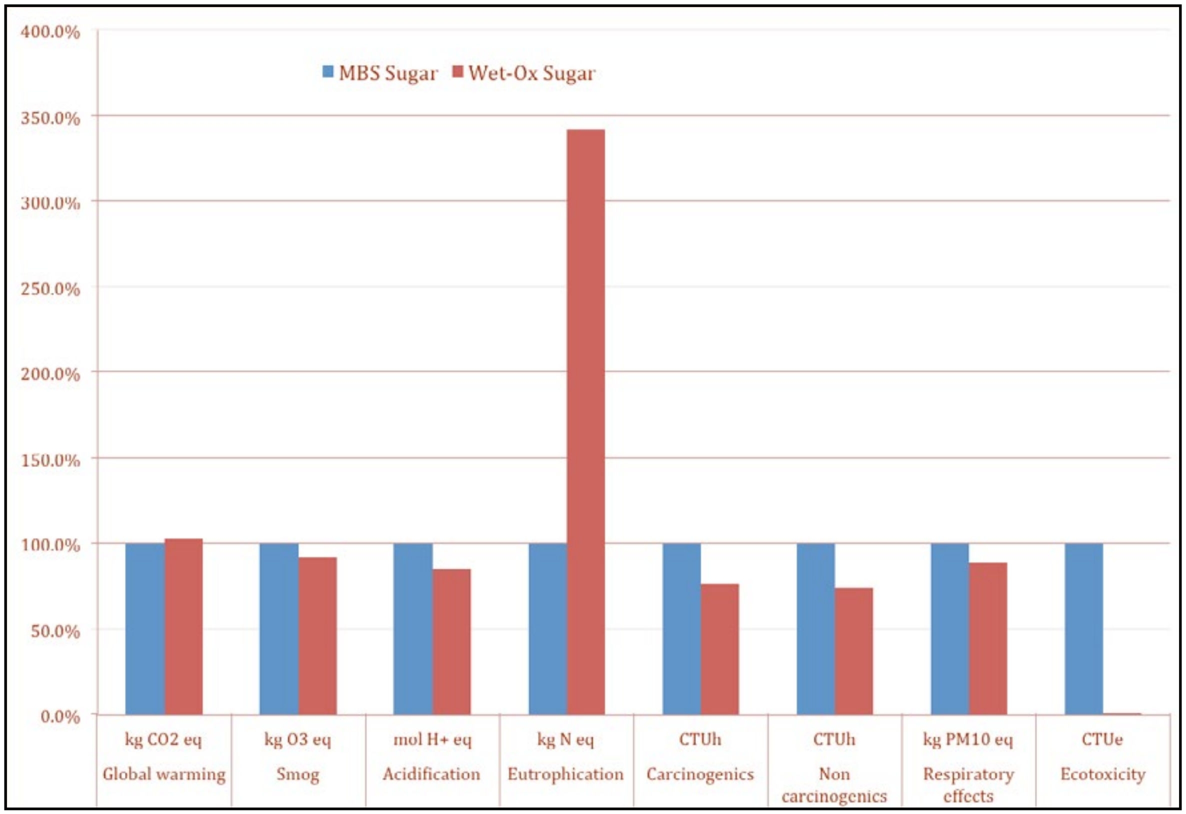

Figure SM-LCA-1.6. LCA results based on the March 3rd, 2014 version of the ASPEN models

Table SM-LCA-1.2. LCA results based on the March 3rd, 2014 version of the ASPEN models

Product 1:	1 kg WOX Sugar		
Product 2:	1 kg MBS Sugar		
Method:	TRACI 2 V4.00		
Sugar LCA: MBS vs WOX			
Impact category	Unit	MBS Sugar (1 kg)	Wet-Ox Sugar(1 kg)
Global warming	kg CO_2 eq	411.9327	422.8851
Smog	kg O_3 eq	67.15906	61.53271
Acidification	mol H+ eq	146.0572	124.3268
Eutrophication	kg N eq	0.250368	0.856023
Carcinogenics	CTUh	5.38E-06	4.12E-06
Non carcinogenics	CTUh	3.64E-05	2.69E-05
Respiratory effects	kg PM10 eq	0.304117	0.268501
Ecotoxicity	CTUe	2172571	424.658

Physical Outputs

REFEREED PUBLICATIONS (ACCEPTED OR COMPLETED)

Francesca Pierobon, Indroneil Ganguly, Ivan L. Eastin, Tait Bowers, and Tommaso Anfodillo. 0000-00-00 Accepted. “Evaluation of Environmental Impacts of Woody Biomass Based Bio-energy: a Life Cycle Assessment (LCA) Approach. Future Forestry Leaders Symposium.” Forestry Chronicle

Devine, W.D., P.W. Footen, R.B. Harrison, T.A. Terry, C.A. Harrington, S.M. Holub and P.J. Gould. 2013. Estimating tree biomass, carbon, and nitrogen in an 11-year-old Douglas-fir plantation on a highly productive site. USFS Research Paper PNW-RP-591. March 2013. Available at: http://soilslab.cfr.washington.edu/publications/Devine-etal-2013.pdf

Himes, AJ, EC Turnblom, RB Harrison, KM Littke, WD Devine, D. Zabowski and DG Briggs. 2013. Predicting Risk of Long-Term Nitrogen Depletion under Whole-Tree Harvesting in the Coastal PacificNorthwest. Forest Science 60:000-000 (currently pdf) Available at: http://soilslab.cfr.washington.edu/publications/Himes-etal-2013.pdf

Holub, SM, TA Terry, CA Harrington, RB Harrison and R Meade. 2013. Tree growth ten years after residual biomass removal, soil compaction, tillage, and competing vegetation control in a highly-productive Douglas-fir plantation. Forest Ecology and Management 305:60-66.
Available at: http://soilslab.cfr.washington.edu/publications/Holub-etal-2013.pdf

James, Jason, Warren Devine, Rob Harrison and Thomas Terry. Deep Soil Carbon: Quantification and Modeling in Subsurface Layers. Prepublished Soil Sci. Soc. Am. J.
Available at: http://soilslab.cfr.washington.edu/publications/James-etal-2014.pdf

Jandl, R., M. Rodeghiero, C. Martinez, M.F. Cotrufo, F. Bampa, B van Wesemael, R.B. Harrison, I.A. Guerrini, D.D. Richter, L. Rustad, K. Lorenz, A. Chabbi and F. Miglietta. 2014. Current status, uncertainty and future needs in soil organic carbon monitoring. Science of the Total Environment 468:376-383.
Available at: http://soilslab.cfr.washington.edu/publications/Jandl-etal-2014.pdf

Knight, E, , P. Footen, R.B. Harrison, T. Terry, S. Holub. 2013. Competing vegetation effects on soil carbon and nitrogen 12 years post-harvest in a Douglas-fir plantation on a highly productive site. Prepublished Soil Sci. Soc. Am. J. doi:10.2136/sssaj2013.07.0320nafsc
Available at: http://soilslab.cfr.washington.edu/publications/Knight-etal-2014.pdf

Littke, K.M., Harrison, R.B., Zabowski, D., Briggs, D.G. and Maguire, D.A. 2014. Effects of geoclimatic factors on soil water, nitrogen, and foliar properties of Douglas-fir plantations in the Pacific Northwest. Accepted by Forest Science.

Shryock, B., K. Littke, M. Ciol, D. Briggs and R.B. Harrison. 2014. The effects of urea fertilization on carbon sequestration in Douglas-fir plantations of the coastal Pacific Northwest. Forest Ecology and Management 318:341-348.
Available at: http://soilslab.cfr.washington.edu/publications/Shryock-etal-2014.pdf

Vance, ED, WM Aust, RE Froese, RB Harrison, LA Morris, and BD Strahm. 2013. Biomass Harvesting and Soil Productivity: Is Science Meeting our Policy Needs? Prepublished Soil Sci. Soc. Am. J. doi:10.2136/sssaj2013.08.0323nafsc
Available at: http://soilslab.cfr.washington.edu/publications/Vance-etal-2014.pdf

CONFERENCE PROCEEDINGS AND ABSTRACTS FROM PROFESSIONAL MEETINGS

Research Presentations

Francesca Pierobon, Indroneil Ganguly, Ivan L. Eastin, Tait Bowers, and Tommaso Anfodillo. 2014. “Evaluation of Environmental Impacts of Woody Biomass Based Bio-energy: a Life Cycle Assessment (LCA) Approach.” In Vancouver, Canada, Feburary 18, University of British Colombia.

Indroneil Ganguly. 2013. “Environmental Implications of Advanced Biofuels in the Pacific Northwest: An LCA Approach” presented at the AAIC 25th Anniversary Meeting, Washington, October 13–16, Washington, DC.

Francesca Pierobon, Tait Bowers, Indroneil Ganguly, and Ivan L. Eastin. 2013. “Feedstock LCA for Bio-Jet Fuel in the West Montana Corridor (WMC): Incorporating Carbon Sequestration.” In Corvallis, Oregon: North West Advanced Renewable Alliance.

Ganguly, I, I Eastin, F Pierobon, and T Bowers. 2014. “Environmental Assessment for Woody Biomass Feedstock for Bio-jet Fuel Production.” In Proceedings of the Seventh National New Crops Symposium New Crops: Bioenergy, Biomaterials, and Sustainability. Washington D.C.: AAIC.

Francesca Pierobon, Indroneil Ganguly, Tait Bowers, Tommaso Anfodillo and Ivan L. Eastin. Feedstock LCA for Bio-Jet Fuel in Temperate Mountain Systems: Incorporating Carbon Sequestration. 2014 IUFRO conference, Salt Lake City, Utah

Indroneil Ganguly, Ivan L. Eastin, Francesca Pierobon, and Tait Bowers. Local Air Quality Impacts of Advanced Biofuels in the Pacific Northwest: A Consequential LCA Approach. 2014 IUFRO conference, Salt Lake City, Utah

Knight, E, T. Terry, S. Holub and RB Harrison. 2013. Competing vegetation effects on soil carbon and nitrogen 12 years post-harvest. Submitted to Soil Science Society of America Journal for North American Forest Soils Conference.

Vance, ED, WM Aust, RE Froese, RB Harrison, LA Morris, and BD Strahm. 2013. Biomass Harvesting and Soil Productivity: Is Science Meeting our Policy Needs? Submitted to Soil Science Society of America Journal for North American Forest Soils Conference.

Indroneil Ganguly, Ivan Eastin, Tait Bowers, Elaine Oneil, Francesca Pierobon, Glenn Johnston, Mike D. Huisenga, Tim Smith. Environmental Implications of Bio-Jet: LCA approach. 2013 NARA Annual Meeting, Corvallis, OR. Sep 10th – 12th 2013.

Indroneil Ganguly, Ivan Eastin, Tait Bowers and Francesca Pierobon. Environmental Implications of Advanced Biofuels in the Pacific Northwest: An LCA Approach. AAIC 25th Anniversary Meeting, Washington, DC, October 13th -16th , 2013.

Research Posters

Francesca Pierobon, Tait Bowers, Indroneil Ganguly and Ivan L. Eastin. Feedstock LCA for Bio-Jet Fuel in the West Montana Corridor (WMC): Incorporating Carbon Sequestration. NARA Annual Meeting, Corvallis, Oregon, Sep 10th – 12th 2013.

Tait Bowers, Indroneil Ganguly, Ivan Eastin, and Francesca Pierobon. Analyzing the Role of Biogenic Carbon and the Global Warming. Impact Assessment of Bio-jet Fuel. NARA Annual Meeting, Corvallis, Oregon, Sep 10th – 12th 2013.

Bowers, T., Ganguly, I., Eastin, I, & Pierobon, F. 2013. Analyzing the role of biogenic carbon and the global warming impact assessment of bio-jet fuel. Northwest Advanced Renewables Alliance Annual Meeting, Corvallis, OR. September 2013.

Bowers, T., Ganguly, I., Eastin, I., & Oneil, E. 2013. Avoided impacts by utilizing woody biomass residuals for bio-jet fuel: A comparative LCA investigating an alternative to slash pile burning. Small Log Conference 2013, Coeur D'Alene, ID.

Bowers, T., Ganguly, I., & Eastin, I. 2013. Scenario based LCA analysis: Minimizing environmental burdens associated with collection of woody biomass for bio-jet fuel. Wood Composites and Adhesives Symposium 2013, Seattle, WA.

Knight, Erika (1),(4), Paul Footen(1), Robert Harrison(1), Thomas Terry(2), and Scott Holub(3)Effects of organic matter removal and competing vegetation control on soil C in a Pacific Northwest Douglas-fir plantation. E. (1) School of Environmental and Forest Sciences, University of Washington, Seattle, WA; (2) Weyerhaeuser Corporation (retired) and USDA Forest Service Pacific Northwest Research Station, Olympia, WA; (3) Weyerhaeuser Co., Springfield, OR; (4) Shannon and Wilson, Inc., Anchorage, AK. NARA Annual Meeting, Corvallis, Oregon, Sep 10th – 12th 2013.

Himes, Austin (1), (2), Rob Harrison(1), Darlene Zabowski(1), Eric Turnblom(1), David Briggs(1), Warren Devine(3), Kimberly Hanft(1)Risk to Long-term Site Productivity Due to Whole-tree Harvesting in the Coastal Pacific Northwest.. (1) School of Environmental and Forest Sciences, University of Washington, Seattle, WA; (2) Greenwood Resources, Portland, OR; (3) Engineering and Environment, Joint Base Lewis-McChord, WA. NARA Annual Meeting, Corvallis, Oregon, Sep 10th – 12th 2013.

James, Jason (1), Robert Harrison(1), Warren Devine(2), & Tom Terry(3). Deep Soil: Modeling and Significance of Subsurface Carbon & Nitrogen.. (1) University of Washington, School of Environmental and Forest Sciences; (2) Engineering and Environment, Joint Base Lewis-McChord, WA; (3) Sustainable Solutions. NARA Annual Meeting, Corvallis, Oregon, Sep 10th – 12th 2013.

Michelsen-Correa, Stephanie (1), Rob Harrison(1), and Betsy Vance(1)Tracing the Fate of Applied 15N Fertilizers in Douglas-fir Plantations.. (1) University of Washington, School of Environmental and Forest Sciences. NARA Annual Meeting, Corvallis, Oregon, Sep 10th – 12th 2013.

Menegale, Marcella (1), Robert Harrison(1), A.B. Adams(1), Scott Holub(2) and Nathan Meehan(2) LTSP Study: Effects of Organic Matter Removal on Nitrogen and Carbon Leaching Fluxes in Douglas-fir Plantations.. (1)School of Environmental and Forest Sciences, University of Washington, Seattle, WA; (2) Weyerhaeuser Co., Springfield, OR

Other Publications

Indroneil Ganguly, Ivan Eastin, Tait Bowers and Francesca Pierobon. Environmental Implications of Advanced Biofuels in the Pacific Northwest: An LCA Approach. CINTRAFOR Newsletter, 2014.

Devine, W.D., P.W. Footen, R.B. Harrison, T.A. Terry, C.A. Harrington, S.M. Holub and P.J. Gould. 2013. Estimating tree biomass, carbon, and nitrogen in an 11-year-old Douglas-fir plantation on a highly productive site. USFS Research Paper PNW-RP-591. March 2013.
Available at: http://soilslab.cfr.washington.edu/publications/Devine-etal-2013.pdf

VIDEOS AND WEBINARS

Trainings, Education and Outreach Materials

Bowers, C.T., Pierobon, F., 2014. MOSS: Biofuels LCA: Study overview and implications. March 13th 2014.

Indroneil Ganguly. 2014. "Overview on Life Cycle Assessment (LCA) of Renewable Energy & Environmental Implications of Bio-Jet Fuel: Using Logging Residue as Feedstock". University of Washington: School of Environmental and Forest Sciences (SEFS) seminar series, February 12, Seattle, WA.

Indroneil Ganguly. Overview on Life Cycle Assessment (LCA) of Renewable Energy & Environmental Implications of Bio-Jet fuel: using logging residue as feedstock, Guest Lecture for ESRM325 & SEFS523 at University of Washington WA, November, 2013.

Indroneil Ganguly. Environmental Implications of Bio-Jet: LCA approach. IDex Presentation Online, Washington State University, Pullman, WA, October, 2013.

Thesis and Dissertations

Knight, Erika. 2013. Harvest intensity and competing vegetation control have little effect on soil carbon and nitrogen pools in a Pacific Northwest Douglas-fir plantation. MS thesis, University of Washington. Currently in draft form only.
Available at: http://soilslab.cfr.washington.edu/publications/Thesis-ErikaKnight-2013.pdf

SYSTEMS METRICS

SUSTAINABLE PRODUCTION TEAM

TASK SM-SP-1: SUSTAINABLE FEEDSTOCK PRODUCTION SYSTEMS

Key Personnel	Affiliation
Scott Holub	Weyerhauser
Greg Johnson	Weyerhauser

Task Description

The importance of ensuring environmental sustainability and carbon benefits of biofuel production cannot be understated. The sustainability of forest residual biomass harvesting is a potential concern in regions where this primarily branch and needle material is removed to provide a source of renewable energy. Concern arises from the removal of nutrients and carbon present in residual biomass, as well as from heavy equipment trafficking used to collect the material, both of which have potential to detriment forest productivity, water quality, and wildlife habitat.

The long-term goal of this research is to contribute to understanding of the amount of residual woody Douglas-fir biomass that can be removed during timber harvest without detrimental effects on soil sustainability, water quality, and wildlife. Moreover, understanding the effects of woody biomass removals and any associated soil compaction is necessary to demonstrate the sustainability (in a productivity and environmental sense) of harvesting woody biomass forest residuals as a source of biomass for bioenergy feedstock. This issue is being addressed by installing a new Long-Term Soil Productivity (LTSP) site in the southern Willamette Valley of Oregon on Weyerhaeuser ownership, the "NARA LTSP", to round out our existing regional studies.

The NARA LTSP design aims to examine a range of above-ground biomass removal treatments in combination with compaction, and fertilization. The new installation leverages over ten years of intensive investigation of the effects on productivity and soil properties in the Northwest. Typical LTSP objectives such as forest productivity, soil nutrient and carbon pools and fluxes, and soil compaction will be quantified. This study is unique in that biomass removal and compaction effects on wildlife and water quality will be studied to round out the environmental sustainability picture for biomass harvesting.

Activities and Results

Over the past 12-months the Sustainable Feedstock Production Systems team, through work at NARA LTSP, has made significant headway toward the goal of providing needed information on the sustainability of residual biomass removal on the forested landscape. Harvest was completed on the 83 acre site and 28 1-acre plots were treated with a factorial of biomass removal and soil-compaction treatments (Figure SM-SP-1.1 and Figure SM-SP-1.2). Immediate post-treatment soil and biomass effects (Figure SM-SP-1.3) were measured and recorded. Weather stations were installed and plot level soil moisture and temperature monitoring equipment. Fencing was installed in November 2013 to keep deer and elk away from the young seedlings, and in March 2014 30,000 seedlings were planted across the site, 5000 of which will serve as our primary indicator of productivity sustainability for the various treatments. Our university collaborators have also begun projects using the study site to examine carbon and nutrient cycling mechanisms, nutrient leaching, wildlife (pollinator abundance) and water effects.

Recommendations | Conclusions

Preliminary findings indicate that the different treatments implemented were successful at creating a range of conditions in residual biomass remaining and soil compaction. As the projects continue, environmental conditions will be monitored, plots and fencing will be maintained, and student projects to examine the effects of the treatments will be supported.

Physical and Intellectual Outputs

PHYSICAL

- Harvest was completed on the 83 acre site and applied biomass removal and compaction treatments were applied to 28 1-acre plots .
- Post-treatment soil and biomass effects were measured and recorded from 25 locations per plot (Figure SM-SP-1.3).
- Weather stations and plot level soil moisture and temperature monitoring equipment was installed; data shared with collaborators.
- Fencing was installed in November 2013 to keep deer and elk away from the young seedlings.
- 30,000 seedlings were planted across the site in March 2014, 5000 which will serve as our primary indicator of productivity sustainability for the various treatments.

REFEREED PUBLICATIONS (ACCEPTED OR COMPLETED)

Holub, S.M., T.A. Terry, C.A. Harrington, R.B. Harrison, R. Meade. (2013). Tree growth ten years after residual biomass removal, soil compaction, tillage, and competing vegetation control in a highly-productive Douglas-fir plantation. Forest Ecology and Management 305: 60-66.

RESEARCH PRESENTATIONS

Holub, S., N. Meehan, B. Carrier, R. Meade, G. Johnson, R. Harrison. (2013). NARA Long-term Soil Productivity (LTSP) Project. Poster Presentation at NARA annual meeting, Corvallis, OR. September 10-12, 2013.

OTHER PUBLICATIONS

Devine, W.D., P.W. Footen, R.B. Harrison, T.A. Terry, C.A. Harrington, S.M. Holub and P.J. Gould. (2013). Estimating tree biomass, carbon, and nitrogen in an 11-year-old Douglas-fir plantation on a highly productive site. USFS Research Paper PNW-RP-591. March 2013.

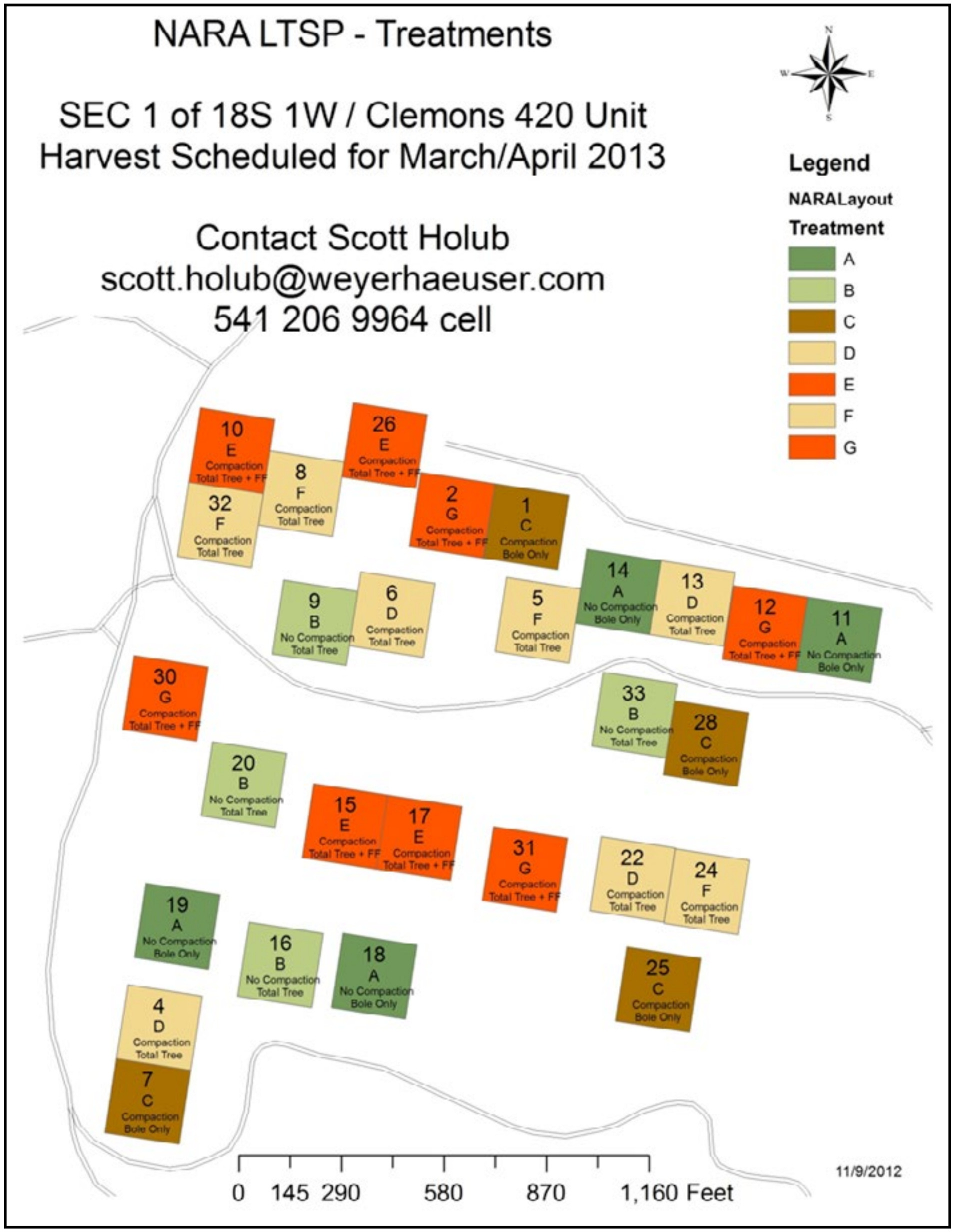

Figure SM-SP-1.1. NARA LTSP Treatment map

Figure SM-SP-1.2. NARA LTSP aerial photo September 2013

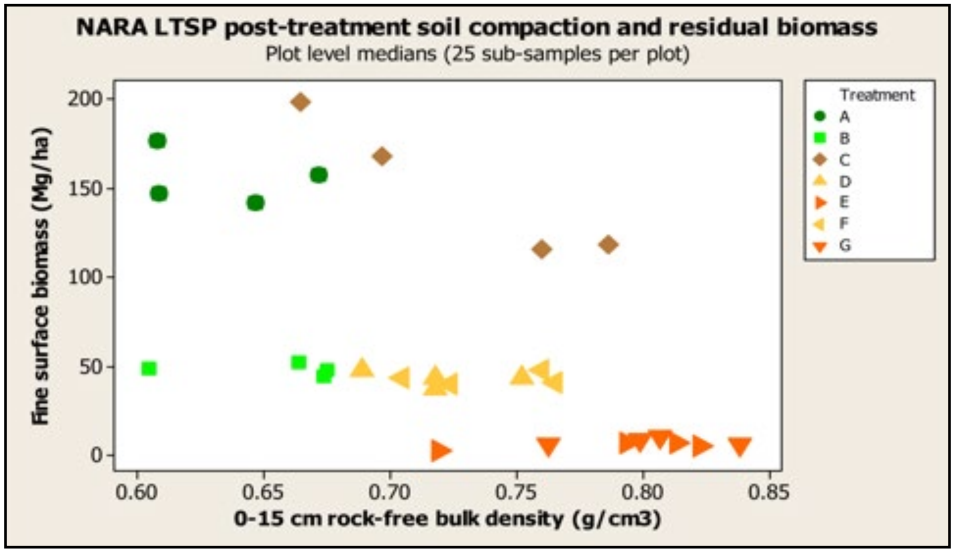

Figure SM-SP-1.3. Post-treatment assessment of compaction and remaining biomass – NARA LTSP

TASK SM-SP-2: SUSTAINABLE BIOMASS SUPPLY FROM FOREST HEALTH AND FIRE HAZARD REDUCTION TREATMENTS

Key Personnel	Affiliation
John Bailey	Oregon State University
Kevin Boston	Oregon State University

Task Description

The goals of this research are to: quantify the effect of regional land management policy and market trends on the supply of available biomass across ownerships in the western region; analyze the range of forest health and fuel reduction management options and obstacles that will limit feedstock supply over time from given landscapes; develop models and tools for policy makers, businesses and advocacy groups to use in order to consistently assess the potential for feedstock yield from landscapes, which integrate long-term forest productivity and health, land management directions and practices, harvesting technologies and transportation systems; and establish large-scale adaptive management studies that demonstrate and refine the options conceptualized in these models and provide a baseline for evaluation of long-term socio-economic and ecological effects.

Activities and Results

Task SM-SP-2.1: Develop Preliminary Prescriptions for Public Landscapes Needed for Regional Supply Model

Task SM-SP-2.1 has been completed. A series of regional, forest type, and owner group specific silvicultural prescriptions have been developed in order to better inform biomass estimates generated from the regional supply model. Prescriptions were generated from a combination of an exhaustive literature of stand reconstruction studies, NEPA harvest planning documents and interviews with local forest managers and certified silviculturists. The developed prescriptions were formally presented at the 5th International Fire Ecology and Management Congress in Portland Oregon as well as at the annual National Advanced Silviculture Program (NASP) workshop in Corvallis, OR. Preliminary model runs may indicate the need for revision prior to the 7/31/2013 due date.

Task SM-SP-2.2: Develop Models and Tools for Public Decision Makers to consistently assess potential for feedstock yields

Task SM-SP-2.2 is ongoing. This team collaborated regularly with Darius Adams and the economic modeling team in order to gain a greater understanding of cross-disciplinary goals and needs. A sensitivity analysis of model assumptions are currently being completed, including: management entry requirements, characteristics of a successful treatment, re-entry requirements and prescription formulation. This analysis is being performed using the ArcFuels tool bar within ArcGIS. A workshop on the functionality of this toolbar and the assumptions of the software was completed at the 5th International Fire Ecology and Management Congress in Portland Oregon. Preliminary forest growth model runs have been completed as well as quality control of those results. In addition, baseline fire hazard modeling has been completed across Oregon in order to measure effectiveness of thinning regimes and ability of the utilization of biomass material to alter landscape level fire hazard. Prototype model runs will be available for review soon and conducted in conjunction with Task SM-SP-2.3.

Task SM-SP-2.3: Establish Large Scale Adaptive Management Studies

The framework for several dozen Integrated Fireshed-level Adaptive Management Evaluation sites (iFLAMES) has been developed and initial reactions are positive for participation among federal Collaborative Forest Landscape Restoration Program (CFLRP) groups, states, and tribes. Given current available funding and public land manager interest, these sites will be established early.

Task SM-SP-2.4: Feedback to Improve Predicative Ability of Task SM-SP-2.2 models

This task is a formative part of designing Task SM-SP-2.3 iFLAMES – anticipating the issues upon which will need improvement in second generation model runs.

Recommendations | Conclusions

Collaboration with the economics modeling group has been very productive, and the modeling effort is coming together well to support other parts of the project and the third task. The timing is most excellent for now establishing iFLAMES, which will be fundamental to model validation and a long-term peer-review publication of this work.

Physical and Intellectual Outputs

CONFERENCE PROCEEDINGS AND ABSTRACTS FROM PROFESSIONAL MEETINGS

Bailey, J.D. "Forest restoration and biomass utilization as a partnership in the Pacific Northwest U.S." Visiting Scientist lecture at Sveriges Lantbriksuniversitet, Focus on Soil and Water Graduate Seminar, March 18, 2013 in Uppsala, Sweden.

RESEARCH PRESENTATIONS

Vogler, K. "Current Fire Hazard of Forested Lands in Oregon." Poster presentation to colleagues in Advanced Application in GIS course at OSU. Corvallis, OR, March 21, 2013.

TASK SM-SP-3: BIOMASS MODELING AND ASSESSMENT

Key Personnel	Affiliation
Darius Adams	Oregon State University
Greg Latta	Oregon State University

Task Description

The tasks for this group are to: develop expanded biomass volume/weight accounting from existing measurements on regional forest inventory analysis (FIA) annual inventory plots; expand forest inventory representation to all public lands in western study region; expand timber market and resource models to ID and MT as necessary; coordinate with researchers in logistics and economics of harvest and transport to establish biomass removal and haul costs for plots and potential plant locations; coordinate with silviculture researchers to establish stand structure targets for post-biomass harvest stands; expand market model format to include both fixed price biomass revenue and price-flexible biomass demand relations for each sub-region and plant location option; extend current work that models the role of biomass supply potential of large-scale regional forest fire fuels treatment in stimulating rural economies in OR and WA to include the full range of biomass supply and the wider regional area identified in this proposal; and generate scenario projections of future resource supplies and costs under alternative assumptions about: (a) biomass processing plant locations and capacities and (b) biomass supply volumes under alternative. biomass prices.

Activities and Results

During this period the models of timber volume/biomass yields and log/biomass transportation costs were completed. The volume/biomass model, based on forest vegetation simulator (FVS), has been applied to all plots in all NARA subregions to generate yield files and allows wide flexibility in specifying biomass pools. The transport cost model, based on commonly available Geographic Information Systems (GIS) mapping functions, recognizes multiple road standards in computing both costs and diesel consumption in moving from each forest inventory and analysis (FIA) plot to any desired set of log/biomass mill destinations. The log market model has been adapted to the MC2P (Douglas-fir) region, and preliminary delivered biomass cost curves have been estimated for example biorefinery locations as illustrated in the attached Figure SM-SP-3.1 for separate runs with either Longview or Cosmopolis as the refinery destination. Model revisions allow any portion of the three current biomass pools (limbs, tops and breakage) to also be made available for use as pulpwood, recognizing an important source of competition for certain classes of biomass. Coordination continues with sub-projects in the logistics group to incorporate emerging research results on biomass concentration and processing costs in the woods (as related to logging methods and terrain) and chipped/ground biomass haul costs from woods to mills. An extend version of the market model allowing establishment of intermediate biomass processing "depots" is operational and being tested under various assumptions on the nature and function of depots (simple concentration/transshipment points, drying, and/or drying, sorting and co-product processing).

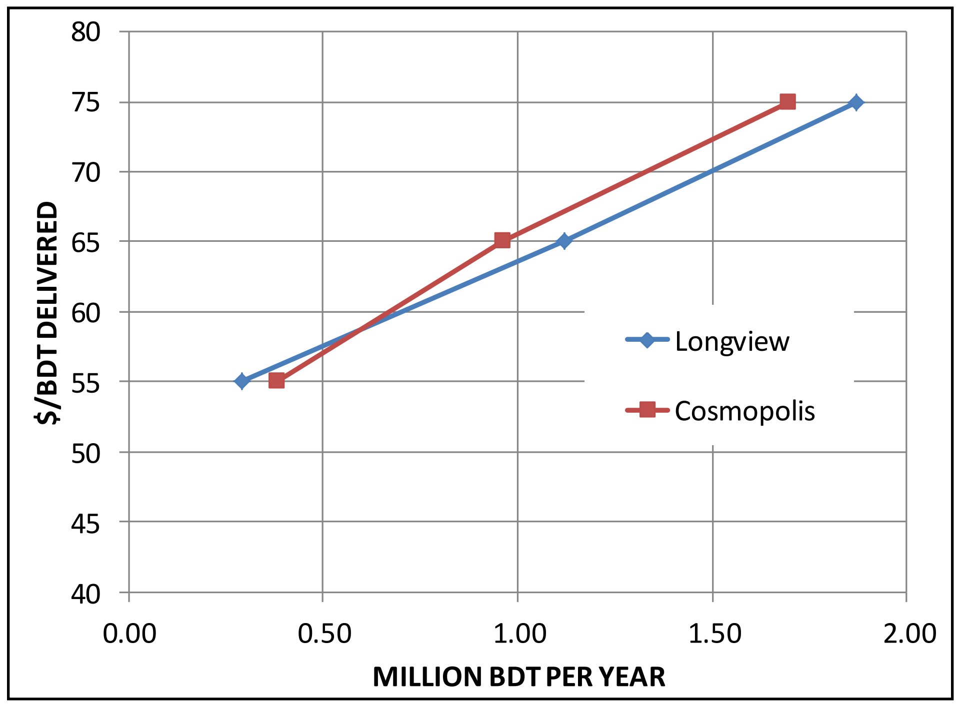

Figure SM-SP-3.1. Delivered biomass cost curves for Longview and Cosmopolis Washington, with only one facility operating at a time

Recommendations | Conclusions

The biomass costs portions of the market model will be enhanced to allow more detailed and representative estimates of delivered costs, incorporating new NARA research as it becomes available. The exploratory cost curve estimates for the western Montana corridor (WMC) area and for the MC2P region will be completed. As this analysis begins to emerge, impact models and measures in the market model (linked to the spatial timber model) will be incorporated to allow projection of NARA ecosystem services impacts over time under alternative policy assumptions. Collaboration with the public lands silviculture subgroup is possible to simulate alternative management schemes on public lands.

Physical and Intellectual Outputs

ORAL, POSTERS, OR DISPLAY PRESENTATIONS

Adams, D., G. Latta, J. Clark and M. Crandall. Modeling the Biomass Supply Chain. Poster presentation at the NARA Annual Meeting, Corvallis, OR, September 10, 2013.

Adams, D. NARA Sustainable Biomass Supply Modeling. Joint annual meetings of the Western Forest Economics Association and Western Forest Mensuration Association, Leavenworth, WA, July, 2103.

TASK SM-SP-4: LONG TERM PRODUCTIVITY STUDIES

Key Personnel
Doug Maguire

Affiliation
Oregon State University

Task Description

This team is tasked to: replace existing biomass equations developed for unmanaged forests with new versions that account for wide variation in stand density and corresponding allometric relationships; quantify nutrient content of different biomass components including tree, shrub and herbaceous vegetation; estimate nutrient and carbon removals under varying levels of biomass harvesting and harvesting systems; develop and apply simulation models to determine sustainable levels of bioenergy feedstock production under a range of silviculture intensities; and estimate changes in long-term productivity under different rates of biomass removal and different climate change scenarios.

Activities and Results

Task SM-SP-4.1. Develop allometric equations for managed stands

Allometric equations have been fully developed, predicting biomass of live and dead branches, foliage, heartwood, sapwood, and bark for trees ranging from 10-77 cm in diameter breast height (dbh) and 10-57 m in height.

Equations have been fit that estimate nutrient contents by tree component for 11 nutrients (N,P,K,-Ca,Mg, S,B,Cu,Fe,Mn,Zn). These equations are available for use in analyzing harvesting scenarios.

An excel-based processor has been developed that projects tree lists with the regional growth model ORGANON, and output estimates of biomass and nutrient content of harvested trees based on the above-mentioned equations. These estimates of nutrient and carbon removals can be adjusted for different utilization standards (i.e. top diameter of tree) and expected crown loss from yarding.

Development of biomass and nutrient equations is finishing up for understory vegetation, both common species and life-form averages.

The development of a literature-based nutrient flux critera for Douglas-fir stands has been started, which will be the basis for judging sustainable bioenergy harvest levels.

Recommendations | Conclusions

Allometric relationships vary significantly by silvicultural regime but to a limited extent by site. Conversely, nutrient concentrations vary significantly by site and only to a limited extent by silvicultural regime. Despite low nutrient concentrations in heartwood and sapwood (but somewhat higher concentrations in bark), harvesting of the merchantable bole only removes a major portion of the above-ground nutrient capital due to the large quantity of biomass involved. Depending on stand age, these removals can be almost doubled when the branchwood and foliage are removed due to their high nutrient concentrations, especially in the foliage. Simulated above-ground biomass accumulation and annual nutrient uptake vary dramatically by initial spacing. The interaction of initial spacing with various combinations of subsequent thinning and fertilization on biomass and nutrient accumulation and corresponding removals under various utilization scenarios are being investigated.

Physical and Intellectual Outputs

- Software: Biomass equations have been incorporated into ORGANON and CIPSANON growth models, enabling users to estimate biomass components of trees and stands.

RESEARCH PRESENTATIONS

Maguire, D., D. Mainwaring, A. Bluhm, R. Harrison, and E. Turnblom. Response of wood density to thinning and fertilization on SMC Type I Installations. Stand Management Cooperative Fall Meeting, September 17, 2013. Vancouver, WA.

Maguire, D., D. Mainwaring, A. Bluhm, R. Harrison, and E. Turnblom. Response of Douglas-fir wood density to intensive thinning and fertilization. MeMoWood conference on Wood Quality and Silviculture. Nancy, France. October 1-4, 2013.

TRAININGS, EDUCATION AND OUTREACH MATERIALS

Workshop wer provided on using XORG and CIPSR. Corvallis, Oregon. March 19, 2014. (XORG is EXCEL application for running ORGANON within EXCEL; CIPSR is R program for running CIPSANON/ORGANON in R; both have been modified to produce component biomass estimates in addition to conventional growth and yield output).

TASK SM-SP-5-AIR: ENVIRONMENTAL IMPACT ANALYSIS TO SUPPORT NARA BIOFUEL DEVELOPMENT IN THE PACIFIC NORTHWEST-AIR COMPONENT

Key Personnel	Affiliation
Brian Lamb	Washington State University

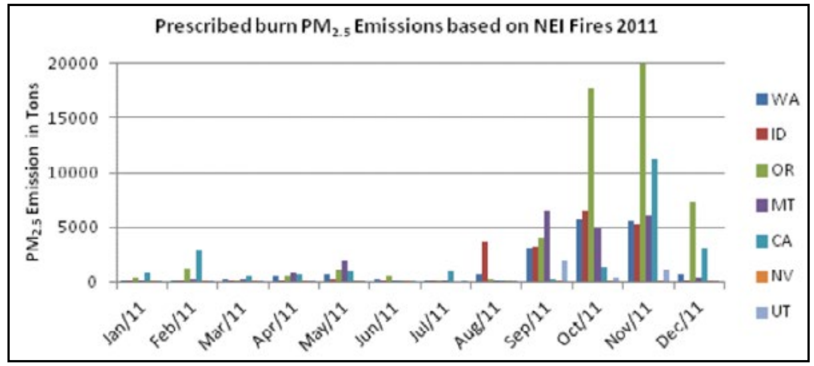

Figure SM-SP-AIR-5.1. Monthly PM2.5 emissions by state from the US EPA National Emission Inventory for 2011.

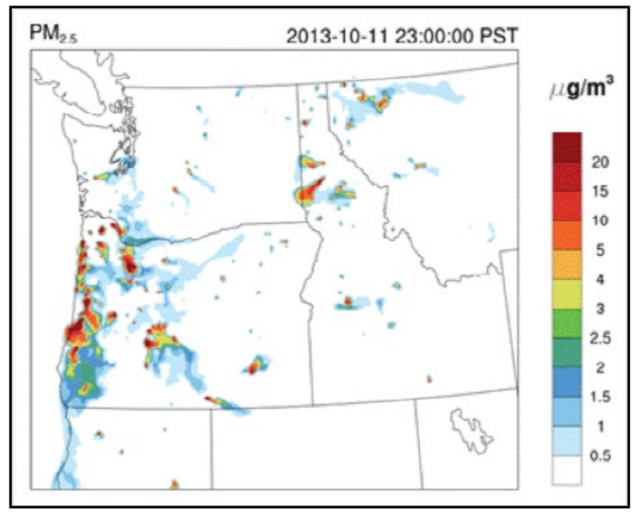

Figure SM-SP-AIR-5.2. Differences in PM2.5 concentration between simulations with and without prescribed fires for a day in October, 2011. These results show significant PM2.5 levels in the local vicinity of prescribed fires.

Task Description

Land use and residuals management changes associated with biofuel growth, harvesting, and processing may pose unique environmental issues related to air quality. There is a need to investigate air quality impacts that biofuel harvesting may have on short- and long- term changes in air pollution within the project's airsheds at scales ranging from field scale to regional scale. The specific objective of this project is to develop supply chain emission scenarios and use these for a regional analysis of the impact of the supply chain on air quality.

Activities and Results

During this period, an analysis of the impact of prescribed fires, including slash pile burning, on local to regional scale air quality was being developed. Data describing air pollutant emissions related to prescribed fires was obtained, and initial model simulations have been conducted using the EPA 2011 National Emission Inventory, which specifically includes prescribed fire emissions. As shown in Figure SM-SP-AIR-5.1, the emissions vary significantly by month with most of the burning taking place in October and November. There are also significant differences in emissions among the northwest states.

The 2011, Nuclear Energy Institute (NEI) prescribed fire emissions were processed using SMOKE and input in CMAQ. For this initial assessment, emissions for the year 2011 were modeled using 2013 meteorology from available Westren Research and Forcasting (WRF) output files. For a more refined analysis, WRF will be re-run for the correct time periods. Yearly emissions peak during September – November, and hence a few days in October were selected as representative period. A concentration difference map from AIRPACT-4 in Figure SM-SP-AIR-5.2 shows the contribution of prescribed fires to the surface layer hourly averaged PM2.5 for the modeled day in October 2013. It shows that although concentrated, prescribed burn emissions can result in significant atmospheric loading of PM2.5.

Recommendations | Conclusions

The initial simulations show the local importance of prescribed fires and the potential benefit to be gained from harvesting these fuels for the biojet supply chain. Further work will continue to refine these simulations using the correct meteorology and to assess the relative impacts of different types of prescribed fires, wildland forest fires, and other anthropogenic PM2.5 sources.

TASK SM-SP-5-WATER: ENVIRONMENTAL IMPACT ANALYSIS TO SUPPORT NARA BIOFUEL DEVELOPMENT IN THE PACIFIC NORTHWEST-WATER COMPONENT

Key Personnel	Affiliation
John Petrie	Washington State University
Michael Barber	University of Utah

Task Description

Land use and residuals management changes associated with biofuel growth, harvesting, and processing may pose unique environmental issues related to water quality. There is a need to investigate water quantity and quality impacts that biofuel harvesting may have on short- and long- term changes in sediment and nutrient loadings, hydrologic dynamics, and stream channel responses within the project watersheds at scales ranging from field scale to regional scale. The specific objectives of this project are:

(1) to examine tree harvesting options at field-scale test plots to examine potential alteration of the ecological environment through measurement of runoff, nutrient export, and sediment erosion;
(2) to collect and examine microbial communities at the test plots;
(3) to develop predictive water quantity and quality models that can be used to evaluate watershed-scale regional impacts; and
(4) evaluate the potential impacts of altered hydrologic conditions on stream channels.

Items 1-3 will be conducted primarily by the University of Utah, although joint collaboration with field data collection is anticipated. Item 4 will be conducted by Washington State University, although joint collaboration with field data collection is anticipated.

Activities and Results

Task SM-SP-5.1.1. Develop sampling plans and methodologies

The study objective of this portion of the NARA project is to investigate the environmental impacts of residual ground cover (biomass) removal in the production of jet fuel in the Pacific Northwest. This specifically includes the impact on water balance as well as potential long-term changes to nutrient ecology as measured by changes in microbial soil populations. To that end, Dr. Flanagan, the Water Erosion Prediction Project (WEPP) model developer, was consulted, and has provided comments regarding the sampling plan with respect to the accurately running the model. The critical issue found was that the ground cover adjustment factor (CKigc) used in WEPP is predicted from

$$CK_{igc} = e^{-2.5\ inr}$$

where inrcov is the interrill cover (0-1). Based on this equation, erosion is an exponential function of cover so reducing groundcover from 1 to 0.5 would increase erosion by 3.5 times. This equation needs altered for our model to accurately predict forest conditions.

The sampling plan has been revised in accordance with his recommendations. Written concepts are being exchanged, and it is expected that he will help with the model data requirements. The revisions, which have been modified to fit with their site requirements, have been sent to Weyerhaeuser.

Dr. Goel sent recommendations on how to sample the microbial populations at the Weyerhaeuser test sites in Oregon. Work plans are being revised for Weyerhaeuser's approval.

Task SM-SP-5.1.2. Conduct field sampling

Sherri Johnson was contacted about obtaining field data from the Trask Creek Watershed to help scale the field plots to the watershed. Due to some concerns about providing this information, alternatives have been examined. Weyerhaeuser has finished clearing the NARA long term soil productivity (LTSP) study area and has installed field equipment. The site was investigated to view the post-harvest operations as shown in the figures below. Figure SM-SP-WATER-5.1 shows complete removal of biomass residual while Figure SM-SP-WATER-5.2 shows biomass left on ground. Once the site has acclimated, soil microbial populations and sediment characteristics will be sampled.

Once the scientists approve the revised study plan, access to Weyerhaeuser's information will be available. Additional information will come this spring and summer as a flume and pressure transducer have been purchased for measuring the groundwater seepage leaving the site with the goal of quantifying timing issues (lag time) from precipitation to runoff.

Task SM-SP-5.1.3. Create water resources models of study areas

A digital elevation model has been obtained, and LiDAR data from Weyerhaeuser has been requested so that representative slopes can be determined. Weyerhaeuser has installed a weather station and soil moisture probes. One-dimensional unsaturated flow models have been investigated to analyze this data. It appears the model unsat-1h will be appropriate for determining deep infiltration. The difference between precipitation and deep infiltration will be the amount prescribed to evapotranspiration.

Task SM-SP-5.1.4. Create stream erosion model of study sites

A literature review on stream channel response to forest practices is being performed and numerical models evaluated to model channel impacts. Preliminary work indicates that changes to peak flows and sediment supply are the most critical parameters for quantifying channel response. The primary focus for the near term is to identify field sites for data collection in summer 2014. Site selection discussions with Weyerhaeuser have been completed. Based on this discussion, a number of options are being explored. Seven to ten days will be spent collecting data in June/July. A graduate student, Ross Wickham, joined the group in January 2014 to assist with these activities. Figures SM-SP-WATER-5.1 and SM-SP-WATER-5.2 show residual removal and residual remaining treatments at the Weyerhaeuser LTSP site.

Recommendations | Conclusions

Even after a relatively large rainfall event, evidence of erosion from the sites, even where biomass was 100% removed, was not present. The sample sites are relatively flat but infiltration seems to be controlling for the soils in Oregon. Soil infiltration rates will be explored from other NARA sites in the Pacific Northwest. The impact of extra infiltration to base flow will also be investigated. Sampling plans have been revised to install a flume on a spring that drains from the site.

Physical and Intellectual Outputs

RESEARCH PRESENTATIONS

Hasan, M.H. and M.E. Barber. Hydrology and Soil Erosion in WEPP. Poster presentation at the NARA Annual Meeting, Corvallis, OR, September 10, 2013.

Figure SM-SP-WATER-5.1.

Figure SM-SP-WATER-5.2.

TASK SM-SP-6: LOCAL AND REGIONAL WILDLIFE IMPACTS OF BIOMASS REMOVALS

Key Personnel	Affiliation
Matthew Betts	Oregon State University

Task Description

Silvicultural regimes proposed will be reviewed to reduce fire hazard and improve forest health. Existing data from the Pacific Northwest (PNW) on the relationship between species and stand structures (e.g., downed woody material, snags) will be used to estimate the potential impact of regimes on vertebrate abundance. Also, using existing published research, a meta-analysis will be conducted that tests the influence of species life-history traits on sensitivity to proposed silvicultural regimes. Landscape patterns resulting from regional models of biomass collection and removal will be reviewed. Potential population level consequences of biofuel harvest will be tested at the regional scale via demographic models for species with a range of life history traits (e.g., dispersal abilities, longevity, fecundity). These simulation models will be used as a way of generating hypotheses about species most likely to be at risk from biofuel treatments.

Activities and Results

A new post-doctorate, Heather Root, began work on the project in mid-January. Silvicultural regimes proposed for biomass harvest in the Pacific Northwest have been reviewed and compared with other regions and biomass feedstock. Other NARA participants and potential collaborators have been consulted including Darius Adams, Andrew Moldenke, and Tom Spies to discuss economic model outputs, soil diversity and function and landscape-level models.

Currently, the literature is being reviewed to understand which habitat characteristics are the most likely to be affected by biofuel harvesting, in particular loss of woody debris and soil disturbance and compaction. Through the literature review, it is evident that woody debris characteristics, such as exposure, decay class, and size, are important habitat features. Wildlife and botany literature is being reviewed to identify species most likely to be affected by these practices both in relation to their habitat needs and life-history patterns.

Betts and Root are working to establish a conceptual model and directions for future biodiversity – biofuel harvest research. The model includes a web of impacts to diversity and ecosystem services as well as the magnitude of scientific knowledge and potential impact.

Recommendations | Conclusions

The brainstorming and literature review have suggested several avenues through which forest biofuel harvest may affect biodiversity in the short- and long-term. It is anticipate that the conceptual model will allow a concrete context for future modeling efforts and identify knowledge gaps to focus future research.

Physical and Intellectual Outputs

RESEARCH PRESENTATIONS

Betts, M.G. 2013. Environmental Considerations in Forest Biomass Harvesting. Invited presentation to the Starker Lecture Series, May 2, 2013, Oregon State University, Corvallis, Oregon.

TASK SM-SP-7: SUPPLY CHAIN ANALYSIS

Key Personnel	Affiliation
Todd Morgan	University of Montana

Task Description

Land managers and bioenergy specialists lack definitive knowledge of woody biomass inventories and availability in the Pacific Northwest. This information is key to understanding the social, economic, and environmental impacts and sustainability of producing new wood-based energy products. To answer these needs, The University of Montana's Bureau of Business and Economic Research's Forest Industry Research Program will characterize the composition, quantities, and spatial distribution of varied sources of woody biomass across the NARA four-state area. The specific objectives of the Feedstock Supply Chain Analysis are to identify and provide primary data necessary to assess the woody biomass inventory with particular emphasis on mill and logging residue in the four-state region (OR,WA,MT,ID) and standing forest inventory in Montana and Idaho.

Activities and Results

Task SM-SP-7.1. Coordinate new and existing Idaho & Montana ("east-side") forest inventory and other data for use in "west-side" models

The University of Montana's Bureau of Business and Economic Research (BBER) Forest Industry Research Group has provided fellow NARA researchers with forest industry and timber products output (TPO) data for modeling and geographic Information Systems (GIS) applications throughout the four-state area since the project started in September 2011. BBER specialists have answered dozens of information requests from NARA researchers and stakeholders. These responses have included estimates of standing forest volumes, timber harvest volumes, mill residues, and logging residues.

BBER researchers have worked with colleagues at Oregon State University (OSU) and Washington State University (WSU) to derive innovative ways to use BBER's data products, particularly BBER's logging residue data. For example, OSU scientists have developed tools to predict woody biomass found in landing residue piles. They plan to create ratios of landing pile versus total stand-level residue biomass using BBER's utilization data. These ratios could then serve as variables in biomass forecasting models.

June 2013 discussions among WSU, OSU, and University of Washington colleagues on estimating available feedstock biomass across the four-state area supported NARA's use of TPO data-based biomass predictions. These data are derived from BBER's state level forest industry reports and logging utilization research.

BBER has made a 5-state timber harvest by county and ownership database available for each year 2000 thru 2012. This has been provided to several NARA researchers, including Adams & Martinkus, and is available online: http://www.bber.umt.edu/FIR/H_Harvest.asp

The BBER and the US Forest Service Forest Vegetation Management staff (Ft. Collins Service Center) are jointly investigating how to modify the Forest Vegetation Simulator to more accurately predict post-harvest logging residue volumes and biomass. This work stems from the BBER's NARA-funded logging utilization research.

BBER researchers have recently created an outline for a refereed journal manuscript that will characterize logging residues throughout the entire 4-state NARA project area. This work will incorporate all logging utilization data collected through year 4 of the NARA project and will focus on residue prediction tools for land managers.

BBER investigators continue to seek ways for our NARA colleagues to use our extensive logging utilization data set.

Task SM-SP-7.2. Enhance and update primary mill residue and capacity information for 4-state region

BBER staff have continually updated primary mill residue and capacity information since the start of the NARA project. Specifically, BBER has provided fellow NARA scientists with TPO data for Idaho (2006), Oregon (2008), Montana (2009), Washington (2010), with updated Idaho (2011) data posted to our BBER website in the fall of 2013.

Mill residue estimates produced (and used/not used) annually are available for each of the 4 NARA states based on our mill census data, annual lumber production, and other information.

Task SM-SP-7.3. Enhance and update logging and other forest residue for 4-state region

Logging utilization fieldwork has continued across the four-state region and is progressing on-schedule, with more than 2,000 felled trees measured at 81 sites across the region (Table SM-SP-7.1).

Logging residue estimates are available for each NARA state at the state and county levels based on our logging utilization field work and ancillary

Table SM-SP-7.1.Logging utilization field work progress through 03/31/14

State	Sites	percent complete
Idaho	18	51
Montana	20	57
Oregon	23	66
Washington	21	60
Total	81	58

information. In addition, supply summarized annual county-level timber harvest data obtained from other sources is available.

RESEARCH OUTCOMES

Pacific Northwest land managers are gaining understanding of post-harvest logging residue volumes and distribution, and inventories of standing timber volumes throughout the four-state project area. This enables them to more accurately forecast woody biomass feedstock availability, plan for coarse woody debris retention, and plan post timber harvest fuels treatments. In particular, BBER's TPO data is essential input to the Greg Latta/Darius Adams econometric model.

Biomass feedstock managers are learning about the overall lack of readily available, affordable mill residues. This information has helped NARA scientists and others focus on logging residues as the primary source for biojet feedstock.

Recommendations | Conclusions

CONCLUSIONS

1. Mill Residues: BBER's recent TPO research (Gale et al. 2012; McIver et al. 2012; Brandt et al. 2012; Simmons et al. 2013) confirms preliminary observations: virtually all mill residues currently produced in the region are used for either internal energy purposes or sold for a variety of industrial uses (primarily pulp and reconstituted board production). Bioenergy firms (such as NARA biomass pretreatment plants) will face competition for mill residues from current residue users. However, mill residue production will increase as primary product (i.e., lumber, veneer, etc.) outputs increase in response to improving economic conditions and increases in domestic new home construction.

2. Logging Residues: BBER's recent summary of Idaho logging utilization research (Simmons et al. 2014) clearly shows that logging residues as a fraction of mill delivered volume have continued to decline through time as land managers have progressively utilized more woody biomass on commercial logging units. Improved technology, such as mechanized processing, helps ensure that more of each felled tree is utilized. BBER analysts have found that more than half of the variation in the logging residue fraction is related to 1. method of harvest- by hand or mechanical, 2. presence/absence of pulp removal, and 3. broad geographic differences in site quality (Berg et al. 2012). Landing residue "slash" piles offer an important source of woody material for potential conversion to bio-jet and ancillary products.

3. Timber Harvest: Timber harvest volumes have declined through time across all four NARA states (Gale et al. 2012; McIver et al. 2012; Brandt et al. 2012; Smith et al. 2012). Private lands timber harvest declined in response to low demand for logs at domestic mills during the U.S. housing bust and Great Recession. Some recovery of private lands harvest has been indicated in western Oregon and Washington as a result of increased overseas demand for logs. As domestic demand for housing and wood products increases, private and state-owned timber harvest is also expected to rise. It is unlikely that federal lands will substantially increase timber harvest levels in the future, regardless of wood products demand. Public support for forest restoration and fire hazard reduction treatments has fostered hope that minor increases in federal harvest will occur over the next several years. However, current legal, policy, and silvicultural barriers suggest federal lands are an unreliable source of long-term biomass supply.

RECOMMENDATIONS

1. Data management: Organize NARA data so that it can be readily accessed and understood by both NARA researchers and the public.
2. Cooperation: Improve collaboration and communication among NARA scientists. The recent change in NARA team structure has fostered better communications among team members; we need to continue seeking innovative ways that our colleagues can use BBER's TPO, logging utilization, timber harvest, forest industry, delivered log prices, and timber harvesting and hauling cost information in their work.
3. Logging utilization studies: Continue collecting logging utilization data across the NARA project area through Year-five of the project. The overall BBER logging utilization study plan calls for sampling five to seven logging sites per state per year resulting in a grand total of 25 to 35 measured sites per state by project completion. This "rotating sampling" scheme helps ensure that spot market influences on utilization are minimized. Stopping short of four years of data collection would substantially reduce the total number of sample sites per state and would jeopardize the utility of the data. BBER intends to focus Year-four logging utilization sampling efforts on coastal Washington and Oregon and western Montana. 33 sites have now been sampled in Idaho (14 funded by NARA, 19 by Interior West FIA); a return to Idaho in years four and five of the project to "freshen the database" and gain information on five to eight additional Idaho logging sites will occur.

THE FUTURE

In Year four, the BBER team will conduct logging utilization field work, analyze and report logging utilization and other forest industry data, and share information with NARA Teams and stakeholders.

In order to provide NARA Teams with current information on the production and potential availability of woody biomass from the residues of commercial timber activities, BBER's Year-four efforts will include:

- Measuring logging utilization at active logging sites across the four-state NARA region;
- Processing, summarizing, and sharing those logging utilization data and results with other members of

NARA, regional stakeholders, and others;
- Collecting, analyzing, reporting, and otherwise sharing a variety of forest industry information in the region, including timber harvest levels by county and ownership, timber use, production of primary wood products, and production & disposition of mill residue.
- Developing predictive tools to enable land managers to gain understanding of post-timber harvest woody residue volumes and distribution.

Measurement efforts will be prioritized in OR and WA to ensure adequate samples per state. The BBER team anticipates being able to complete five-six more sites (each) in WA and OR. Neither state has had a comprehensive logging utilization study conducted in 20 years, and more up-to-date information is critically needed in both states. Approximately three to five sites each in Montana and Idaho will be measured in year four.

Physical and Intellectual Outputs

PHYSICAL: ACCOMPLISHED FROM APRIL 2013 THROUGH MARCH 2014

- Felled tree woody residues were sampled at 25 logging sites across the four state region.
- State of Idaho timber harvest, forest product outputs (e.g. lumber), and mill residues were quantified with summary data tables posted to the BBER website.

REFEREED PUBLICATIONS (ACCEPTED OR COMPLETED)

Simmons, E., E. Berg, T. Morgan, S. Zarnoch, S. Hayes and M. Thompson. 2014. Logging utilization in IDAHO: current and past trends. Gen. Tech. Rep. RMRS-GTR-318. Fort Collins, CO.: USDA Forest Service. Rocky Mountain Research Station. 15 p. http://www.bber.umt.edu/pubs/forest/util/ID_logging_util_2014.pdf

CONFERENCE PROCEEDINGS AND ABSTRACTS FROM PROFESSIONAL MEETINGS

Simmons, E., E. Berg, T. Morgan, S. Hayes. 2013. Logging residues: comparative efficiency by tree diameter and logging methods in 3 western states. Poster presented at the Council on Forest Engineering (COFE). Missoula, Montana. July 8-11, 2013.

RESEARCH PRESENTATIONS

Simmons, E., E. Berg, T. Morgan, S. Hayes. 2013. Logging residues: comparative efficiency by tree diameter and logging methods in 3 western states. Poster presented at the Council on Forest Engineering (COFE). Missoula, Montana. July 8-11, 2013.

OTHER PUBLICATIONS

Simmons, E., E. Berg, T. Morgan, S. Zarnoch, S. Hayes and M. Thompson. 2013. Logging utilization in IDAHO: an investigation of current and past trends. Draft USDA Forest Service Rocky Mountain Research Station Resource Bulletin.

TASK SM-SP-8: EFFECTS OF VARYING FOREST FLOOR AND SLASH RETENTION ON SOIL NUTRIENT AND CARBON POOLS IN A REGENERATING DOUGLAS-FIR TREE FARM: NARA-SOILS

Key Personnel	Affiliation
Jeff Hatten	Oregon State University

Task Description

This scope of work describes a collaboration with Dr. Jeff Hatten (OSU) and Dr. Scott Holub (Weyerhaeuser). The overall goal is to examine the effects of organic matter (forest floor and slash) removal and soil compaction on soil carbon and nutrient cycles and site productivity. The responsibilities of the OSU Forest Soils Lab (Hatten) include 1) monitor and report on soil moisture and temperature data, 2) analyze whole soils and density fractions pre-, post-, one-year post- and two-tear post for elemental contents stable isotopic ratios, 3) examine whole soils pre-, post-, one-year post- and two-year post for exchangeable nutrient pools, 4) examine inputs of carbon and nutrients into mineral soils using pan lysimeters, 5) foliar response to soil changes, and 6) examine soil carbon cycling through soil respiration. Jeff Hatten will be ultimately responsible for all work completed under this scope of work, and he will oversee one master level student that will be conducting most of the work on the project with the assistance of undergraduate workers.

1) Soil moisture and temperature.

32 soil monitoring locations in all treatment plots (seven treatments (A, B, C, D, E, F, and G) x four replicates) will be monitored and additional stations installed in the uncut forest. These soil monitoring stations will include Decagon data loggers with one relative humidity/air temp @ 15cm sensor and soil moisture/temperature probes installed at 10, 20, 30, and 100cm soil depth. This data will be compiled and treatments differences written up into reports, theses, and submitted for publication. The compiled data will be made available to all collaborators on the project prior to publication of the data.

2) C, N, 13C, and 15N of whole soils and density fractions.

Composited soils will be examioned from the <4.75mm size fraction collected pre-, post-, one-year post- and two-year post-harvest from five treatments (A, B, C, D, and E) + the uncut forest (six treatments x four replicates = 24 plots). Pre- and post-harvest soils have been collected to 100 cm and will be analyzed to that depth. Soils from 25 locations will be collected in plot from the 0-15 cm horizon and forest floor for the one-year post- and two-year post-harvest assessment. The carbon (C) and nitrogen (N) content plus stable isotopic composition of whole soils, three density fractions and roots (from pre-harvest sample collection only) will be analyzed.

3) Exchangeable nutrient pools.

The available nutrient pools of the surface soil and O-horizons for pre-, post-, one-year post- and two-year post-harvest assessments in five treatments (A, B, C, D, and E) and the uncut forest will be examined in addition to exchangeable nitrate and ammonium using potassium chloride (KCl) extractions and Bray extractable P. These extracts will be analyzed at the Institute of Water and Watersheds (IWW) collaboratory. Exchangeable cations will be extracted using ammonium acetate and analyzed using inductively coupled plasma mass spectrometry (ICP-MASS).

4) Pan lysimeters.

Two pan lysimeters will be developed, constructed, and installed into the five treatments (A, B, C, D, and E) and the uncut forest. Atmospheric deposition and throughfall deposition will be collected from this apparatus and from a limited number of locations. Soil solutions from these lysimeters will be collected and analyzed once per month (when present). These solutions will be examined for nitrate, ammonium, total N, total organic carbon (TOC) and ortho-phosphate. Cations will be analyzed using an ICP-MASS.

5) Foliar response.

During year two, tree height and foliar concentrations will be analyzed for nutrients in five treatments (A, B, C, D, and E). These assessments will be made on trees in 0.1ha plots near the pan and tension lysimeters (UW). One year old foliage from five trees will be collected. Foliage will be analyzed for Total C, N, P, Ca, Mg, K, and Al, and foliage samples will be sent out for 13C and 15N analysis.

6) Soil respiration.

Soil respiration measurements will be taken once per month in five treatments (A, B, C, D, and E) and the uncut forest measurements taken from four locations per plot. These measurements will be made for at least two growing seasons. Soil respiration measurements will be made with a LiCor 8100 and 10 cm soil respiration chamber. At each location, two kinds of soil collars will be installed: six cm inserted one cm into mineral soil with no O horizon and 35 cm inserted 30 cm into mineral soil to exclude roots. From each location, three kinds of soil respiration will be montored: 1) total soil respiration + O horizon respiration – soil respiration chamber set directly on soil surface; 2) total soil respiration – soil respiration chamber set on six cm soil collar; and 3) heterotrophic soil respiration + O horizon respiration – soil respiration chamber set on 35 cm soil collar.

Activities and Results

1) *Soil moisture and temperature*

At all weather stations, soil moisture and soil temperature data loggers and probes were installed and have been collecting data since December 2013. Regular and unexpected site visits will be required throughout the critical summer period to maintain instrumentation in ensure complete data-sets.

2) *C, N, 13C, and 15N of whole soils and density fractions.*

Procedures are being developed to perform the density fractionations with the assistance of Dr. Kate Lathja (OSU, Crop and Soil Science). Pre-, immediate post-, and one-year post-treatment samples will be fractionated this summer and submitted for stable isotopic determination by Fall, 2014. Two year post-treatment samples will be collected and analyzed during the Summer and Fall, 2015. Density fractionation and stable isotopic determinations by September 30, 2015 and December 29, 2015 respectively are planned for completion. Costs are available for the density fractionation of the pre-, immediate post-, and one-year post-treatment samples in Hatten's year three budget. Since these items are all supplies (not services), all items needed to complete the work prior to July 31, 2014 will be purchased.

3) *Exchangeable nutrient pools*

Analysis of soils collected one year post-treatment for total C and N and exchangeable nutrients are planned to be completed by September 1, 2014. Costs for this work were included in Hatten's year-three budget and, while work completion is anticipated by July 31, 2014, some funds may need to be deferred into Hatten's the year-four budget to complete the work.

4) *Pan lysimeters*

All pan lysimeters are installed and two rounds of soil solutions have been collected since January, 2014. Samples are currently being stored (frozen) until time permits for the laboratory analysis. These solutions will be analyzed periodically throughout the length of the task period. Collection and analysis of pan lysimeter solutions should be completed by March 31, 2015.

5) *Foliar response*

No work was planned during this reporting period.

6) *Soil respiration*

Soil respiration collars are installed and soil respiration measurements have been collected since January, 2014. Past studies show that the biomass treatments may impact maximum soil temperatures. To assess impact of these extreme swings in temperature on soil respiration, soil moisture and temperature will be monitored and soil respiration will be measured throughout the day on selected days during the growing season. This small modification to the plan will require some additional funds for travel and consumables, which will be funded from cost-savings of items that have cost less than estimated.

Recommendations | Conclusions

In general, the project is in its initial phases and everything is proceeding according to plan. No major changes are necessary at this point.

Physical and Intellectual Outputs

RESEARCH PRESENTATIONS

Oral, Posters or Display Presentations

Gallo, A., Hatten, J. 2014. Long-term soil productivity on managed forests: Mechanisms of apparent resilience after intensive biomass removal. Northwest Forest Soils Council. 21 February 2014. Ellensburg, WA. Poster

Gallo, A., Hatten, J. 2014. Long-term soil productivity on managed forests: Mechanisms of apparent resilience after intensive biomass removal. Oregon Society of Soil Scientists. 27 February 2014. Bend, OR. Poster

SYSTEMS METRICS

TECHNO-ECONOMICS TEAM

TASK SM-TEA-1: TECHNO-ECONOMICS ANALYSIS

Key Personnel	Affiliation
Gevan Marrs	Weyerhauser
Tom Spink	TSI

Task Description

Weyerhaeuser and TSI will work cooperatively to construct a complete techno-economic model for the NARA softwood-to-biojet production. The model will define a base case for key elements:

- Feedstock cost estimates at various facility scales
- Key process blocks
- Mass and energy balances for each block, tracking
    - Wood polysaccharides to bio-jet
    - Wood lignin residuals to co-products
    - Other wood components (volatiles, ash: waste) where appropriate
- Operating costs for each block (materials, energy)
- Capital cost for each process block
- Total capital expenditure (Capex) vs. scale, optimization against feedstock costs at scale, selection of base case facility scale.
- Other financial incentives (renewable identification numbers (RINS) for renewable fuel standard 2 (RFS2), tax incentives, etc.)
- Financial assumptions (cost of capital, facility life, depreciation, etc.)

These will be assembled in a standard discounted-cash-flow return-on-investment/net present value (DCF-ROI, NPV) analysis sheet with input blocks for key variables allowing user interaction for sensitivities. The key outputs will be:

1. Base Case Executive Summary: a one page base case summary including key values

2. Cost Components Analysis: depiction of major cost elements with interpretations for main leverage points for improvement opportunities.

3. Sensitivity Analysis: using equal-probability estimates from experts in each key area, assess which elements have the most potential to improve overall economics (e.g., Capex, feedstocks, yields, etc.)

4. A Lignin Co-Products Valuation: quantify a realistic return on lignin co-products, and/or an analysis to define what would be needed to bring the entire project to profitability

5. Pretreatment Alternatives Evaluation: the base case model will need variations to estimate the impact(s) of each contending pretreatment option. This comparison will be a key determinant in down-selecting for a preferred route.

It is expected that the analysis will be iterative, as an "initial" overall model is needed to identify key leverage points for subsequent refinement. Once the initial base case assumptions are reviewed and digested, it is highly likely that additional refinements will be desired to improve the resolution of key assumptions that are driving the output results. The basic tasks for this project are as follows:

Task SM-TEA-1.1.: build and populate first-cut NARA project TEA model framework

Task SM-TEA-1.2.: obtain and assemble first-cut capital cost estimates

Task SM-TEA-1.3.: obtain and assemble first-cut process flow and operating cost estimate

Task SM-TEA-1.4.: construct first-cut pass at overall economics

Task SM-TEA-1.5.: summarize reporting elements and communicate with stakeholders

Task SM-TEA-1.6.: evaluate the pretreatment options on an equitable basis

Task SM-TEA-1.7.: solicit process improvements in key leverage areas and update economics

Task SM-TEA-1.8.: refine and update model for process and siting specificity

Task SM-TEA-1.9.: further refine and update model for process and siting specificity

Task SM-TEA-1.10.: further refine and update model to pro forma balance sheet level

Activities and Results

One major accomplishment during this reporting period for the NARA TEA team was to accommodate the growing evidence and realization that producing only iso-paraffinic kerosene (IPK) was not an economically viable option. As the NARA lignin residue co-products team identified and developed plausible co-products (lignosulfonates and activated carbon), estimates were made for production costs and market values. These estimates were incorporated in the TEA to construct an integrated multi-product facility. This added complexity necessitated altering the base NREL model approach for a "minimum IPK selling price" since a multiple-product facility cannot solve for a unique product selling price to earn a target return. For our model, all products are sold at expected market prices, capital funding is shifted to 100% equity, and the project's NPV and internal rate of return (IRR) are calculated via a full DCF-ROI analysis. This model basis, using the Catchlight Energy (CLE) mild-bisulfite pretreatment protocol (that was most highly quantified to date), results in significant income contribution from the co-products (Figure SM-TEA-1.1) and an IRR of 10.7%. A major result here was the significance of co-products revenue compared to IPK—nearly twice as much. Accordingly significant attention should be paid to firming up production and marketing values, as they are somewhat less well developed compared to the IPK process and market value.

A second major accomplishment was to collaborate with the team producing a full ASPEN model with improved mass flows and operating costs. This effort was largely driven by the need to qualify for renewable fuel standard's (RFS) renewable identification numbers (RINs); one criteria for which is greenhouse gas (GHG) reduction levels. RINs qualification requires a disciplined life cycle assessment (LCA) to demonstrate achievement. The LCA assessment requires detail to the level provided by the ASPEN model. The ASPEN model data improved the OPEX and CAPEX estimates for the mild-bisulfite (MBS) pretreatment process. The MBS pretreatment process combines elements of the CLE and SPORL pretreatment processes. In addition, recent improvements in the MBS process were quantified via the ASPEN model, including significant impacts of using a sulfur boiler and calcium carbonate to lower costs and improve GHG reductions for LCA. These updated MBS costs and lab-verified improved yields for FS-10 reference feedstock were then incorporated into a new TEA version (6.41) which gives an improved IRR of 12.5%.

A third significant identifiable result (although obviously integrated and intertwined with results reported above) was to simultaneously build an ASPEN model, including OPEX and CAPEX for the second pretreatment process—wet oxidation (WOX). Both the MBS and WOX updated cost and yield numbers were incorporated into separate NARA TEA versions so that direct economic comparisons would be valid. Depending upon the assumptions about CAPEX (more or less optimistic, the IRR for the WOX process was 8.9% to 10.5%. The updated and directly comparable OPEX, CAPEX, and a subjective rating evaluation was provided as input to the Phase-Gate process for NARA leadership to downselect a pretreatment process for future NARA work. The main components leading to the differences in IRR between the two (using the more optimistic WOX CAPEX) are:

1. WOX pretreatment has significantly lower ($35 million/yr) co-products revenue compared to mild bisulfite, as there is no lignosulfonates produced.

2. WOX OPEX is significantly higher ($22 million/yr) than mild bisulfite, due to higher enzyme loading.

3. WOX CAPEX is lower ($23 million/yr annualized) compared to mild bisulfite due mostly to shorter pretreatment retention times and third party supply of the required oxygen plant.

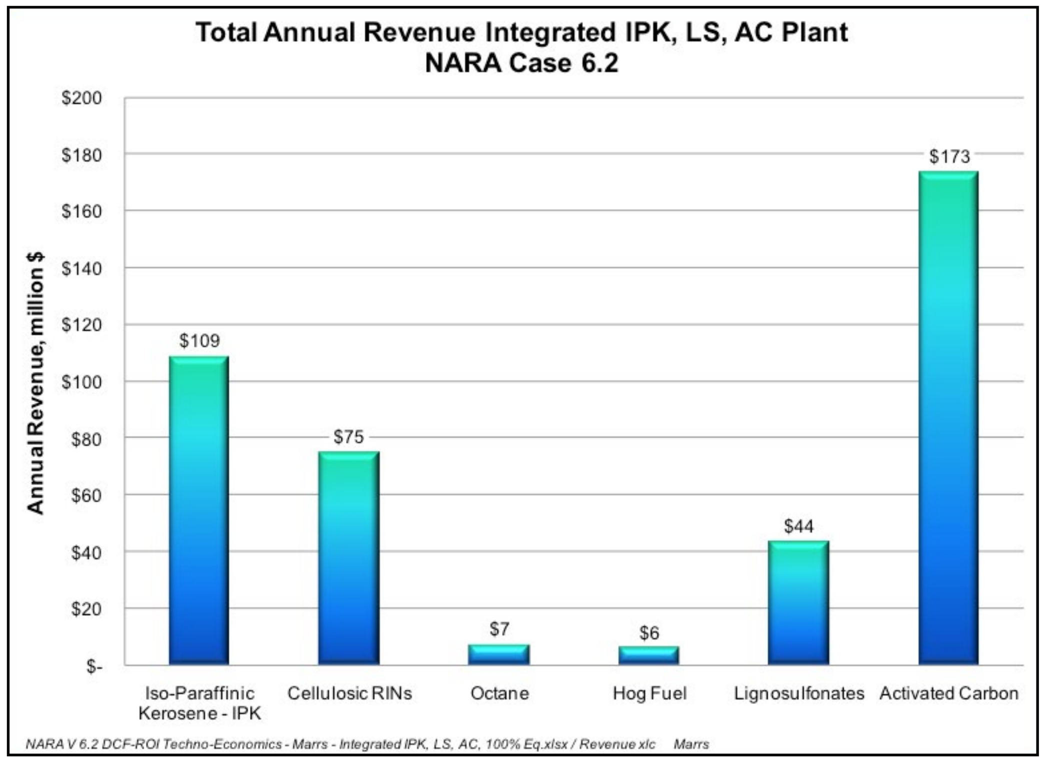

Figure SM-TEA-1.1. Contributions to annual revenue from multi-product integrated plant

Recommendations | Conclusions

1. The integrated TEA model, with multiple products all selling at market prices, and using 100% equity funding for Capex and a full DCF-ROI analysis gives an improved economic basis for decision-making in this relatively complex bio-jet and lignin co-products NARA process.

2. Comparing on an apples-to-apples basis for CAPEX, OPEX, and all other economic factors, the TEA team recommended selection of the MBS pretreatment process due mostly to reduced enzyme costs and increase revenue from lignosulfonate sales. A somewhat more subjective supporting argument is that the MBS process is relatively proven (via sulfite pulping) compared to WOX.

3. The importance of co-products revenue is now very apparent, and given IPK commodity pricing and yield constraints, adding higher-valued co-products seems to be the only route to significant improvements in overall economics.

Physical and Intellectual Outputs

- NARA TEA Model Versions 6.0, 6.1, 6.2, 6.3, 6.4 and 6.41 – varying degrees of full DCF-ROI and 100% equity funding for MBS pretreatment with sulfur burner, calcium carbonate, higher FS-10 yield, all based upon on-going collaborative improvements with ASPEN team.

- NARA TEA Model Versions 7.0 and 7.1 – Wet Oxidation pretreatment for direct economic comparisons against MBS Versions 6.x, with Capex and Opex specific to wet oxidation.

- Summary comparison spreadsheet for WOX and MBS for unit process area Capex, Opex, and an expert subjective differences ranking.

- Significant input into Phase-Gate packet for NARA leadership to down-select between MBS and WO pretreatment process.

SYSTEMS METRICS

ASPEN MODELING TEAM

TASK SM-AM-1: ASPEN MODELING OF THE NARA CONVERSION PROCESS

Key Personnel	Affiliation
Shulin Chin	Washington State University

Task Description

The Washington State University Biological Systems Engineering (WSU-BSYSE) team will work in collaboration with Weyerhaeuser and TSI to evaluate and improve upon currently developed techno-economic analysis (TEA) models for the softwood-to-bio-jet production project. Existing knowledge and models will be incorporated for this task and the improved models built by the team will be used to evaluate the trade-offs in capital expenditures versus operating cost based on the choice of different design and operational parameters. Analysis of logistics will also include economic benefits using a system of distributed sugar depot, which could reduce transportation costs. A sensitivity analysis of differing fuel prices at varied plant capacities will be used to allow determination of delivered feedstock and output products in relation to plant capacities. The main scope of work includes:

- development of an integrated ASPEN model with key modules with consideration of various alternatives for conversion and pre-processing as identified by the project team;
- conduct TEA of the system for the major operations specified;
- conduct sensitivity analysis to identify high return improvements for the unit operations to guide the research and development and process integration efforts;
- optimize the system based on the improvements made on the processes during the project and various major constraints that the operation may have; and
- interact with the LCA team to provide needed inputs to their work.

Discounted cash flow rate of return analyses will be conducted to incorporate capital and operating costs into a single framework along with business decisions and cash flow assumptions. The result will be an estimated minimum fuel selling price, Internal Rate of Return, or net present value, depending on the desired metric. The key outputs will be:

1. evaluation of alternative pretreatment technologies: the developed model will help to compare the performance of different pretreatment technologies under investigation in terms of efficiency and overall cost reduction;

2. co-product valuation: Assess value of co-products such as lignin, and other small molecules and its effect on profitability of plant;

3. use of distributed sugar depots vs. a traditional biomass processing, evaluating an alternative plant design that could reduce the final cost of the biojet fuel.

All the analyses performed in this task will be performed in consultation with other teams in the overall project and iterative refinement will be performed to help guide future developments.

Activities and Results

The Aspen Plus modeling team has been working on the development of process models for the mild bisulfite pretreatment (MBS) and wet oxidation (WOX) processes. In conjunction with Mr. Tom Spink, department based models for these two separate processes have been developed. The current state of these models covers all unit operations starting from feedstock handling at the gate of the biorefinery through enzymatic hydrolysis to monomeric sugars. These models are mass accurate. An energy assessment was conducted for each department based on the models to determine operating costs and steam usage. The results, in terms of chemical and energy usages, as well as overall operating costs predicted from the Aspen models, were summarized in two white papers submitted to the NARA management in the first week of March, 2014.

From the model results, it was determined that the MBS process has significantly lower operating costs compared to the wet oxidation process. This was attributed mainly to reduced steam usage in pretreatment, as well as a much lower enzyme dosage required in the enzymatic hydrolysis department.

After completion of these first three department models (feedstock handling, pretreatment, and enzymatic hydrolysis), the data output from the models was submitted to Bob Wooley from Gevo. He placed the data into Gevo's Aspen model for the fermentation, upgrading and IPK production processes, and gave us the output from the Gevo "black box".

Currently, work is progressing on interpreting the Gevo results and understanding how they will fit into the whole integrated process model to be developed in the future. In addition, work is being done to build the co-products modules for the MBS process, for the drying and storage of the spent sulfite liquor (SSL) lignin as well as the pyrolysis of fermentation residuals into activated carbon.

Recommendations | Conclusions

The Aspen Team is currently awaiting information from the NARA leadership on the choice of pretreatment process before continuing modeling efforts for the pretreatment technical details. A meeting is planned for the beginning of May between the Aspen, TEA, and Co-products teams to get more details on the co-product processes. There is currently not enough information to model the co-products production accurately.

Physical and Intellectual Outputs

Two white papers were developed by Allan Gao and Tom Spink and submitted to the NARA leadership team in February. These white papers were titled: " WHITE PAPER: Mild Bisulfite Pretreatment Aspen Model" and "WHITE PAPER: Wet Oxidation Pretreatment Aspen Model", respectively.

Additional detailed information on these two processes was released to the NARA management team. These research products included the process flow diagrams, component lists and associated mass balances, and details involving generation of the Aspen Plus models. Large portions of those documents could be considered a intellectual property (IP) and will not be disclosed here.

SystemsMetrics_EPP

NARA

	Task Name	% Complete
1	SYSTEMS METRICS - ENVIRONMENTALLY PREFERRED PRODUCTS TEAM	
2	SM-EPP-1. Environmentally Preferred Products	69%
3	Task SM-EPP-1.1. "Public" stakeholders (SHs): demographic, psychographic, and market-specific assets through dataset analysis (Leigh Stowell, Rupasingha, and Roper-Putnam)	100%
4	Analysis + literature review to predict public bioenergy behaviors	100%
5	Preliminary Report	100%
6	Refine "public" SH perceptions	100%
7	Final Report	100%
8	Task SM-EPP-1.2. Review Sustainability Approaches: ecolabels, stds., product claims, LCA/EIO data sources & models	88%
9	Research environmental claims, labels and standards associated with product categories in N. America, including detailed criteria (focus on products qualifying under USDA's BioPreferred program)	100%
10	Preliminary Report	100%
11	Develop in a common format comprehensive assessment of criteria across life cycle phases of up to 4 representative bioproducts categories, and where possible, production process stages - Analyzing for common attributes	75%
12	Final Report	90%
13	Task SM-EPP-1.3. Review Regional Bioenergy Stakeholder Perceptions: issues, influencial groups, etc.; NARA site personal/focus group interviews and analysis	100%
14	Examine criteria for initial NARA Community (NC) screening from NARA project experts	100%
15	Analyze Outreach team input	100%
16	Report	100%
17	Analyze physical asset criteria	100%
18	Preliminary Report	100%
19	Final Report	100%
20	Preliminary NC site selection	100%
21	Preliminary report (for NC site selection)	100%
22	Final report (for NC site selection)	100%
23	Preliminary protocols, constructs, and interviews	100%
24	Preliminary report, Preliminary protocols, constructs, and interviews	100%
25	Final report, Preliminary protocols, constructs, and interviews	100%
26	Task SM-EPP-1.4. "Informed" stakeholder interaction/operationalization (pop's., sampling, constructs, protocols)	85%
27	Western Montana Corridor (WMC)	85%
28	Preliminary Report	100%
29	Final Report	0%

Timeline: 2011–2016, Q1–Q4

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	Task Name	% Complete
30	West Side (WS)	85%
31	Preliminary Report	100%
32	Final Report	0%
33	Task SM-EPP-1.5. Refine Operationalization – pop's., sampling, constructs, protocols – select additional NARA community sites and provide Social Hotspot Analysis	10%
34	Nara community SH interviews	10%
35	Report	0%
36	Task SM-EPP-1.6. Techno-Market Assessment: Jet Fuels	83%
37	Examine & define market opportunities for select aviation fuels	100%
38	Collect biofuels supply chain SH data; Assess procurement needs of key fuel sectors via primary data collection	90%
39	Identify key channels, buyers & specifiers for select aviation fuels in the PNW	30%
40	Jet fuel products - data collection preliminary report	0%
41	Jet fuel products - data analysis report	0%
42	Task SM-EPP-1.7. Economic, Environmental & Social Assessment: Jet Fuels	85%
43	Life cycle inventory (LCI) development for preprocessing and processing stages for biojet; Baseline biojet fuel module for EPP decision-making using GaBi	100%
44	Define select "ideal" aviation fuels and bio-based polymer co-products & substitutes; Eval env/social criteria against hot-spot analysis; dev value propositions fuels	90%
45	Parameterized model for Biojet developed (assessed for GHG, water and abiotic depletion)	70%
46	Task SM-EPP-1.8. Techno-Market Assessment: BioProduct Polymers (1-2 product categories)	68%
47	Examine & define market opportunities for select co-products	85%
48	Collect co-products supply chain SH data; Assess procurement needs of key product sectors via primary data collection	85%
49	Identify key channel, buyers & specifiers for select bio-based polymer co-products in PNW	0%
50	Bio-based polymer co-products - data collection preliminary report	0%
51	Bio-based polymer co-products - data analysis report	0%
52	Task SM-EPP-1.9. Economic, Environmental & Social Assessment: BioProduct Polymers	38%
53	Collaborate w/ LCA & SH NARA teams to develop env & social hotspot analyses	80%
54	Define select "ideal" bio-based polymer co-products & substitutes in terms of properties, prices, & other attributes; Evaluate env/social criteria; Dev value props	0%
55	Incorporation of co-product modules into parameterized biojet model	35%
56	Task SM-EPP-1.10. Prototype Integrated EPP Protocol	0%
57	Develop a prototype integrated protocol for expanding methodologies developed in Tasks 6 & 8 across product categories by designing a process consistent with EPP best practices	0%
58	Develop an EPP marketing and procurement decision support tool to integrate economic, environmental and social impacts of NARA biojet and co-products	

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	Task Name	2011				2012				2013				2014				2015				2016			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
59	Final EPP Report																							⧫ 0%	

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SystemsMetrics_LCA

NARA

	Task Name	% Complete
1	SYSTEMS METRICS - LCA & COMMUNITY IMPACT TEAM	
2	SM-LCA-1. LCA Assessment of Using Forest Biomass as a Feedstock for Biofuels	62%
3	Task SM-LCA-1.1. Soil Carbon Analysis	86%
4	Review literature on carbon impacts of forest thinning and residual collection	90%
5	Review literature of carbon implications of alternate systems for harvest, collection and transport of forest thinnings and residuals	90%
6	Review literature of impacts of collecting forest thinnings and residuals on soil carbon and stand productivity including the soil impact of avoided wildfires	90%
7	Review impact of forest residual removal on soil carbon and stand productivity	92%
8	Collect soil carbon data	75%
9	Preliminary report	40%
10	Final report	0%
11	Task SM-LCA-1.2. LCA Analysis	47%
12	Review literature on LCA of forest residuals and their use in producing biofuel	100%
13	Collect LCA data for coniferous forest and plantation feedstock (in conjunction w/WeyCo)	40%
14	Develop framework LCA analysis for forest residuals (Inland Empire)	100%
15	Conduct framework LCA analysis for pretreatment (in conjunction with Gevo and Catchlight)	90%
16	Integrate framework forest residual and pretreatment LCA with biofuel LCA (with Gevo)	10%
17	Collect LCA data for Inland Empire	100%
18	Preliminary LCA report for feedstock (Inland Empire)	100%
19	Integrate LCA data into framework LCA (Inland Empire)	40%
20	Preliminary LCA framework with report for complete process (Inland Empire) (in conjunction with Gevo and Catchlight)	90%
21	Develop framework LCA analysis for forest residuals (NARA Community #2)	30%
22	Collect LCA data for NARA Community #2	30%
23	Preliminary LCA report for feedstock (NARA Community #2)	0%
24	Preliminary LCA framework with report for complete process (NARA community #2) in conjunction with Gevo and Catchlight	0%
25	Integrate LCA data into framework LCA (NARA Community #2)	0%
26	Complete LCA analyses for both locations	0%
27	Conduct peer review of LCA data and revise	0%
28	Upload LCI data to national databases	0%
29	Preliminary LCA report	0%
30	Final LCA Report	0%

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	Task Name	% Complete
31	Collect and assess information for eco-labels and environmental product declaration (EPD) for jet biofuel (in conjunction with EPP Task 9)	0%
32	Develop EPD for bio-jetfuel (in conjunction with EPP team)	0%
33	Draft EPD completed	0%
34	Final EPD	0%
35	Task SM-LCA-1.3. Community Economic Impact Assessment	50%
36	Review literature on rural economic impact and infrastructure requirements	70%
37	Model community economic impacts of biofuel production for both locations	30%
38	Preliminary Economic Impact Report	0%
39	Final Economic Impact report	0%

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SustainableProduction_Holub

NARA

	Task Name	% Complete
1	SM-SP-1. Sustainable Feedstock Production Systems	50%
2	Task SM-SP-1.1. Pre-treatment site selection and assessment	100%
3	Coordinate with operations to identify potential sites	100%
4	Examine potential sites for feasibility and select stands	100%
5	Perform pre-harvest site assessments	100%
6	Stands selected and pre-harvest site assessments completed	100%
7	Task SM-SP-1.2. Implement treatments	79%
8	Harvest stands and apply treatments	100%
9	Construct Fences	100%
10	Plant seedlings	95%
11	Post planting assessment and measurements	10%
12	Stands harvested and treatments applied, fences constructed, seedlings planted	85%
13	Establishment Report	0%
14	Task SM-SP-1.3. On-going plot maintenance	5%
15	Maintain fences and weed control	5%
16	Weather station monitoring and maintenance	5%
17	General site maintenance	5%
18	Task SM-SP-1.4. Post treatment 2 year assessment	0%
19	Monitor sites for early post-treatment effects	0%
20	Early post treatment effects recorded	0%
21	Write Final Report	
22	Second year growth report	0%

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SustainableProduction_Bailey_Boston

NARA

	Task Name	% Complete
1	SM-SP-2. Sustainable Biomass Supply from Forest Health and Fire Hazard Reduction Treatments	58%
2	Task SM-SP-2.1. Develop Preliminary Prescriptions for Public Landscapes Needed for Regional Supply Model	100%
3	Synthesize existing example prescriptions	100%
4	Review prescription options with managers	100%
5	Preliminary prescription developed for regional supply model	100%
6	Task SM-SP-2.2. Develop Models and Tools for Public Decision Makers to consistently assess potential for feedstock yields	100%
7	Review of prototype model runs by managers	100%
8	Compiled regional model runs	100%
9	Modeling Tools developed	0%
10	Task SM-SP-2.3. Establish Large Scale Adaptive Management Studies	42%
11	Draft framework	100%
12	Review by managers	100%
13	First installations	10%
14	Updated framework	0%
15	Adaptive management framework report	0%
16	Task SM-SP-2.4. Apply tools and models of first year results to large scale experiments to improve predictive ability of models	26%
17	Draft framework	80%
18	Review by managers	0%
19	First installations	0%
20	Updated framework	0%
21	Large-scale experimental framework report	0%
22	Task SM-SP-2.5. Final Report	0%

Timeline: 2011–2016 (Q1–Q4)

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SustainableProduction_Adams_Latta

NARA

	Task Name	2011–2014 (Q1–Q4)
1	SM-SP-3. Biomass Modeling and Assessment	60%
2	Task SM-SP-3.1. Develop Preliminary Biomass Model and Supply Curves for OR, WA, ID, MT	95%
3	Extend existing models to include biomass	100%
4	Develop transportation model	95%
5	Develop harvest projections	95%
6	Coordinate with silviculture, soil productivity and logistics groups on model inputs	25%
7	Task SM-SP-3.2. Second iteration regional biomass supply curves as improved estimates of biomass availability and costs become available.	0%
8	Revise and iterate the Task 1 models in response to information from other groups (including logistics and silviculture groups)	0%
9	Task SM-SP-3.3. Model alternative plant locations and capacities	0%
10	Generate projections of resource supplies and costs under alternative assumptions of biomass processing locations and biomass supply	0%
11	Task SM-SP-3.4. Final Report	0%
12	Summary of harvest projections, transportation model, alternative plant location/capacities, and biomass/supply curve model	0%

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SustainableProduction_Maguire

NARA

	Task Name	%
1	SM-SP-4. Long Term Productivity Studies	57%
2	Task SM-SP-4.1. Develop allometric equations for managed stands	100%
3	First season of biomass sampling	100%
4	Complete first field season of biomass sampling; construct and edit database for first field season of biomass sampling, including elemental analysis of all plant tissues	100%
5	Second season of biomass sampling	100%
6	Complete second field season of biomass sampling; complete database for both field seasons of biomass sampling; develop biomass equations	100%
7	Task SM-SP-4.2. Estimate nutrient and carbon removals under various levels of biomass harvesting	99%
8	Methodology developed for quantifying nutrient content of different biomass components for tree, shrub and herbaceous vegetation; estimate nutrient and carbon removals under varying levels of biomass harvesting	99%
9	Task SM-SP-4.3. Determine sustainable levels of bioenergy feedstock under range of silvicultural intensities	10%
10	Sustainable levels of bioenergy feedstock production determined under a range of silvicultural intensities using forest simulation models	0%
11	Task SM-SP-4.4. Estimate changes in long term site productivity under different climate change scenarios	1%
12	Changes estimated in long-term site productivity under different rates of biomass removals and different climate change scenarios using forest simulation models	0%
13	Task SM-SP-4.5. Synthesis of Results & Final Report	0%
14	Report summarizing: 1) key tools dev. For simulating biofuel feedstock production as part of total system production in managed Doug-fir forests; 2) conclusions about sustainable levels of feestock production on diff sites characterized by soil & climate	0%

Timeline: 2011–2016, Q1–Q4

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SustainableProduction_Petrie_Lamb

NARA

#	Task Name	% Complete
1	SM-SP-5. Environmental Impact Analysis to Support NARA Biofuel Development in the Pacific Northwest	23%
2	Task SM-SP-5.1. Water Resources Component	23%
3	Task SM-SP-5.1.1. Develop sampling plans and methodologies	43%
4	Investigate appropriate methods and write sampling/QA plan	50%
5	Conduct exploratory field evaluation of potential sites	40%
6	Revise sampling plan, order materials, and install equipment	40%
7	Task SM-SP-5.1.2. Conduct field sampling	26%
8	Monitor runoff quantity from field plots and weather stations	35%
9	Monitor sediment erosion from sites	20%
10	Collect water/sediment samples for stream erosion model	25%
11	Sample and identify microbial community at test plots	25%
12	Task SM-SP-5.1.3. Create water resources models of study areas	23%
13	Evaluate water quality/quantity model input requirements	60%
14	Set-up, calibrate, evaluate multi-scale water resources models	25%
15	Run and appraise models using field data, evaluate future impacts	0%
16	Task SM-SP-5.1.4. Create stream erosion model of study sites	14%
17	Conduct literature review of stream erosion processes	20%
18	Evaluate models describing stream channel response to hydrologic changes	20%
19	Explore representative sites for field data collection	30%
20	Develop model for scenario evaluation	0%
21	Run and appraise model, evaluate future impacts	0%
22	Final report	♦
23	Task SM-SP-5.2. Air Component	23%

Timeline: 2011–2016 (Q1–Q4 each year)

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SustainableProduction_Petrie_Lamb

NARA

	Task Name	% Complete
1	SM-SP-5. Environmental Impact Analysis to Support NARA Biofuel Development in the Pacific Northwest	23%
2	Task SM-SP-5.1. Water Resources Component	23%
3	Task SM-SP-5.1.1. Develop sampling plans and methodologies	43%
4	Investigate appropriate methods and write sampling/QA plan	50%
5	Conduct exploratory field evaluation of potential sites	40%
6	Revise sampling plan, order materials, and install equipment	40%
7	Task SM-SP-5.1.2. Conduct field sampling	26%
8	Monitor runoff quantity from field plots and weather stations	35%
9	Monitor sediment erosion from sites	20%
10	Collect water/sediment samples for stream erosion model	25%
11	Sample and identify microbial community at test plots	25%
12	Task SM-SP-5.1.3. Create water resources models of study areas	23%
13	Evaluate water quality/quantity model input requirements	60%
14	Set-up, calibrate, evaluate multi-scale water resources models	25%
15	Run and appraise models using field data, evaluate future impacts	0%
16	Task SM-SP-5.1.4. Create stream erosion model of study sites	14%
17	Conduct literature review of stream erosion processes	20%
18	Evaluate models describing stream channel response to hydrologic changes	20%
19	Explore representative sites for field data collection	30%
20	Develop model for scenario evaluation	0%
21	Run and appraise model, evaluate future impacts	0%
22	Final report	
23	Task SM-SP-5.2. Air Component	23%

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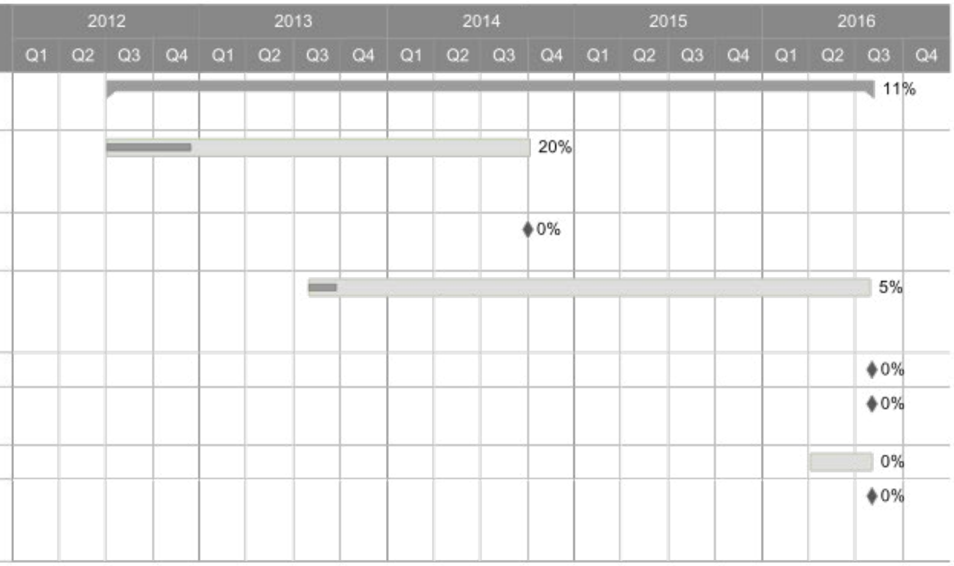
SustainableProduction_Betts

NARA

	Task Name	% Complete
1	SM-SP-6. Local and Regional Wildlife Impacts of Biomass Removals	11%
2	Task SM-SP-6.1. Analysis of preliminary regional models completed to provide metrics for regional runs and to inform future regional model runs	20%
3	Development of wildlife metrics to be used for regional impact analysis of projected biomass harvests	0%
4	Task SM-SP-6.2. Synthesis of local wildlife impacts from WY LTSP field work, forest health treatments and summarize regional wildlife impacts from regional biomass simulation	5%
5	Report summarizing wildlife impacts from regional biomass	0%
6	Report summarizing local wildlife impacts from WY LTSP field work and local wildlife impacts from proposed forest health treatments	0%
7	SM-SP-6.3. Final Report	0%
8	Report summarizing wildlife impacts at regional scale for final biomass supply model runs and local wildlife impacts from WY LTSP and proposed forest health treatments	0%



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SustainableProduction_Morgan

NARA

	Task Name	% Complete
1	SM-SP-7. Supply Chain Analysis	59%
2	Task SM-SP-7.1. Coordinate new and existing Idaho & Montana ("east-side") forest inventory and other data for use in "west-side" models	70%
3	Coordinate with "west-side" modeling team on data needs and standards for Idaho & Montana	70%
4	Task SM-SP-7.2. Enhance and update primary mill residue and capacity information for 4-state region	93%
5	Task SM-SP-7.2.1. Survey of primary mill facilities in Washington and Oregon	87%
6	Cooperate with Washington DNR on mill surveys to collect mill residue and capacity information	80%
7	Washington primary mill (residue, wood use, capacity, etc.) data available for modeling	80%
8	Provide updated estimates of Oregon mill residue and capacity information from mill censuses	100%
9	Oregon primary mill (residue, wood use, capacity, etc.) data available for modeling	100%
10	Provide updated estimates of Montana mill residue and capacity information from mill censuses	100%
11	Montana primary mill (residue, wood use, capacity, etc.) data available for modeling	100%
12	Provide updated estimates of Idaho mill residue and capacity information from mill censuses	100%
13	Idaho primary mill (residue, wood use, capacity, etc.) data available for modeling	100%
14	Task SM-SP-7.3. Enhance and update logging and other forest residue for 4-state region	39%
15	Conduct logging utilization studies in Idaho, Montana, Oregon and Washington	58%
16	Incorporate updated logging residue data into woody supply analysis	0%
17	Final report on forest/logging residue and primary and secondary mill residue	0%

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SustainableProduction_Hatten

NARA

	Task Name	% Complete
1	SM-SP-8. Effects of Varying Forest Floor and Slash Retention on Soil Nutrient and Carbon Pools in a Regenerating Douglas-fir Tree Farm: NARA-Soils	20%
2	Task SM-SP-8.1. Monitor and report on soil moisture and temperature data	36%
3	Soil Moisture Installation	100%
4	Soil Moisture and Temperature Measurements	30%
5	Task SM-SP-8.2. Analyze whole soils and density fractions pre-, post-, 1 yr post- and 2 yr post for elemental contents stable isotopic ratios	3%
6	Soil Collection - Year 1 after treatment	0%
7	Soil Collection - Year 2 after treatment	0%
8	Density Fractionations	10%
9	Elemental Determinations	0%
10	Stable Isotope Determinations	0%
11	Task SM-SP-8.3. Examine whole soils pre-, post-, 1 yr post- and 2 yr post for exchangeable nutrient pools	0%
12	Available Nutrients pre- and post-treatment	0%
13	Available Nutrients 1 yr post-treatment	0%
14	Available Nutrients 2 yr post-treatment	0%
15	Task SM-SP-8.4. Examine inputs of carbon and nutrients into mineral soils using pan lysimeters	33%
16	Pan Lysimeter Installation	100%
17	Pan Lysimeter Solution Collection	25%
18	Task SM-SP-8.5. Foliar response to soil changes	0%
19	Task SM-SP-8.6. Examine soil carbon cycling through soil respiration	33%
20	Respiration Collar Installation	100%
21	Soil Respiration Measurements	25%
22	Task SM-SP-8.7. Manuscript, Report Preparation, Data Archive	0%
23	Milestone/Deliverable 1: Conference presentation on effect of compaction on distribution of soil carbon and nutrients	0%
24	Milestone/Deliverable 2: Conference presentation on the effect of organic matter removal on soil carbon and nutrients	0%
25	Milestone/Deliverable 3: Manuscript preparation on soil carbon	0%
26	Milestone/Deliverable 4: Manuscript preparation on soil nutrients and site productivity	0%
27	Milestone/Deliverable 5: Final Report preparation	0%

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SystemsMetrics_TEA

NARA

	Task Name	% Complete
1	SM-TEA-1. Techno-Economic Analysis	65%
2	Task SM-TEA-1.1. Build and populate first-cut NARA project TEA model framework	100%
3	Determine scope, detail, contents and obtain or build starting model template	100%
4	Task SM-TEA-1.2. Obtain and Assemble first-cut Capital Cost Estimates	100%
5	Determine facility scale optimum from preliminary total CAPEX and feedstock cost	100%
6	Obtain initial CAPEX estimates for each process block at scale	100%
7	Task SM-TEA-1.3. Obtain and Assemble first-cut Process Flow and Operating Cost Estimate	100%
8	Perform literature review relative to softwood to Jet via Gevo process	100%
9	Review flow with experts via meeting contacts and phone conferences	100%
10	Draft layout of individual units of process	100%
11	Collaboratively prepare and communicate "Yield Chain" base case	100%
12	Obtain market price for materials and energy	100%
13	Estimate material and energy requirements for each process step	100%
14	Prepare Admin and labor staffing and cost diagrams	100%
15	Estimate utility costs	100%
16	Estimate Co-product financial impact	100%
17	Identify and estimate all other non Co-product revenue	100%
18	Task SM-TEA-1.4. Construct first-cut pass at overall economics	100%
19	Incorporate Capex into base case model and document	100%
20	Incorporate Opex into base case model and document	100%
21	Investigate and quantify base case incentives value (RINs)	100%
22	Build preliminary estimate of Co-products breakeven need or value estimate	100%
23	Task SM-TEA-1.5. Summarize reporting elements and communicate with stakeholders	100%
24	Build overall Executive Summary report sheet	100%
25	Develop and report Cost components in order to understand key leverage points	100%
26	Develop and report Probability Adjusted Sensitivity Analysis for major leverage points	100%
27	Develop full Discounted Cash Flow - Net Present Value - Return on Investment sheet	100%
28	Document initial results and review with stakeholders, revise as needed	100%
29	Task SM-TEA-1.6. Evaluate the Pretreatment options on an equitable basis	93%
30	Obtain initial CAPEX estimates for each alternative pretreatment process.	100%
31	Estimate Opex for each alternative pretreatment process	100%
32	Meld Capex and Opex into NARA TEA and report out	80%
33	Task SM-TEA-1.7. Solicit process improvements in key leverage areas and update economics	60%
34	Hold communications meetings with key NARA task elements and explain results	60%
35	Work with NARA staff to identify key improvement possibilities	60%

Timeline: 2012–2016 (Q1–Q4 per year)

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	Task Name	% Complete
36	Modify TEA model to incorporate speculative improvements and quantify impact	60%
37	Document key findings and recommend path(s) forward	60%
38	Task SM-TEA-1.8. Refine and update model for process and siting specificity	65%
39	Identify key process improvement possibilities	60%
40	Quantify and incorporate key feedstock cost reduction discoveries	75%
41	Increase specificity about facility scale, siting, and product off-take plans	60%
42	Task SM-TEA-1.9. Further refine and update model for process and siting specificity	0%
43	Identify additional key process improvement possibilities	0%
44	Quantify and incorporate key feedstock cost reduction discoveries	0%
45	Increase specificity about facility scale, siting, and product off-take plans	0%
46	Investigate specific siting incentives to add to economic feasibility (state, local, etc.)	0%
47	Task SM-TEA-1.10. Further refine and update model to pro forma balance sheet level	0%
48	Identify most plausible financing and implications (rates, capital recovery, etc.)	0%
49	Identify most plausible specific siting, infrastructure costs, assets in place	0%
50	Identify specific year-by-year build and operate model	0%
51	Identify plausible future key product values (biojet, co-products), incentives (RINs).	0%

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SystemsMetrics_AM

NARA

	Task Name	Timeline 2013 Q1 – 2016 Q4 (% complete)
1	SM-AM-1. ASPEN Modeling of the NARA Conversion Process	18%
2	Task SM-AM-1.1. Develop integrated ASPEN model for entire plant	27%
3	Feedstock, pretreatment and enzymatic hydrolysis	100%
4	Fermentation, separation, purification	50%
5	Coproduct	40%
6	Multi-functional boiler/utilities	0%
7	IPK, Distillation	0%
8	Integrated model	0%
9	Task SM-AM-1.2. Perform TEA for different pretreatment processes	100%
10	Task SM-AM-1.3. Cost estimation of distributed sugar depot (contingent on inputs from Schwartz group)	0%
11	Task SM-AM-1.4. Coproduct evaluation and model refinement	0%
12	Task SM-AM-1.5. Directing process improvements in key areas based on TEA	0%
13	Task SM-AM-1.6. Refining and updating models with inputs from other team members	0%

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