NARA Goal Three

3RD Cumulative Report

April 2014 - March 2015

Rural Economic Development

Enhance and sustain rural economic development.

SUMMARY

ENVIRONMENTALLY PREFERRED PRODUCTS (EPP), LIFE-CYCLE ASSESSMENT (LCA), COMMUNITY IMPACT ASSESSMENT (CIA)

Sustainability is the crucial attribute 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 impact data through the Sustainable Production Team. The following efforts within the Systems Metrics program are integrated to provide a sustainability analysis of the NARA project:

NARA Image

ENVIRONMENTALLY PREFERRED PRODUCTS TEAM

The Environmentally Preferred Products (EPP) Team evaluates the social viability of the industry. This analysis of social sustainability investigates community social assets, stakeholder needs and perceptions, market opportunities for biojet and co-products, and governmental regulations and incentives for renewable products. To evaluate community social assets, the EPP team refined the biogeophysical and social asset assessment described in NARA Year-3 reporting to incorporate NARA's new goals of retrofitting existing facilities. The EPP team reassessed the site selections in the Western Montana Corridor (WMC) region and applied the refined assessment to the Mid-Cascade-to Pacific region (MC2P). The results for the revised WMC assessment were submitted for publication to the Journal of Politics. Regional and national benchmark metrics to assist in identifying receptive communities for biofuel facilities have been created (Task SM-EPP-1.5)

To evaluate stakeholder needs and perceptions, a qualitative analysis was completed on the stakeholder survey described in the NARA Year-3 reporting period. Findings show that a majority of stakeholders support using woody biomass to produce bioenergy or a refined liquid biofuel, and they recognize the benefits, such as improved regional economies and reduced fire hazards. Findings also show that stakeholders are concerned about the potential negative impacts on soil and wildlife by forest residual use. Published survey results are anticipated in late spring 2015. (Task SM-EPP-1.4).

To better define market opportunities for biojet and co-products, the EPP team mapped and generated datasets regarding U.S. biofuel biorefineries (n=412). The team is currently examining cellulosic and algae biofuel biorefinery (BR) product portfolios and evaluating the strategic relationships across value chains through surveys and interviews. To assess and improve our understanding of biojet opportunities, in-person interview protocols, that include scripts, interviewee lists and methodology, and an online e-survey questionnaire have been developed and will be presented in summer 2015 to key aviation supply chain stakeholder groups in the four-state NARA region (Task SM-EPP-1.6). The team completed a preliminary examination of lignin value-added markets and identified activated carbon (AC) as a potential high-growth market for mercury sequestration from power plant flue gas due. Potential AC buyer populations have been identified, and primary data collection is scheduled for summer-fall 2015 to: (1) better understand the value proposition for NARA AC vis-à-vis existing AC products; and (2) delineate the product and service characteristics buyers desire for an AC to sequester mercury from coal-fired power plant flue gas (Task SM-EPP-1.8).

To better understand governmental regulations, incentives for renewable products, and life-cycle assessment approaches for biofuels and co-products, a literature review was completed (Task SM-EPP-1.2). Based on this information, a comparative life cycle assessment (LCA) for different fossil/biomass derived PET bottle production scenarios was finalized (Task SM-EPP-1.7) plus life-cycle iterations were completed for activated carbon and paraxylene production (Task SM-EPP-1.9). The PET bottle LCA indicates that PET bottles derived from forest residuals generate significantly less greenhouse gas effects compared to PET bottles derived from corn stover or crude oil if avoided impacts are taken in consideration. It is clear from these assessments that the type and quantity of co-products can significantly affect the level of greenhouse gas emissions. A mixed integer linear programming (MILP) optimization model is being constructed to help evaluate the economically optimal co-product type and quantity produced while minimizing negative environmental impacts.

LIFE CYCLE ASSESSMENT TEAM

The Life Cycle Assessment (LCA) Team assesses the environmental and economic impacts of producing aviation biofuels, using NARA's chosen production pathway, and compares those impacts to the production of petroleum-based fuel. For this reporting period, the LCA team replaced a majority of the surrogate processes used to structure the LCA with modules and data developed by NARA team members. The LCA team also established a final model integration plan to be implemented once the relevant NARA research teams define all bio-refinery and co-product processes. The final LCA documents should be ready for submission to the International Organization for Standardization (ISO) by the end of summer, 2015 (SM-LCA-1).

COMMUNITY IMPACT ASSESSMENT TEAM

The community impact assessment (CIA) spreadsheet model developed for the western Montana corridor (WMC) region, as reported in NARA year-3 results, was adapted for the western Washington and Oregon region (WWO). To determine the most accurate source of forest biomass potential in the region, biomass supply data from the Western Biomass Assessment and from the NARA Supply Model (Task SM-SP-3) were entered into separate spreadsheets and compared. Distinctions regarding biomass supply and distribution were apparent; however, total sector economic impact differences are relatively small: $244 million (WA Biomass Assessment) versus $258 million (NARA Supply Model), and it was determined that the NARA Supply Model data would be used in the CIA. In addition, it was determined that the calculated county multipliers for the WMC and WWO regions differed. A further breakout of the sectors will allow more precise multiplier estimates associated with the forestry sector (Task SM-LCA-1.3).

SIGNIFICANT OUTPUTS REPORTED FOR THE EPP, LCA, AND CIA TEAMS

- A dataset was developed to identify, classify and locate all US biorefineries (Task SM-EPP-1)
- A environmental and economic optimization model was established in GAMS optimization software (Task SM-EPP-1)
- Co-product use and allocation scenarios were modeled – including emission credit calculations for co-product scenarios (Task SM-EPP-1)
- A peer-reviewed manuscript (Pelton et al) was published titled "Hotspot Scenario Analysis: Comparative Streamlined LCA Approaches for Green Supply Chain and Procurement Decision Making" doi: 10.1111/jiec.12191 (Task SM-EPP-1).
- A comparative life cycle assessment for varied fossil and biomass derived PET bottle production scenarios was finalized (Task SM-EPP-1).
- A peer-reviewed manuscript (Pierobon et al) was published titled "Evaluation of Environmental Impacts of Harvest Residue-based Bioenergy Using Radiative Forcing Framework" doi:10.1016/j.foreco.2014.10.010 (Task SM-LCA-1).
- A peer-reviewed manuscript (James et al) was published titled "Deep soil: quantification, modeling, and significance of subsurface nitrogen" doi:10.5558/tfc2014-120 (Task SM-LCA-1).
- A peer-reviewed manuscript (Littke et al) was published titled "Effects of geoclimatic factors on soil water, nitrogen, and foliar properties of Douglas-Fir plantations in the Pacific Northwest" doi:10.5849/forsci.13-141 (Task SM-LCA-1).
- A peer-reviewed manuscript (Littke et al) was published titled "Assessing Nitrogen Fertilizer Response of Coastal Douglas-fir in the Pacific Northwest using a Paired-tree Experimental Design" doi:10.1016/j.foreco.2014.07.008 (Task SM-LCA-1).

SIGNIFICANT OUTCOMES

- None reported

NARA Image

SUSTAINABLE PRODUCTION TEAM

To provide specific information regarding the impact of removing forest residuals on tree growth productivity, 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 to improve and verify a variety of predicted impacts from an industry that would use forest residuals to produce biojet fuel and co-products.

Soil Nutrients

To develop improved tools and models used to predict soil nutrient levels, 160 decaying stump samples from stumps cut in years spanning 1992 through 2013 were taken from five sites. These samples were analyzed for density and nutrient (carbon and nitrogen) content. The data will be incorporated into a model used to estimate decomposition rates and contribute to developing a carbon life cycle assessment. Additional deep soil excavations were performed this year to measure soil nutrients, moisture levels and temperature. The data will be used to determine the importance of hydraulic redistribution during the dry summer season (Task SM-LCA-1.1). New versions of biomass equations were completed In NARA Year-4 to estimate nutrient and carbon removal under various levels of biomass harvesting. These equations provided estimates of soil nutrient replenishment rates, atmospheric deposition rates, and nutrient release rates for a number of western U.S. Douglas-fir sites and help determine sustainable nutrient levels for bioenergy feedstock production (Task SM-SP-4).

Soil and Tree Productivity

The NARA LTSP site located near Springfield Oregon 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 soil water retention and wildlife. In NARA Year-3, timber harvest was completed on the 83-acre site, and 28 1-acre plots were treated with varied biomass removal and soil-compaction treatments. Seedlings were planted and fencing plus monitoring equipment were installed. For this reporting period, post-treatment soil and biomass effects plus seedling growth after one year growing season were measured (Tasks SM-SP-1; SM-SP-8). Preliminary results show that organic material removal results in warmer soil temperatures to a depth of 100 cm; however, no changes in soil respiration have yet been detected due to the temperature increase (Task SM-SP-8). Traps were established to quantify the emergence of ground nesting bees and other invertebrate pollinators. Captured bees are being identified to species in an effort to determine whether organic material removal impacts pollinator diversity (Task SM-SP-6). Microbial population data was collected from individual treatment plots, and the results indicate that the varied organic material treatments had no effect on microbial ecology (Task SM-SP-5-water).

Water and Wildlife

Additional research on the effects of forest residual removal on wildlife, air quality and stream erosion was conducted outside of the NARA LTSP site. A hillslope model approach was used to model stream flow and sediment transport in north central Idaho as impacted by forest residual removal. Preliminary results indicate that biomass removal decreased average bed material diameter by up to 3 mm and increased bedload transport by up to 5% (Task SM-SP-5-Water). Based on 14,000 bird community observations, preliminary occupancy models have been run for stand-level and landscape-level impacts of intensive forest management on species richness, cavity-dwellers, and individual bird species from eight study regions, including two in the Pacific Northwest (Task SM-SP-6). A series of regional air quality simulations were completed to investigate the impact of prescribed fires on local and regional air quality. These simulations show that harvesting woody biomass for biojet fuel production will decrease the amount of slash burning that occurs in the region by 70% and produce a positive air quality benefit (Task SM-SP-5-Air).

Biomass Availability
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. The NARA biomass supply model was used to estimate impacts to standing biomass supply if RIN credits were applied to federal lands or if public harvests were changed dramatically. Results will be provided in the next reporting period. A variant of the supply model was also used to determine optimal depot facility locations (Task SM-SP-3; Task E-3). To determine the amount of forest residuals left after logging operations, Montana's Bureau of Business and Economic Research (BBER) Forest Industry Research Group extended the logging utilization fieldwork to account for over 2,000 felled trees at 100 sites throughout Idaho, Montana, Oregon and Washington. This effort provides logging residue estimates for each NARA state at the state and county levels. Years 2002 through 2012 timber harvest data (in MBF Scribner) by county and ownership for ID, MT, OR and WA; 2013 data for all ownerships in Washington; and 2013 data for several but not all owners in Oregon, Idaho and Montana are available (Task SM-SP-7). To quantify the effect of regional land management policy and market trends on the supply of available biomass, the first NARA based Integrated Fireshed-Level Adaptive Management Evaluation Site (IFLAMES) was established at Warm Springs, Oregon, and pre-treatment measurements were completed and summarized (Task SM-SP-2)

TECHNO ECONOMIC ANALYSIS

To understand the economic considerations and sustainability of a biojet fuel and co-products industry based on wood residuals, a techno-economic analysis (TEA) is underway. A rough draft of the ASPEN Model and Integrated Biorefinery Report is near completion. This document is intended to demonstrate the mass and energy flows in the NARA biorefinery as well as the capital and operating costs for each department (Task SM-AM-1). A sensitivity analysis was completed for some of the uncertain factors that would impact the internal rate of return (IRR) of a wood-to-biofuels and co-product biorefinery. This data, coupled with a projection of the mass and economic values applied to anticipated revenue streams, demonstrates the challenges of estimating product prices, yields and the value of Renewable Identification Numbers (RINs). A significant development in this reporting period is that the yield estimated for activated carbon was reduced from 40% to 22.5%, which reduces annual revenue by $84 MM. Taken together, the latest "base case" expected rate of return for a biorefinery is 12% (Task SM-TEA-1).

SIGNIFICANT OUTPUTS REPORTED THIS PERIOD FOR THE SUSTAINABLE PRODUCTION AND TEA TEAMS

- NARA graduate student Kevin Vogler submitted his master's thesis at Oregon State University titled "Sustainable Biomass Supply from Fuel Reduction Treatments: A Biomass Assessment of Federally Owned Land in Eastern Oregon " Link (Task SM-SP-2).

- The first NARA-based Integrated Fireshed-Level Adaptive Management Evaluation Site (IFLAMES) was established at Warm Springs, Oregon (Task SM-SP-2).

- NARA graduate student Mindy Crandall submitted her doctoral dissertation at Oregon State University titled "The effects of increased supply and emerging technologies in the forest products industry on rural communities in the northwest U.S." Link (Task SM-SP-3).

- NARA graduate student Kristin Coons submitted her master's thesis at Oregon State University titled " Douglas–fir (Psuedotsuga menziesii) biomass and nutrient removal under varying harvest scenarios involving co-production of timber and feedstock for liquid biofuels." Link (Task SM-SP-4).

- Soil samples for all treatments at the NARA LTSP site were obtained, and DNA samples were analyzed to detect 56 genera of soil microbes (Task SM-SP-5-Water).

- A general technical report titled " Logging Utilization in Idaho: Current and Past Trends" was authored by BBER staff and published by the USDA Rocky Mountain research Station http://www.fs.fed.us/rm/pubs/rmrs_gtr318.pdf (Task SM-SP-7).

- Draft tables covering the Oregon timber harvest and forest products industry for 2013 were made available online http://www.bber.umt.edu/pubs/forest/util/ID_logging_util_2014.pdf (Task SM-SP-7).

SIGNIFICANT OUTCOMES

- Due to the BBER NARA-funded logging utilization research, BBER and the US Forest Service Forest Vegetation Management staff (Ft. Collins Service Center) are jointly modifying the Forest Vegetation Simulator to more accurately predict post-harvest logging residue volumes and biomass (Task SM-SP-7).

TRAINING

Name	Affiliation	Role	Contribution
Allan Gao	WSU	Graduate Res Asst	Allan is the primary Aspen modeler on the team and is creating the model as well as producing various reports, which document the mass and energy balances in the refinery.
Tait Bowers	UW	PhD student	Research on LCA; presentations and publications
Jason James	UW	MS student	Field and lab, presentations, publications
Matt Norton	UW	MS student	Field and lab, presentations, MS thesis
Chrisitiana Dietzen	UW	PhD student	Field and lab, presentations
Marcella Menegale	UW	PhD student	Field and lab, presentations
Kim Littke	UW	Post-doctoral researcher	Field and lab, presentations, publications
Ike Nwaneshiudu	UW	Post-doctoral researcher	Research on pre-treatment and ASPEN modeling; presentations and publications
Cody Sifford	UW	MS student	Research on air quality modeling; presentations and publications
Cindy X. Chen	UW	PhD student	Research on logistics LCA; presentations and publications
BJ Birdinground	UW	MS student	Research on timber inventory modeling
Francesca Pierobon	UW	Exchange PhD student	Research on carbon cycle modeling; presentations and publications
Luis Souza	Univ. Sao Paulo	Intern	Field and lab
Rodolfo Bernardi	Univ. Sao Paulo	Intern	Field and lab
Thiago Bonassi	Univ. Sao Paulo	Intern	Field and lab
Eduardo Marques	Univ. Sao Paulo	Intern	Field and lab
Dr. Ling Jiang	Chang'An Univ	(Visiting faculty)	Field and lab
Stephen Cline, MS	PSU	MS - SU/ FA '14	Lignin market opportunity - activated carbon
Wenping Shi	PSU Postdoc	PSU - NARA & FAA ASCENT	R-t-W SH Assessment and BGP/Social Asset Analysis
Wenping Shi, Ph.D.	PSU	Research; grad. Ph.D - Dec.'14	Social Asset dataset developer, analyst, and manager
Min Chen, Ph.D.	PSU	Research	Biorefinery structure and value stream outputs
Kristina Dahmann	PSU Post-J.D.	Res. Assoc.	Biofuel policy and law
Jennifer Schmitt	U MN Postdoc	Research Postdoc	Spatial variation aspects of supply chain structure and environmental assessment
Rylie Pelton	U MN	Research RA	Environmental assessment of intermediate products and co-products re: activated carbon; development of optimization model
Luyi Chen	U MN	Research RA	Environmental assessment of intermediate products: isobutanol to paraxylene
Jillian Moroney, Ph.D.	U of Idaho	Research; PhD	SH assessment; aviation fuel SH assessment
Ibon Ibarrola, MS & 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	WSU	Research; PhD	Social asset analysis

Natalie Martinkus	WSU	Research: PhD	Biogeophysical and social asset assessment
Preenaa Venugopal	PSU	NARA SURE (SU '14 – PSU)	Potential Technological Pathways for the Production of Alternative Jet Fuel
Dr. Heather Root	Oregon State University	Post-Doc	JoF Review paper, Bird meta-analysis
Dr. Jim Rivers	Oregon State University	Post-Doc	Manipulative study on biofuel impacts on pollinators, White-crowned sparrow survival as a function of slash removal
Codey Mathis	Oregon State University	Undergraduate Student	Manipulative study on biofuel impacts on pollinators
Ian Lively	Oregon State University	Undergraduate Student	Manipulative study on biofuel impacts on pollinators
Kaedra Emmons	Oregon State University	Undergraduate Student	Manipulative study on biofuel impacts on pollinators
Theodore Squires	Oregon State University	Undergraduate Student	Manipulative study on biofuel impacts on pollinators
James Johnston	OSU	Graduate Student	Understanding of fire histories and treatment opportunities in the Blue Mountains
Katherine Morici	OSU	Graduate Student	Understanding longevity of fuels treatments (thinning and prescribed fire)
Kevin Vogler	OSU	Graduate Student	Regional biomass supply and economic accessibility
Kristin Coons	OSU	Graduate Student	Master's thesis
Mohammad Hasan	Univ. of Utah	Graduate Student	Collection and analysis of microbial data, modeling of sediment transport, analysis of soil moisture.
Ross Wickham	WSU	Graduate Student	Numerical modeling of flow and sediment transport, field data collection
Eric Sorensen	Humboldt State Univ.	Undergraduate Student	Assistance with field data collection, literature review of sediment sampling techniques
Adrian Gallo	Oregon State Univ	Graduate Student	Installed and maintained field monitoring equipment, monitoring of soil respiration and collection of lysimeter solutions, performed density fractionations, developing data analysis method for soil temperature, moisture, and respiration data.
Mindy Crandall	OSU	Graduate (PhD)	Doctoral Candidate
Vikram Ravi	WSU, Civil Engr.	Grad Student	Responsible for all air model simulations and analysis

RESOURCE LEVERAGING

Resource Type	Resource Citation	Amount	Relationship or Importance to NARA
PSU GIA (Grant-In-Aid) (tuition)	Min Chen ($16,000/semester)	$80,000; FA ’13, SP/FA ’14, SP/FA ’15;	Research on the US biorefinery structure; biopolymer market opportunity
Industrial Match from CLH Aviation	Ibon Ibarrola, CLH, NARA Affiliate Member	$15,000	Toward a better understanding of aviation fuel supply chains in the US and Spain
PSU Dickinson School of Law	Kristina Dahmann	$5,000 Match	Contributions toward understanding biofuel policy and law
AJF Supply Chain Analysis	FAA ASCENT1 Project	$1,400,000	Contributions toward understanding biofuel policy and law
PSU=$400K	US Regional (incl. NARA) AJF supply chain issues.	$40,000,000 for total 10-year program	Includes Alternative Jet Fuel research and development activities to better benchmark NARA efforts.
CLH Industrial Match for FAA	Ibon Ibarrola, CLH, industry cooperator	$200,000	AJF Supply Chain research in the NARA, MASBI, and ITAKA regions.
PSU RA + GIA support	Stephen Cline	$72,000; 2 yr. Dept funding	NARA SURE - Weyco (SU ’13); PSU wages; MS – PSU.
UMN Buckman endowment	R. Pelton; UMN RA BBE/CFANS	$89,000 (2013-15)	Parameterized LCA of co-product (Activated Carbon) credit/debits to biojet fuel system.
UMN scholar recruitment	L. Chen; UMN RA BBE/CFANS	$43,000	Conducting parameterized LCA of co-product (bioPET) credit/debits to biojet fuel system.
NARA SURE program	Preenaa Venugopal	$6,000	Potential Technological Pathways for the Production of Alternative Jet Fuel
Funding	AFRI-USDA	$50,000	Allowed collection of data on white-crowned sparrow demography (in relation to fine woody debris amount)
Funding	NCASI	$34,890	Performing additional analyses on NARA samples

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. Environmentally 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 and 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/ coproducts and allocation of methods influencing the environmental assessment and reporting of aviation fuels.

Task 1 - 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 2 – 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 3 - 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 4 – This task operationalizes informed stakeholder mixed-method surveys in the NARA region.

Task 5 – This task's overall goal is to produce a refined community asset assessment model (CAAM) to apply to biofuel development issues throughout the NARA region. This model may then be refined and re-calibrated to apply to other US regions and to additional community asset situations, such as preparedness and response to wildfire.

Task 6 – One particular area of the aviation fuels space is biojet. This research will specifically target the supply chain aspect of biojet, from Refinery-to-Wing. Opportunities for utilizing the petro-jet supply chain, and the challenges that must be overcome to bring bio-jet to commercial scale, will be examined.

Task 7 – Working closely with the 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 8 - This task inventories, categorizes and locates all US biorefineries. In addition, the biopolymer and lignin market opportunities will be explored and key biorefinery product portfolio issues addressed.

Task 9 – 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)

The team completed this task in year 2 of the project. Various national data sets were combined that provide important information on different community and social assets utilized in Task 1.5. The team focused on combining Rupasingha, Roper-Putnam, Cultural Vitality Index, various public health data and education data into a single dataset that could be utilized for site selection determination. In 2014, the dataset was updated to include recent updates to Rupasingha, public health and education data. The national-level dataset provides social capital data (Rupashingha/Roper-Putnam), cultural data (Cultural Vitality Index), public health data (obesity rates, mortality rates, number of people insured, etc), and educational data at the county-level. The national dataset and a codebook have been developed by the Team and is currently being used for research described in Task SM-EPP-1.5.

Task SM-EPP-1.2. Review Sustainability Approaches: ecolabels, stds., product claims, LCA/EIO data sources & models. (R. Pelton, Luyi Chen, and T. Smith) Research for task 1.2 has been completed. A literature review was conducted, which identified key governmental policy drivers (RFS2/EISA 2007, FCEA 2008, EO 13514 and 13423, EU Blending Mandate, etc.), voluntary initiatives and standards (USDA Biopreferred, RSB, IATA, ATA, etc.) and aviation biofuel LCAs. This review suggests overwhelming evidence toward the importance of flexible and scalable life cycle assessment approaches to accommodate the speed of innovation and increased process complexity associated with advanced biorefineries. Our review also confirmed the continued integration of life cycle approaches in current and anticipated public policies aimed at stimulating fossil fuel/product substitution (see Figure SM-EPP-1.1). Efforts to assess co-product criteria influential to quantitative life cycle performance has also been completed, which will inform the continued development of Tasks 1.7 and 1.9. With regard to activated carbon co-products, the key criteria identified centers around the substitute fuel choice in combined heat and power (CHP). Specifically, additional energy inputs required for subsequent processing/drying of lignin, as part of the NARA process (e.g. natural gas, biomass, coal, etc.), should be specified as an important sustainability criteria as these inputs significantly alter the environmental performance (e.g. greenhouse gas (GHG) emissions) of both the primary jet fuel product and the activated carbon co-product. Similarly, energy in manufacturing and feedstock substituted (petroleum, corn, sugarcane, etc.) are key criteria in the assessment of paraxylene (and subsequent plastics and chemical) co-products. Finally, pretreatment pathways and their associated processes might be important criteria in the identification of low-carbon cement dispersant products produced as a co-product in isobutanol iso-paraffinic kerosene (IPK) production (see Table SM-EPP-1.1).

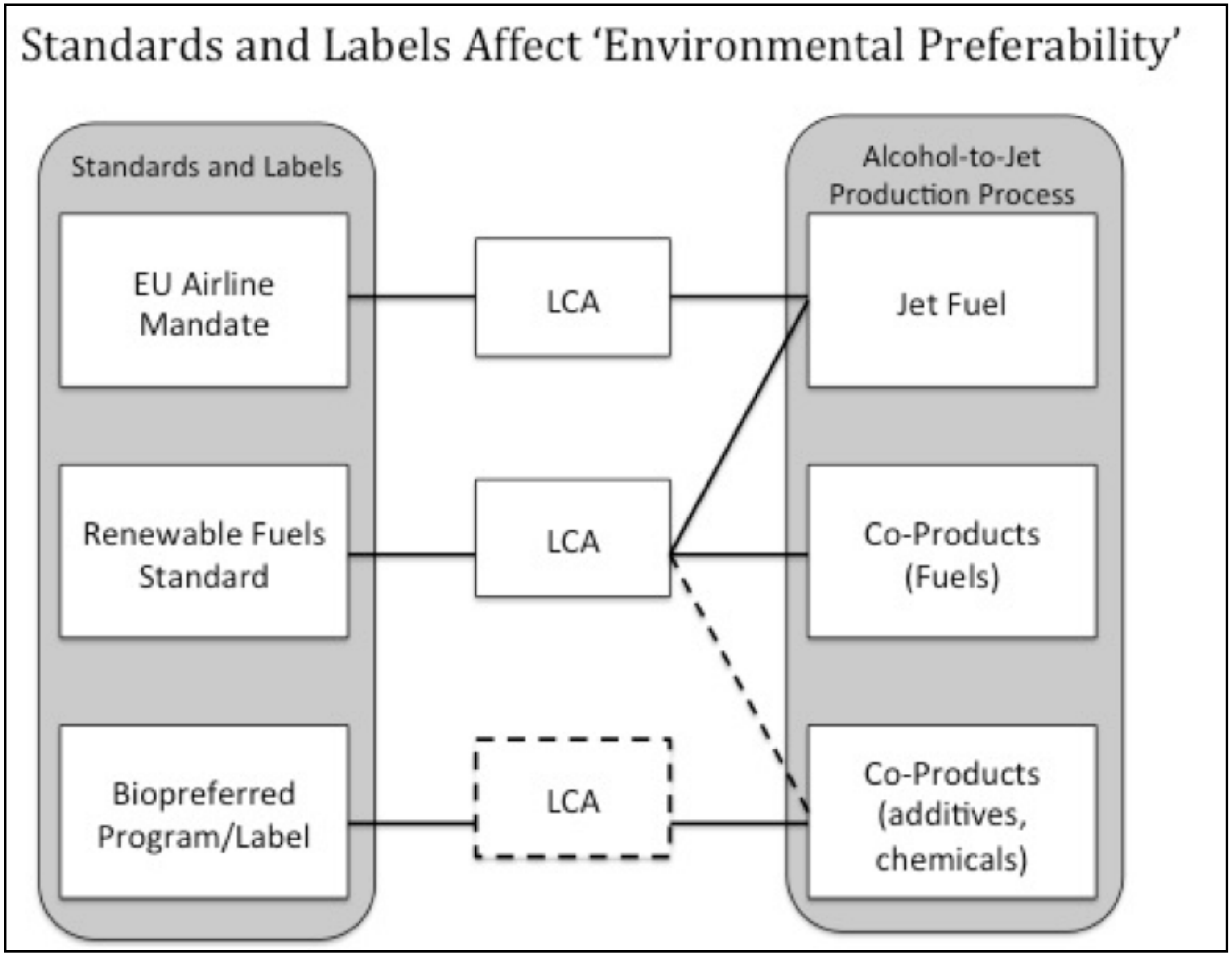


Figure SM-EPP-1.1. Fuel and product standards influence varying aspects of the alcohol-to-jet fuel production process.

Table SM-EPP-1.1. Co-product Criteria Assessment

	Recommended Impact Allocation Method	GHG Impact Levers	Directional Effects on Jet Fuel GHG Emissions[2]	Profit Levers	Directional Effects on Biorefinery Profit[3,4]
Activated Carbon	Displacement	Preprocessing (drying) Substitute fuel choice in CHP[1]	+ or -	Dried lignin price relative to cost of drying and substitute fuel prices for CHP[1]	+ or -
Paraxylene	Displacement or	Energy in Manufacturing PX	-	PX price relative to cost to process and price for jet fuel	+ or -
	Mass Allocation	Fermentation (relative volume of IBA diverted to PX versus to jet fuel)	No effect		
Cement Dispersant	Mass Allocation	Pretreatment (relative volume of lignosulfonate versus sugars)	-	Lignosulfonate price relative to substitute fuel prices[5]	+ or -
Sold Electricity	Displacement	Facility energy use	-	Price for sold electricity	+

[1] CHP stands for combined heat and power.

[2] The + sign indicates jet fuel CO2e emissions could increase with the production of each co-product, the – sign indicates jet fuel CO2e emissions could decrease with the production of each co-product, + or – indicates jet fuel CO2e emissions could either increase or decrease depending on the production choices indicated in the GHG impact levers.

[3] Directional effects on the biorefinery profit assumes a baseline where jet fuel is the only saleable product.

[4] The + sign indicates biorefinery profit could increase with the sale of each co-product, the – sign indicates biorefinery profit could decrease with the sale of each co-product, and + or – indicates biorefinery profit could either increase or decrease depending on the dynamics of the profit levers.

[5] Assumes that the baseline red liquor use is for combined heat and power.

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 SH 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, which 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. We employed a mixed methods approach 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 Western Montana Corridor (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.

This study focused on potential NARA supply chain stakeholders (SH) 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), Mid-Cascade to Pacific (MC2P), 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 stakeholders 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 (see Figure SM-EPP-1.2). 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 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 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.

Findings presented at the Fall 2014 NARA conference in Seattle indicated that stakeholders who perceive themselves as more knowledgeable in various topics related to biofuels, production, and forest health are more supportive of using woody biomass to produce liquid jet fuel. Analysis is currently underway to determine the demographics of participants who are less knowledgeable about various topics in order to better understand how the education and outreach team can mitigate these knowledge gaps. Specifically, analysis is being done to determine if there are differences among demographic groups in terms of their knowledge, what demographic factors participants with similar concerns and levels of agreement have in common, and what are the main concerns and questions raised by participants by state.

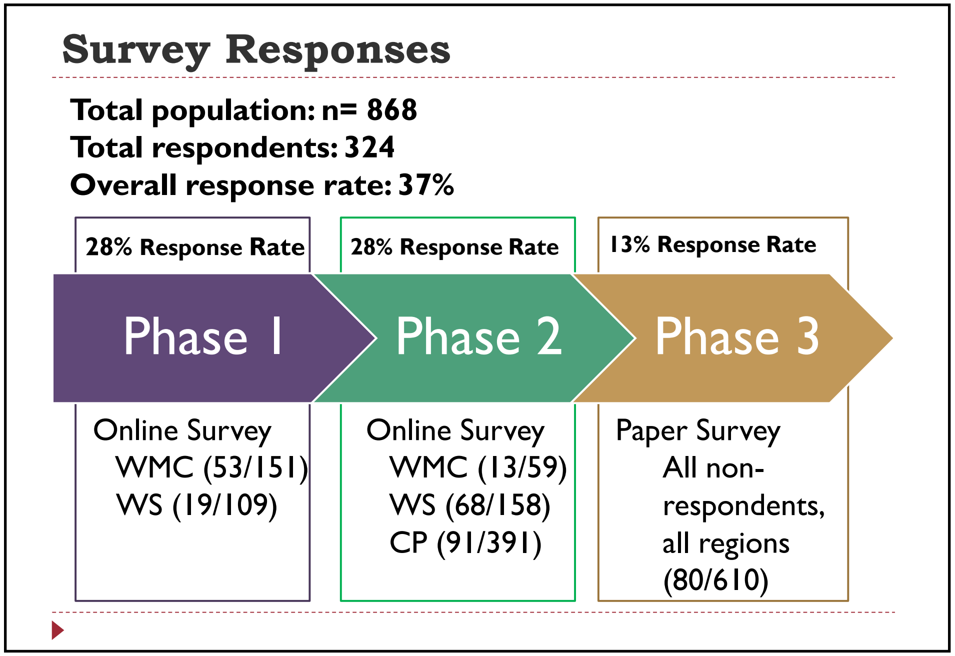


Figure SM-EPP-1.2. NARA Stakeholder Survey response information.

Qualitative survey research presented at the Association of Colligate Schools of Planning conference in Philadelphia at the beginning of November discussed analysis of qualitative survey results including how participants see current forest conditions in their regions, and the possible benefits or negative effects of using woody biomass in their region. Participants' answers were compared by stakeholder group, region, and state. Findings show that stakeholders support utilizing woody biomass to produce bioenergy or a refined liquid biofuel. We also know that stakeholders are concerned about the conditions of private and public forests and see that there are benefits to removing woody biomass to support a liquid biofuels industry that would positively impact forest conditions, regional economies, and reduce fire hazards. However, respondents do have concerns related to the negative impacts on soil and wildlife by the removal of forest residuals. Qualitative analysis is complete and a paper discussing these findings is in the process of completion.

Additional analysis of survey data is ongoing and is being written about in detail in J. Moroney's dissertation Barking up the Right Tree: A Social Assessment of Wood to Liquid Biofuels Stakeholders in the Pacific Northwest. The dissertation is formatted into three chapters which are written as journal articles to be submitted to peer review journals. The articles cover an overview of the quantitative survey findings, a write up of the qualitative survey findings, and an application article that identifies stakeholder concerns and questions and recommends outreach methods. J. Moroney will defend her dissertation in April, 2015, and the three articles will be revised and submitted to journals after.

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

Biogeophysical and Social Assets for Biorefinery (BR) Site Selection

The refined operationalization of the social asset modeling has been completed. DGSS researchers have created regional and national benchmark metrics to assist in identifying receptive communities for biofuel facilities. The team argues that benchmark measures should be met or exceeded to be considered for site-selection. The benchmark measures were developed utilizing regional and national averages to determine appropriate cut-off points for each county. These benchmark metrics are available for the entire United States and can be incorporated into decision-making metrics. They allow for flexibility in the decision-making process as they can be adjusted based on the cut-off points that decision-makers view most appropriate. The national dataset and codebook developed for social asset measures is available to be incorporated in decision-making metrics.

The new Community Asset Assessment Model (CAAM) was combined with biogeophysical (BGP) asset modeling utilized in the Martinkus et al. (2014) publication to identify potential communities in the Western Montana Corridor region. The refined analysis of the Western Montana Corridor, which combines biogeophysical assets with more complete measures of each social asset component, has been submitted for review to the Journal of Politics.

The refined Community Assessment Model (CAAM) is being utilized in the MC2P, the entire NARA region and will applied to another US region (TBD) starting in Fall 2015. Currently, the refined CAAM model is being combined with an updated biogeophysical analysis to analyze the MC2P and the entire NARA region. The biogeophysical analysis is being updated to incorporate NARA's new goals of retrofitting existing facilities. Biogeophysical asset modeling is updating site selection models developed by Integrated Design Experience (IDX) students in cooperation with DGSS researchers and determining appropriate weights for each component. This refined BGP analysis is being combined with the CAAM modeling to identify potential communities in the MC2P and entire NARA region. A manuscript updating this analysis is being prepared for the Journal of Biomass & Bioenergy, expected submission is Summer 2015.

The team is also working on applying the refined CAAM modeling to another US region (TBD). In order to ensure that the social assets are appropriately weighted for each region and can predict successful community-level implementation, new US case studies for retrospective analysis are being identified. The benchmark measures developed for each social asset will be examined to determine their predictive capacity and appropriate weighting for analysis in the new region. In combination with biogeophysical assets, the model will be utilized to determine appropriate US communities. Ground truthing will then be utilized to validate selected communities and ensure support.

Task SM-EPP-1.6. Techno-Market Assessment: Jet Fuels. (I. Iborrola, M. Gaffney, S. Hoard, W. Shi and P. Smith)

Refinery-to-Wing (R-t-W) Stakeholder Assessment
The major objectives of the R-t-W SH assessment:
1. Identify key aviation fuel supply chain stakeholder groups in the Pacific Northwest region;
2. Assess perceptions of key regional stakeholders regarding the opportunities and barriers of blended Alcohol-to Jet Fuel (AJFs) into the aviation fuel supply chain; and
3. Examine AJF molecule tracking options for ASTM D7566 approved Alternative Jet Fuels (AJFs) blends into the ASTM D1655 Jet A1 aviation fuel supply chain.

The team has identified key aviation supply chain stakeholder groups in the four-state NARA region of Washington, Oregon, Idaho, and Montana for primary data collection via personal communications and secondary data search. Both in-person interview protocols including scripts, interviewee lists and methodology, and an online e-survey questionnaire have been developed to assess stakeholders' awareness and perceptions. These vehicles are ready to field, and will be implemented Summer 2015.

e-Survey
The e-survey questionnaire is designed to assess regional airport managers' awareness, opinions and perception regarding the opportunities and barriers to adding blended alternative jet fuel (AJF) into the aviation supply chain. Additionally, factors affecting an economically viable AJF production industry in the NARA region such as policy certainty, biorefinery technology breakthroughs, financial incentives, and the sustainability of AJFs are also addressed. Pre-testing has been completed and adjustments are being made based on the feedback. We are also seeking the cooperation of relevant and credible airport leadership groups.

In-person interviews
Stakeholder interviews are designed for in-depth exploration on select topics such as AJF molecule tracking from airport managers, airlines, Fixed Base Operators (FBOs), terminal/pipeline operators, and fuel resellers. As AJFs enter the jet fuel supply chain, questions arise regarding AJF molecule tracking. Demonstration-oriented AJFs are produced in batches and delivered in dedicated consignments. However, as "drop-in" AJF production is scaled-up, tracking blended AJF molecules becomes an issue.

Biofuels Policy
This work was designed to better understand biofuels policies and the impacts of such regulations on the development of the biofuels industry. Output from this work includes a literature review, peer-reviewed book chapter (Dahmann et al. 2015; accepted and in-press), several posters, and two presentations. The book chapter reviewed the history of U.S. federal renewable energy (bio)fuel policies and state developments, including of several state-level case studies, as well as, advancements in the forestry and U.S. military arenas.

Task SM-EPP-1.7. Economic, Environmental, & Social Assessment: Jet Fuels (R. Pelton, Luyi Chen, T. Smith)

A comparative life cycle analysis of different fossil/biomass derived PET bottle production scenarios has been finalized. Figure SM-EPP-1.3 displays the system boundary of the system considered in that analysis. Although the primary focus is to develop cradle to factory gate LCA for PET bottles produced from forest residues (woody biomass) derived terephthalic acid, the analysis also includes other partially/fully bio-based PET bottle scenarios to deliver more robust comparative results. Table SM-EPP-1.2 illustrates the 12 scenarios, where they are a complete permutation of three terephthalic acid (TA) production schema (from fossil, wood and corn stover) and four ethylene glycol (EG) production methods (from fossil, corn, switchgrass and wheat straw). Figure SM-EPP-1.4 shows the breakdown of impacts generated form unit processes for different TA/EG production methods combinations. As TA contributes to approximately 70% of the mass in final PET bottle product and EG takes about 30%, impacts generated from TA production should not exceeds the 70% threshold to be considered as a viable production scenario. However, for most of impact categories both corn stover and wood derived TA lead to more than 70% impacts. However, as Figure SM-EPP-1.5 shows the cumulative results, where displacement credits (avoided impacts) are taken into consideration, forest residue PET bottles have significantly lower environmental profile than fossil and corn stover bottles. It is obvious that the advantage of NARA PET bottles (from forest residue isobutanol) outshine traditional fossil bottles as well as corn stover bottles, however the results are highly dependent on allocation methods applied, value of excess electricity produced from the systems, and the value of impacts generated by slash pile burning of forest residues are two key factors contributing to credits of the bottle production system.

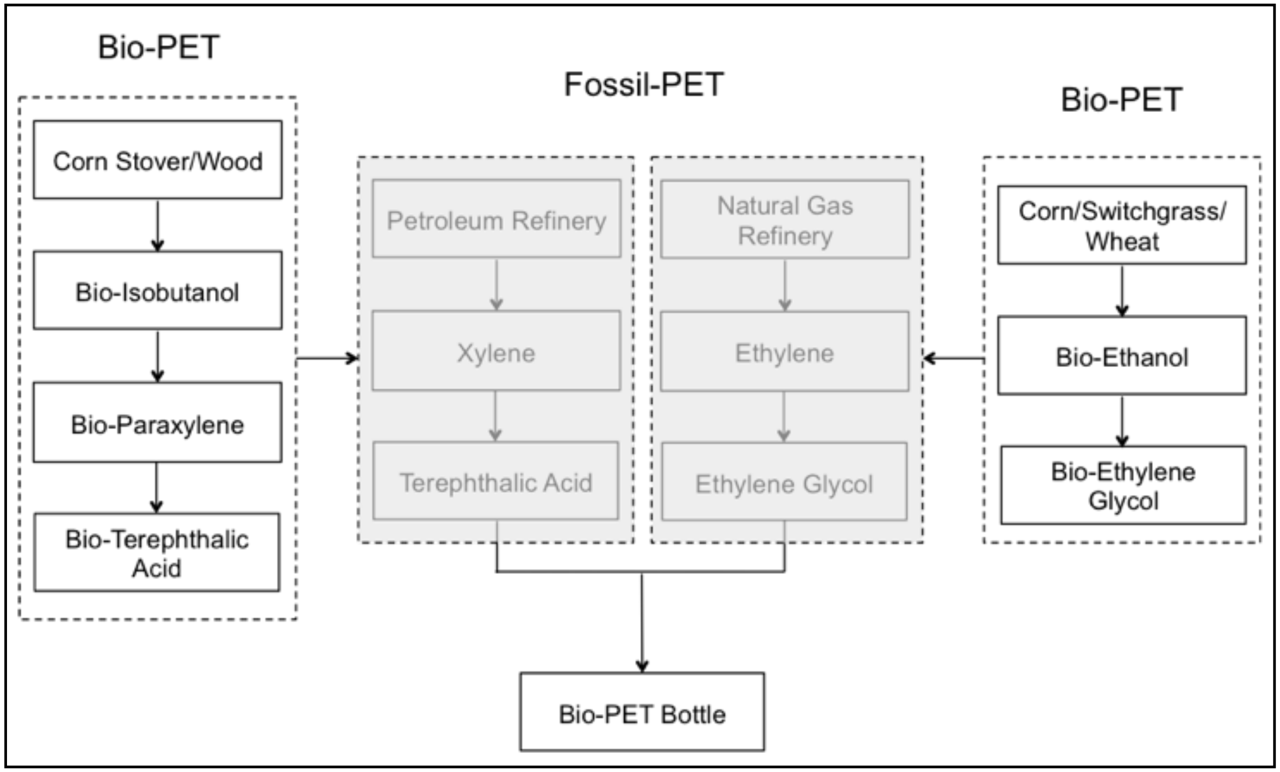


Figure SM-EPP-1.3. System Boundary of Comparative Life Cycle Analysis

Table SM-EPP-1.2. PET Bottle Production Scenarios of Comparative Life Cycle Analysis

TA/EG	Fossil	Corn	Switchgrass	Wheat Straw
Fossil	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Wood	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Corn Stover	Scenario 9	Scenario 10	Scenario 11	Scenario 12

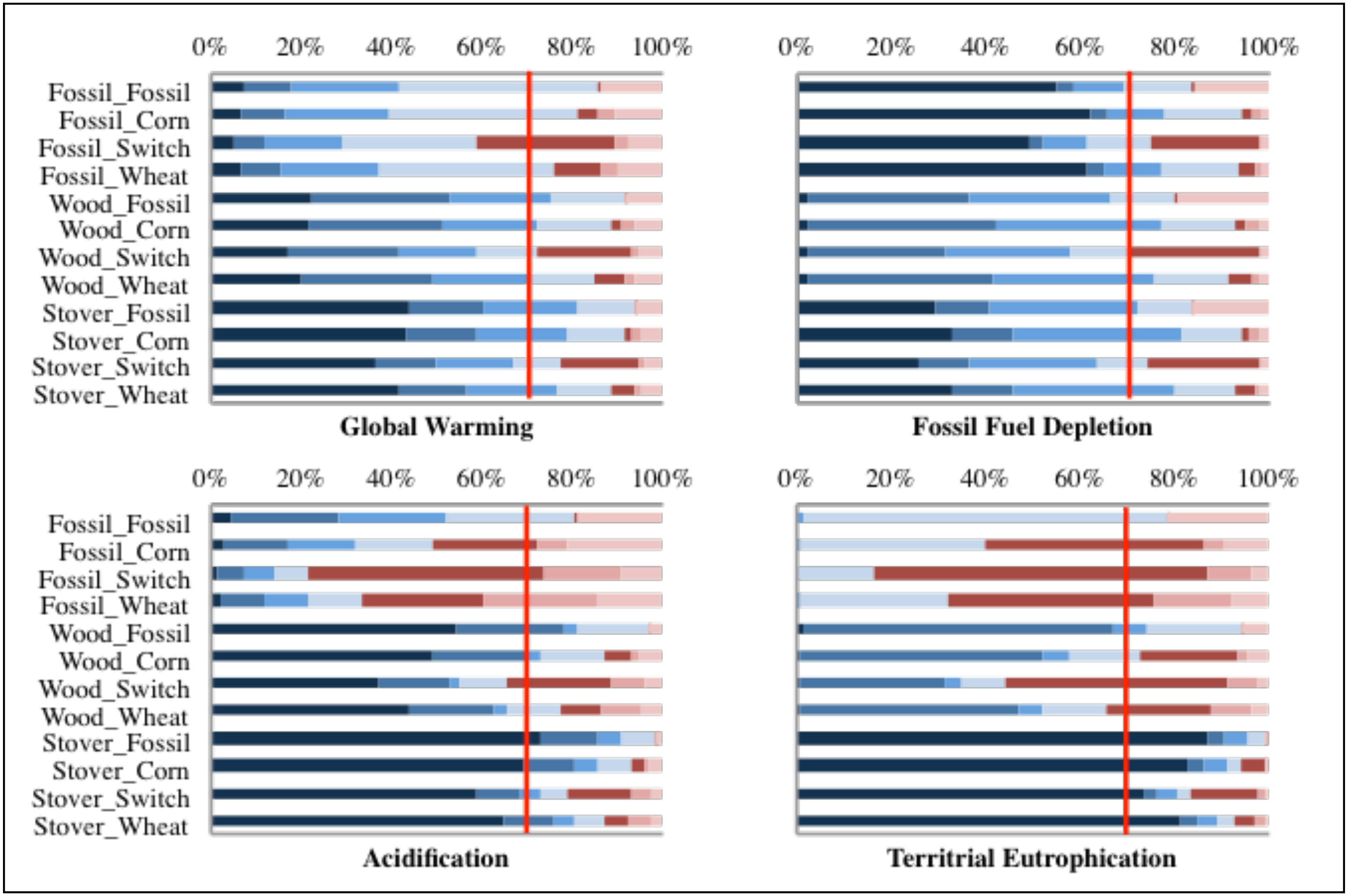
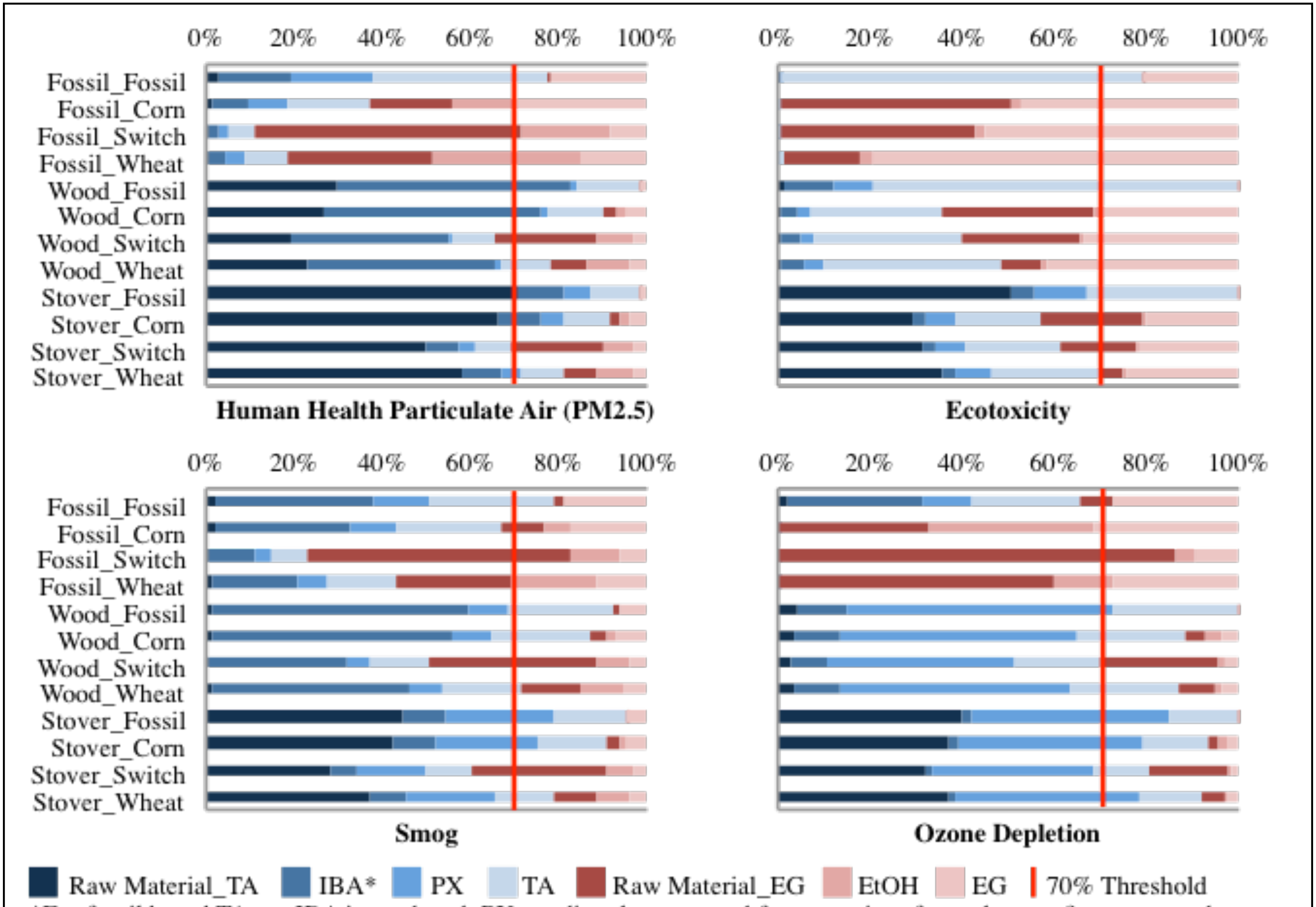


Figure SM-EPP-1.4a. Comparison of impacts generated from unit process for manufacturing terephthalic acid and ethylene glycol of 12 PET bottle production scenarios (scaled to 100%). Scenarios are marked as '(Raw material for TA)_(Raw material for EG)' at the vertical axis. Functional unit is 1 kg PET bottle final product. Each color block implied the impacts caused by conversion processes to acquire a particular intermediate product.



*For fossil based TA, no IBA is produced. PX are directly processed from a series of petroleum refinery co-products, so the IBA blocks for Fossil TA actually indicated impacts from petroleum refinery co-products.

Figure SM-EPP-1.4b. Comparison of impacts generated from unit process for manufacturing terephthalic acid and ethylene glycol of 12 PET bottle production scenarios (scaled to 100%). Scenarios are marked as '(Raw material for TA)_(Raw material for EG)' at the vertical axis. Functional unit is 1 kg PET bottle final product. Each color block implied the impacts caused by conversion processes to acquire a particular intermediate product.

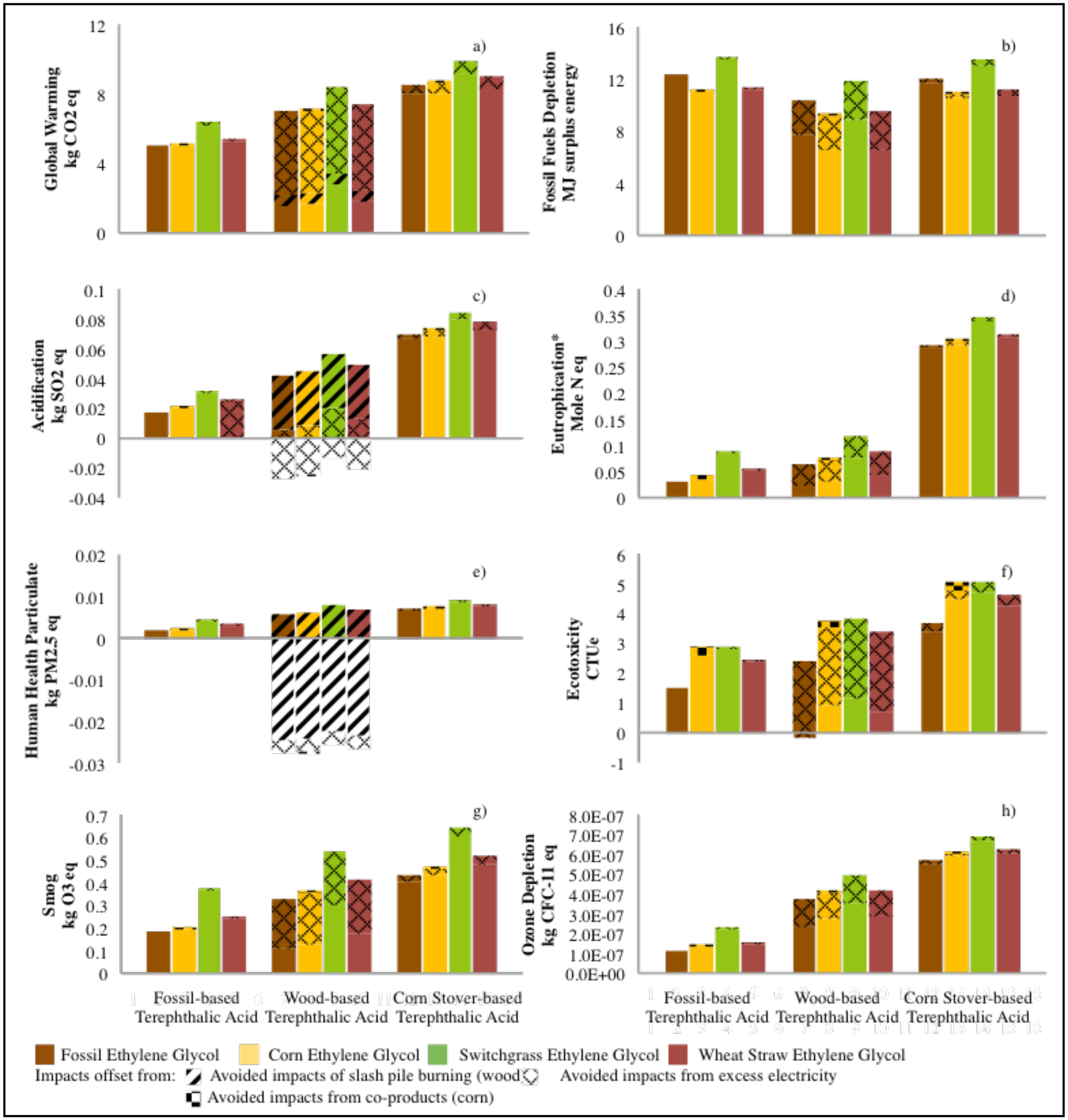


Figure SM-EPP-1.5. Comparative LCA results of 12 PET bottle production scenarios with terephthalic acid and ethylene glycol derived from different raw materials. a) IPCC Global Warming, exclude biogenic carbon (kg CO_2-Equiv.); b) TRACI Resource Depletion, fossil fuels (MJ surplus energy); c) TRACI Acidification (kg SO_2-Equiv.); d) Accumulated Exceedance (AE) Terrestrial Eutrophication Mole of N eq.); e) TRACI Human Health Particulate Air (kg PM2,5-Equiv.); f) TRACI Ecotoxicity (CTUe); g) TRACI Smog Air (kg O3-Equiv.); h) ReCiPe 1.08 Midpoint (H) – Ozone Depletion (kg CFC-11 eq).

Task SM-EPP-1.8. Techno-Market Assessment: Bio-Product Polymers (M. Chen, S. Cline, P. Smith)

Bio-Based Polymers

A techno-market assessment of selected bio-based polymers, which was initiated in January 2013, was completed by Year-3. Major research efforts have been focused 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 over 80% of total market share in 2016, is analyzed regarding value chain and market-driven factors [summarized in April 2014 Cumulative Report].

The Structure of U.S. Biorefineries

A review of secondary sources regarding U.S. biofuel biorefineries has been completed. Four biofuel biorefinery groups have been identified: corn grain ethanol biorefineries (N=207), biomass-based diesel biorefineries (N=140), "bolt-on" and "stand-alone" cellulosic biofuel biorefineries (N=58), and algae biofuel biorefineries (N=7). The competitive forces within the U.S. road transportation fuels industry, including established rivals, threat of substitutes and new entrants, and power of suppliers and buyers has been examined (Porter 1985) to help academic researchers, practitioners and policy makers better understand the relative position of biofuels in terms of opportunities and barriers. Compared to petro-based gasoline and diesel, renewable biofuels enjoy the benefits of lower GHG emissions, sustainability and energy security. However, substitutes and new entrants face entry barriers to the U.S. transportation fuel market, including feedstock costs and logistics, technical obstacles, and uncertainty in government policies. This work addresses potential barriers of biofuels scale-up; that is, production of value-added co-products (e.g. bio-based chemicals) and the formation of strategic relationships. A manuscript is in progress with submission plans for Summer 2015.

We have systematically identified renewable sugar (especially cellulosic sugar) and bio-chemical produc-

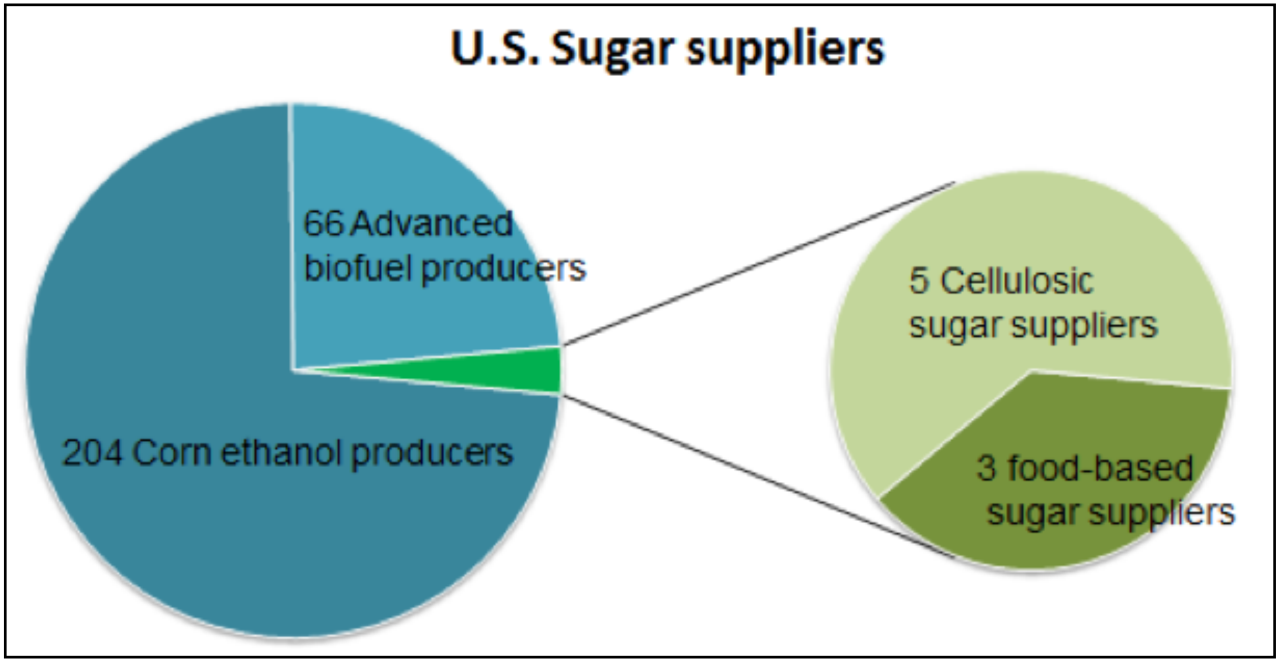


Figure SM-EPP-1.6. U.S. sugar suppliers

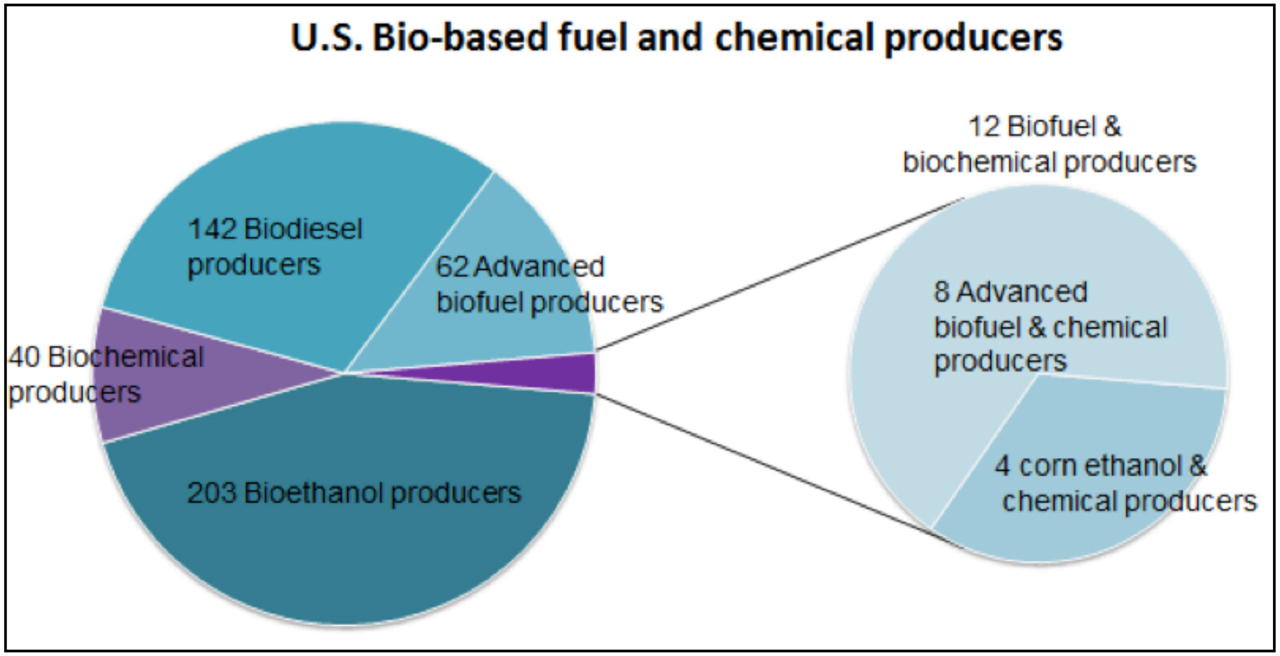


Figure SM-EPP-1.7. U.S. biofuel and biochemical producers

ers. To date, eight sugar suppliers have been identified through non-probability (judgmental or purposive) sampling (Figure SM-EPP-1.6), including:
(1) Food-based sugar suppliers: such as ADM, Cargill, Abengoa; and
(2) Cellulosic sugar suppliers: such as Virdia, BlueFire Renewables, Renmatix, Beta Renewables and Sweetwater Energy (Soare and Kersh, 2014).

In addition, we have identified forty biochemical producers, 207 bioethanol producers (of which 4 also produce biochemicals), and 70 advanced biofuel producers (of which 8 also produce biochemicals) (Figure SM-EPP-1.7).

The four corn ethanol and biochemical producers:
(1) ADM: propylene glycerol, ethylene glycerol;
(2) POET: specialty chemicals (edible protein product);
(3) Cargill: acrylic acid;
(4) GEVO: isobutanol;

The eight advanced biofuel and biochemical producers:
(5) Dupont T&L: 1,3-propanediol (PDO), 1,4-BDO;
(6) Virent: BTX (group of aromatic hydrocarbons benzene, toluene and xylene);
(7) Aemetis: isoprene;
(8) OPXBio: fatty acids, acrylic acid;
(9) Amyris: farnesene;
(10) Solazyme: algal oil
(11) LanzaTech: biobutanediene;
(12) Cobalt Technologies: biobutanediene

Future Research

The overall goal of the primary data collection effort is to better understand cellulosic and algae biofuel biorefinery product portfolio and new product development decisions and to explore strategic relationships in this industry sector. Previous literature indicates that alliances provide access to resources, markets, and technical information, and help companies to achieve economies of scales (Gomes et al., 2014; Ulaga and Chacour, 2001).

Co-Product Market Opportunity (in-progress)

1. Examine cellulosic and algae biofuel biorefinery (BR) value-stream outputs (product portfolios) via mixed method multi-stage design (May 2015 – July 2016).

   a. e-Surveys of cellulosic and algae biofuel BRs:
   - Examine cellulosic/ algae BRs potential to produce bio-based chemicals and/or sugars;
   - Investigate the drivers and barriers for developing new bio-based chemicals.

   b. Phone interviews of select BRs (based on 1-a findings):
   - Examine potential sources of new ideas about bio-based chemicals;
   - Develop a theoretical and conceptual research framework to examine the perceived factors affecting new idea/product selection; and
   - Explore current and future specific classes of bio-based chemicals of greatest interest to cellulosic and algae biofuel BRs.

2. Evaluate strategic relationships across value chains of cellulosic/algae-based products via qualitative design (May 2015 – July 2016).

   c. In-depth interviews:
   - Define and categorize buyer-seller relationships across the value chain of cellulosic/ algae-based biofuels, biochemicals and sugars; and
   - Investigate the benefits and impediments of forming long-term strategic relationships.

Lignin in Activated Carbon Markets:

Lignin typically represents 15% to 40% of a biorefinery's lignocellulosic feedstock and identifying value-added market opportunities is critical to a firm's bottom line (Ragauskas n.d.; Smolariski 2012; McCarthy 1999). Lignin, as a feedstock, however, is limited due to restricting factors outlined by Vistal and Kraslawski (2011) including:

- The recovery of lignin from the product streams
- The purification of lignin
- The heterogeneous structure of lignin, and
- The unique reactivity of lignin.

Research suggests lignin may be a viable and economic feedstock for the manufacturing of activated carbon for mercury sequestration from power plant flue gas due to its high carbon content and abundant supply (Ragan et al. 2011; Carrott et al. 2007). Experts agree the activated carbon market has great potential to drastically grow over the upcoming years. Greiner et al. (2010) projected the volumes of activated carbon (AC) to sequester mercury from flue gas streams to grow from 35,000 metric tons in 2009 to 420,000 metric tons by 2014. Additionally, Transparency Market Research (PRWeb 2013) projected the powdered activated carbon market to grow at nearly 14% per year from 2013 to 2019.

The growth in the activated carbon market is due largely to the Mercury and Air Toxic Standards (MATS) mandate implemented on 16 December 2011. MATS affects both new and existing U.S. coal and oil-fired electric utility generating units greater than 25 megawatts (MW) and supplying electricity to the National Power Grid (EPA 2011). Approximately two-thirds of the U.S. coal fired capacity has already complied with MATS to allow operation through 2016 (EIA 2014). MATS will require coal-fired power plants to capture as much as 90% of mercury released into the atmosphere.

In 2012 the U.S. activated carbon market was valued at $1.9 billion, at the current CAGR growth rate 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 compound annual growth rate is estimated at 13% (PRWeb, 2013).
Exploratory work indicates that activated carbon is purchased either directly from the supplier or via a chemical brokerage company (Carter 2015). Upon delivery by rail, truck, or barge, the AC is then blown

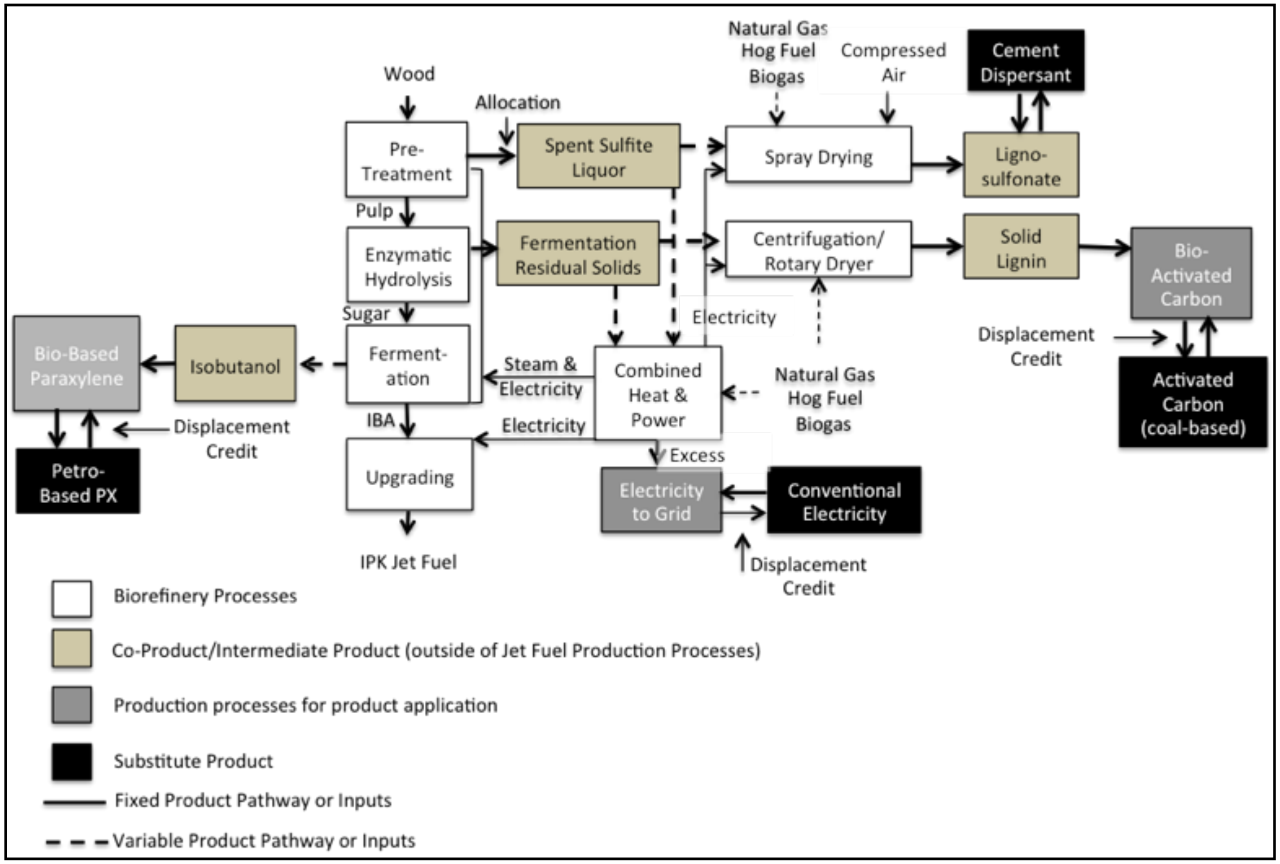


Figure SM-EPP-1.8. Biorefinery co-product options and corresponding methods to allocate impacts.

via flexible tubing into a silo where it is stored until needed (The Babcox and Wilcox Company 2015; Fesseden 2012). Each power plant uses activated carbon differently (Carter 2015) to address mercury emissions which are regulated on a quarterly basis (Carter 2015). Some power plants run their AC injection system continuously due to the type of coal being burned, while others run the system sparingly to meet quarterly regulations.

The population of coal-fired power plants who may potentially buy lignin-based AC has been identified (EIA 2015) exploratory content analysis of current AC suppliers' websites conducted and a database and map developed in preparation of primary data collection. Content analysis identified 33 AC (for this application) product and service attributes to be refined and tested in interviews and surveys of AC buyers. The next step is to query these potential buyers to better understand the value proposition for NARA AC vis-à-vis existing AC products and to better delineate the product and service characteristics buyers desire in an AC for mercury sequestration from coal-fired power plant flue gas.

The EPA has recently (Feb 2015) released comments regarding an updated MATS proposed rule. The edited rule addresses issues regarding how plant malfunction reporting is accomplished. Moreover, the open comment period remains open through April 3rd, 2015. Comments will be addressed and a new proposed rule will be published. As of the recent publication, the MATS implementation, scheduled for April 2016, remains on schedule.

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

Several life cycle assessment iterations for activated carbon and paraxylene have been completed to begin to assess the environmental implications of different co-product output configurations. Each iteration reflects the changes in assumptions and data that have resulted from ongoing communication with the NARA TEA team. It is clear from these assessments that the type and quantity of co-products can have significant effects on the greenhouse gas emissions of the primary jet-fuel products due to the recommended methods for allocating environmental impacts, and the substitute product choices (such as substituting lignin fuels for fossil fuels to produce internal energy). This in turn can have significant implications for the ability of the jet fuel to adequately meet the Renewable Fuels Standard GHG emission reduction targets, which can affect the ability of the refinery to secure the sale of RIN credits, thereby potentially bringing the economic viability of the refinery into question.

To produce the economically optimal quantity and type of co-products under a variety of market conditions while considering the environmental impacts, a mixed integer linear programming (MILP) optimization model is being constructed. The MILP considers the marginal environmental impacts of product outputs, the marginal operating costs, and the marginal sales prices. The marginal environmental impacts have been determined using information from the NARA LCA and TEA team, as well as various assumptions taken from the literature (Davis et al 2013; Humbird et al 2011). Recent adjustments to assumptions and data will be incorporated in the beginning of June, once coordination with the technical economic assessment team occurs in May. The marginal operating costs have been determined using the NREL techno-economic assessment of the isobutanol (from corn stover) to renewable diesel pathway (Davis et al 2013; Humbird et al 2011), and the marginal prices have been determined from a variety of literature and market sources. The co-products under consideration for potential product output options, and the corresponding recommended allocation methods that will be used are depicted in Figure SM-EPP-1.8. The optimization model is currently specified to reflect the annually optimal product outputs for validation purposes, however this will be later altered to a multi-period specification to reflect more frequent changes in market prices and the possibility to store product outputs for sale in alternative periods under more favorable market price conditions.

In addition to bioenergy research directly addressing the NARA Isobutanol pathway, additional research exploring economic assessment of biomass gasification technologies and their integration with concentrated solar technologies for process heat was also conducted. Implications of this work identify competing energy technologies for large scale biomass utilization in the western united states which could be economically viable, even at reasonably low product gas prices (approximately $4.50/MBtu and higher) and significant facility capital costs ($60-$100 million). The work – while largely funded by outside sources, but leveraging knowledge gained from this project – resulted in a publication in Biomass and Bioenergy.

Recommendations | Conclusions

We continue to struggle a bit with coordination with other groups creating information critical to LCA modeling for the EPP Team, however, we are planning a meeting for the end of May to rectify these issues. In general, timing has been a challenge, but we have made progress in developing our methods and approaches based on literature-driven assumptions and plan to update the models with NARA specific data this summer.

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)

Completed with published journal output – Biomass & Bioenergy

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

Completed with published journal output – J. of Industrial Ecology

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)

Findings show that stakeholders support utilizing woody biomass to produce bioenergy or a refined liquid biofuel. They are also concerned about the conditions of private and public forests and see that there are benefits to removing woody biomass to support a liquid biofuels industry that would positively impact forest conditions, regional economies, and reduce fire hazards. However, respondents do have concerns related to the negative impacts on soil and wildlife by the removal of forest residuals.

Qualitative analysis is complete and a peer-reviewed journal article is in progress. Additional quantitative and qualitative analysis of survey data is in progress and J. Moroney's dissertation "Barking up the Right Tree: A Social Assessment of Wood to Liquid Biofuels Stakeholders in the Pacific Northwest" will be completed May 2015 with additional journal articles to be submitted in 2015.

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

Completed a refined operationalization of the social asset modeling has been completed and combined with biogeophysical (BGP) asset modeling (Martinkus et al. 2014 – Biomass & Bioenergy). A refined analysis of the Western Montana Corridor, which combines biogeophysical assets with more complete measures of each social asset component, has been submitted for review to the Journal of Politics.

The refined Community Assessment Model (CAAM) is currently being deployed in the MC2P and the entire NARA region. A manuscript updating reflecting these refinements is being prepared for the Journal of Biomass & Bioenergy for Summer 2015. Future efforts will apply the CAAM to other geographic regions within the US (TBD).

Task SM-EPP-1.6. Techno-Market Assessment: Jet Fuels. (I. Iborrola, M. Gaffney, S. Hoard, W. Shi and P. Smith)

Refinery-to-Wing Stakeholder Assessment: R-t-W SH's have been identified in the NARA region. Primary data collection via in-person interviews and an online e-Survey will be implemented Summer 2015. The e-survey assesses regional airport managers' awareness, opinions and perception regarding the opportunities and barriers to adding blended alternative jet fuel (AJF) into the aviation supply chain. Additional SH interviews will examine AJF molecule tracking from airport managers, airlines, Fixed Base Operators (FBOs), terminal/pipeline operators, and fuel resellers.

Biofuels Policy: Completed with in-press peer-reviewed book chapter output - Dahmann et al. 2015.

Task SM-EPP-1.7. Economic, Environmental, & Social Assessment: Jet Fuels (R. Pelton, Luyi Chen, T. Smith)

Completed a comparative life cycle analysis of different fossil/biomass derived PET bottle production scenarios.

Task SM-EPP-1.8. Techno-Market Assessment: Bio-Product Polymers (M. Chen, S. Cline, P. Smith)

Bio-Based Polymers

Completed an overview of 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 over 80% of total market share in 2016, was examined regarding value chain and market-driven factors [summarized in April 2014 Cumulative Report].

The Structure of US Biorefineries

Completed a review of secondary sources with mapping and datasets regarding U.S. biofuel biorefineries (n=412). Currently examining cellulosic and algae biofuel biorefinery (BR) value-stream outputs (product portfolios) via mixed method multi-stage design and evaluating strategic relationships across value chains of cellulosic/algae-based products via qualitative design (May 2015 – July 2016).

Lignin in Activated Carbon Markets:

Completed a preliminary examination of lignin value-added markets and identified activated carbon as a potential high-growth market for mercury sequestration from power plant flue gas due. AC growth is due largely to the US EPA Mercury and Air Toxic Standards (MATS) mandate implemented on 16 December 2011. Potential AC buyer populations have been identified and primary data collection is scheduled for Summer-Fall 2015 to: (1) better understand the value proposition for NARA AC vis-à-vis existing AC products; and (2) delineate the product and service characteristics buyers desire in an AC for mercury sequestration from coal-fired power plant flue gas.

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

Completed several life cycle assessment iterations for activated carbon and paraxylene – leveraging other work – resulted in a Biomass & Bioenergy publication. Plan to assess the environmental implications of different co-product output configurations using a mixed integer linear programming (MILP) optimization model. We are also exploring economic assessment of biomass gasification technologies and their integration with concentrated solar technologies for process heat.

Physical and Intellectual Outputs

PHYSICAL OUTPUTS

Database and Dataset Development :

1. Continued refinements and revised weightings for a national social assets database to examine local, regional and national social collaborative capacity;
2. A biomass-to-biofuel stakeholder dataset for the NARA region;
3. Updated US coal-fired electric generating unit population – to examine the market opportunity for activated carbon for mercury and other metals emissions mitigation.
4. Updated and current datasets to identify, classify and locate all US biorefineries (n=412);

Model Development:

1. Bio-PET LCA model was established and completed in GaBi LCA software;
2. Environmental and economic optimization model was established in GAMS optimization software;
3. A revised Community Assets Assessment Model (CAAM) to help explain biomass-to-biojet economic development opportunities in the NARA region.
4. Isobutanol conversion to jet fuel process modeling.
5. Modeling of alternative production pathways (specifically regarding feedstock and pretreatment options).
6. Co-product use and allocation scenarios modeled – including emission credit calculations for co-product scenarios

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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
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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, an 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 we will combine biomass growth/yield models and life cycle assessment (LCA) models 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 green house 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.

Activities and Results

Task SM-LCA-1.1. Soil Carbon Analysis (Tasks 4 thru 10)

DEEP SOIL CARBON AND NITROGEN

We continue to work on the role of deep soil carbon, nutrients, water and other resources in determining the resilience of ecosystems to additional biomass harvesting and nutrient removal for biofuel feedstocks. The specific objectives of our current work are:

1. To determine the effect of systematic sampling to variable depths on estimates of forest soil carbon (C) and nitrogen (N).
2. To evaluate the ability of mathematical models to accurately predict total soil C and N in soil horizons up to 300 cm depth.
3. To assess which soils are most important to sample more deeply.
4. To investigate the vertical distribution of exchangeable cations (calcium (Ca), magnesium (Mg), potassium (K)) and their relationship with other soil and stand variables.

As mentioned in previous reports, 22 deep soil sampling sites from the Stand Management Cooperative nutrition study of 73 sites representing the entire coastal Douglas-fir production region from north Vancouver Island, Canada to southern Oregon were sampled. During the summer of 2014, 20 more deep soil excavations were completed. The sites were selected from remaining Type V stands that were not previously sampled, as well as a subset of the Type I installations. At the Type I stands, pits will be dug in both fertilized and unfertilized plots. At 10 sites, in addition to soil samples, moisture probes were installed at depths of 10, 50, 100, and 200 cm. A temperature probe was also deployed at 50 cm depth. Data loggers are collecting data once every hour in order to give enough temporal resolution to examine whether hydraulic redistribution (the passive movement of water from deep soils to the surface through plant roots) is an important process during the dry summer season across a variety of sites and soils in the Pacific Northwest. A paper on the distribution and modeling of forest soil C was published in the Soil Science Society of America Journal (James et al. 2014a). A second paper was recently published, also in 2014 (James et al. 2014b).

NARA LONG-TERM SOIL PRODUCTIVITY (LTSP) SITE - LYSIMETERS STUDY

Lysimeters were installed in 2013: the 100-cm depth lysimeters were installed in July 8-10/2013. Those with 20-cm depth were installed in September 26-27/2013. Soil solution samples were collected monthly (from February/2014), but collections continued to be small and irregular. Unfortunately, the collections from this study were insufficient to construct a nutrient budget for this site, as was done earlier for the similar site a Fall River LTSP.

RESIDENCE TIME OF CARBON AND DECOMPOSITION OF DOUGLAS-FIR STUMPS FOR LCA CARBON MODEL

We are working with Indroneil Ganguly to make sure that our work helps him complete the carbon life-cycle assessment (LCA). All samples for the LCA – Douglas-Fir Stump Decay project have been collected, and preliminary data results are promising. Samples were taken at five sites from stumps cut in 2013, 2012, 2010, 2006, 1999 and 1992; totaling roughly 160 stumps. For each of those stumps we collected at least two density and two resistograph measurements to estimate density; two samples for carbon and nitrogen analysis; and various field observations including diameter, height and perceived decay class (based upon a decay classification system that we developed for Douglas-fir stumps). We are currently analyzing the woody material for carbon and nitrogen and analyzing the other field data. We are building a model for decomposition that accounts for loss of density as a function of time, climate and other factors. We currently have a detailed report on progress, but it is too long to present here. The report can be downloaded at http://soilslab.cfr.washington.edu/publications/NARA-StumpDecomposition-150201.pdf

Task SM-LCA-1.2. Life Cycle Assessment (Tasks 12 thru 34)

During the 2014-2015 reporting period, the LCA team has made significant progress towards the successful attainment of the proposed project goals. The research undertaken by the LCA team not only met the requirements underlined in the specific task areas, but went above and beyond the basic requirements. In the initial phases of the project, the LCA team developed a 'hybrid NARA woody biomass to biojet fuel framework model' using surrogate modules available in established literature (namely, National Renewable Energy Laboratory (NREL) and the Consortium for Research on Renewable Industrial Materials (CORRIM)). During the reporting period, the LCA team was able to successfully replace a majority of those surrogate processes with the modules developed by NARA team members. The LCA team also established a final model integration plan to be implemented once all the bio-refinery and co-product processes are developed by the relevant research teams.

The Life Cycle Assessment (LCA) requires detailed data from all the subcomponents of the NARA biofuels project; effective collaboration between the NARA team members determines the success of the LCA work. During the reporting period, the LCA team members conducted multiple meetings with all the relevant NARA researchers to ensure timely delivery of all required data. The following section summarizes the meetings held on the various aspects of NARA LCA work.

FEEDSTOCK LOGISTICS: Oregon State University (OSU) is heading the feedstock economic and logistic analysis for the west of cascades region. Following up on the preliminary discussion during the 2014 annual meeting, Dr. Ivan Eastin and Dr. Indroneil Ganguly visited Corvallis on the 5th and 6th of November to coordinate with the OSU researchers on their research project. Meetings were held with Dr. Kevin Boston, Dr. John Sessions, Dr. Darius Adams and Dr. Greg Latta. Following that meeting, updated data was provided to the LCA group by the aforementioned researchers.

AIR QUALITY MODELING: A pre-annual coordination meeting on LCA and air quality impacts was held in Pullman on the 10th of September. Dr. Ganguly and Cody Sifford (graduate student) from the University of Washington (UW) attended the meeting. The meeting was extremely successful in terms of understanding the nature of data that will be available to the LCA team from the Washington State University (WSU) air quality team. A follow-up meeting was held at the U.S. Forest Service fire lab in Seattle, where, Dr. Lamb, Vikram Ravi (WSU PhD student), and Dr. Vaughn of WSU attended the meeting along with all the members of the UW-LCA team.

PRE-TREATMENT AND BIO-REFINERY: A meeting was held in Seattle on August of 2014, which was attended by, the ASPEN modeling group, NARA leadership, Gevo Inc. representatives, Co-products LCA group, and the UW-LCA group. The focus of this meeting was the pretreatment through jet fuel component of the LCA. The purpose of the meeting was to coordinate the data acquisition between the LCA team and our partners at Gevo Inc. and within the NARA pretreatment, ASPEN, techno-economic analysis (TEA) and co-products groups. The meeting emphasized the need to have a completed LCA of the entire wood-to-biofuel/co-product process ready for submission for a technical review by the end of June 2015. The discussion focused on the status of the ASPEN modeling and delineating the boundaries of the Gevo Inc.'s "proprietary black box" (essentially the fermentation and oligomerization process). The discussion also touched on the inputs/outputs for the GIFT™ process, including the power requirements. A follow-up discussion session was held at the 2014 NARA annual meeting, and roles and responsibilities, as is explained in Figure SM-LCA-1.1, were finalized for the NARA-LCA project.

Task SM-LCA-1.3. Community Economic Impact Assessment (Tasks 36 through 39)

We continued with the literature review focusing on studies with biorefinery direct employment estimates. The review will become part of the Preliminary Economic Impact Report (Task 38). Spreadsheet models to produce a sensitivity analysis with respects to commodity versus industry assumptions were completed and commodity versus industry production differences on economic impacts were populated with IMPLAN data. We began the analysis that describes 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 and how these results differ in the economic impact assessment.

Adaption of the Western Montana Corridor (WMC) spreadsheet model to western Washington was made using biomass supply data from the Washington Biomass Assessment and preliminary supply data from the NARA supply model, recently obtained from Darius Adams at Oregon State University. Data on supply estimates are presented tables SM-LCA-1.1 and SM-LCA-1.2 respectively, first from the Washington Biomass Assessment, followed by data from the NARA supply model. Figure SM-LCA-1.2 compares the mill values in the two data sets.

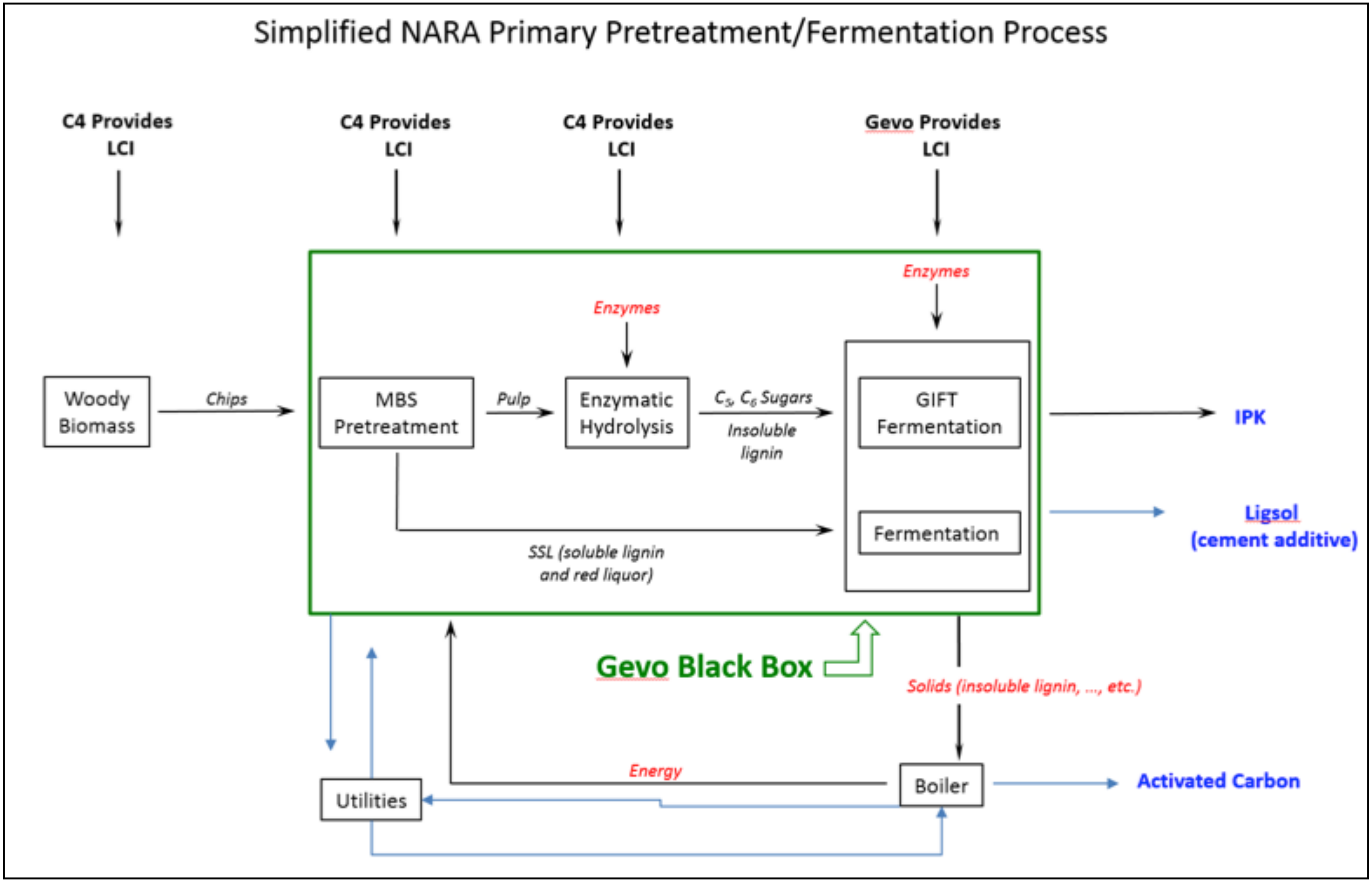

Figure SM-LCA-1.1. NARA-LCA layout

Table SM-LCA-1.1. Values using the Washington Biomass Supply Assessment

County	Mill value	Forest Value	Transport Value
Clallam	$7,367,696	$2,488,314	$4,879,383
Clark	$943,015	$324,192	$618,824
Cowlitz	$4,569,030	$1,668,931	$2,900,099
Grays Harbor	$2,869,573	$1,088,807	$1,780,765
Island	$51,240	$11,869	$39,371
Jefferson	$3,225,590	$1,235,311	$1,990,280
King	$2,809,239	$970,488	$1,838,751
Kitsap	$449,250	$157,203	$292,048
Lewis	$6,019,453	$1,985,090	$4,034,363
Mason	$2,629,480	$873,636	$1,755,843
Pacific	$460,167	$157,843	$302,324
Pierce	$3,417,444	$1,146,155	$2,271,289
Skagit	$1,558,853	$549,736	$1,009,117
Skamania	$638,577	$233,743	$404,833
Snohomish	$2,161,982	$813,260	$1,348,722
Thurston	$900,160	$280,169	$619,991
Wahkiakum	$337,145	$115,521	$221,624
Whatcom	$977,687	$335,169	$642,517
San Juan	$4,215	$304	$3,911
Grand Total	$41,389,797	$14,435,741	$26,954,056

Table SM-LCA-1.2. Values using the NARA Supply Model

County	Mill Value	Forest Value	Transport Value	Haul Value	Processing Value
Clallam	$0	$0	$0	$0	$0
Clark	$0	$0	$0	$0	$0
Cowlitz	$0	$0	$0	$0	$0
Grays Harbor	$19,629,215	$3,145,491	$16,483,724	$5,159,177	$11,324,547
Island	$0	$0	$0	$0	$0
Jefferson	$0	$0	$0	$0	$0
King	$0	$0	$0	$0	$0
Kitsap	$0	$0	$0	$0	$0
Lewis	$2,140,439	$53,083	$2,087,356	$852,487	$1,234,869
Mason	$3,806,120	$340,644	$3,465,477	$1,269,638	$2,195,839
Pacific	$21,563,754	$2,585,785	$18,977,968	$6,537,341	$12,440,627
Pierce	$0	$0	$0	$0	$0
Skagit	$0	$0	$0	$0	$0
Skamania	$0	$0	$0	$0	$0
Snohomish	$0	$0	$0	$0	$0
Thurston	$4,486,092	$589,531	$3,896,561	$1,308,431	$2,588,130
Wahkiakum	$3,335,130	$84,454	$3,250,608	$1,326,534	$1,924,074
Whatcom	$0	$0	$0	$0	$0
San Juan	$0	$0	$0	$0	$0
Grand Total	$54,960,750	$6,798,988	$48,161,694	$16,453,608	$31,708,086

Differences include 1) greater biomass supply under the NARA supply model at $65/BDT, and 2) greater geographical distribution of where the supply comes from under the Washington Biomass Supply Assessment. The Washington Biomass Supply Assessment secured less volume (~83%) at $65/BDT than the NARA Supply Model. The Washington Biomass Supply Assessment supply region is more evenly spread across surrounding counties. The majority of the supply and hence economic impacts from the NARA Supply Model are in Grays Harbor and Pacific counties. Total sector economic impact differences are relatively small: $244 million (WA Biomass Assessment) versus $258 million (NARA Supply Model).

A discussion regarding the differences between the two models occurred during the NARA annual meeting. Possible reasons for the discrepancies were mentioned. We decided to continue with the use of the NARA model since the WA biomass assessment model does not include Oregon counties in its database. Differences are thought to arise from variances in scale and inventory assumptions. Scale variance may operate as follows: 1) the biomass calculator uses parcel sizes that are significantly smaller than FIA plot representative areas that are in the NARA Supply model; 2) the smaller sized parcels contain less volume; hence supply requirements of the same fixed amount require more parcels than FIA plot areas; 3) the effect of requiring more parcels supplying the required supply is a larger and more diverse geographic distribution of the supplying counties. Inventory assumption differences are particularly relevant with respects to Pacific County, Washington. Inventory variance is thought to be related to different estimates of Pacific County inventory. Inventory, and its potential to attain a specified harvest level, in the biomass calculator is low relative to surrounding counties due to major wind storm damages that occurred there during December 2007.

Conversion of the Western Montana Corridor (WMC) Community Impacts spreadsheet model to western Washington, western Oregon (WWO) county data was made available to Natalie Martinkus for her

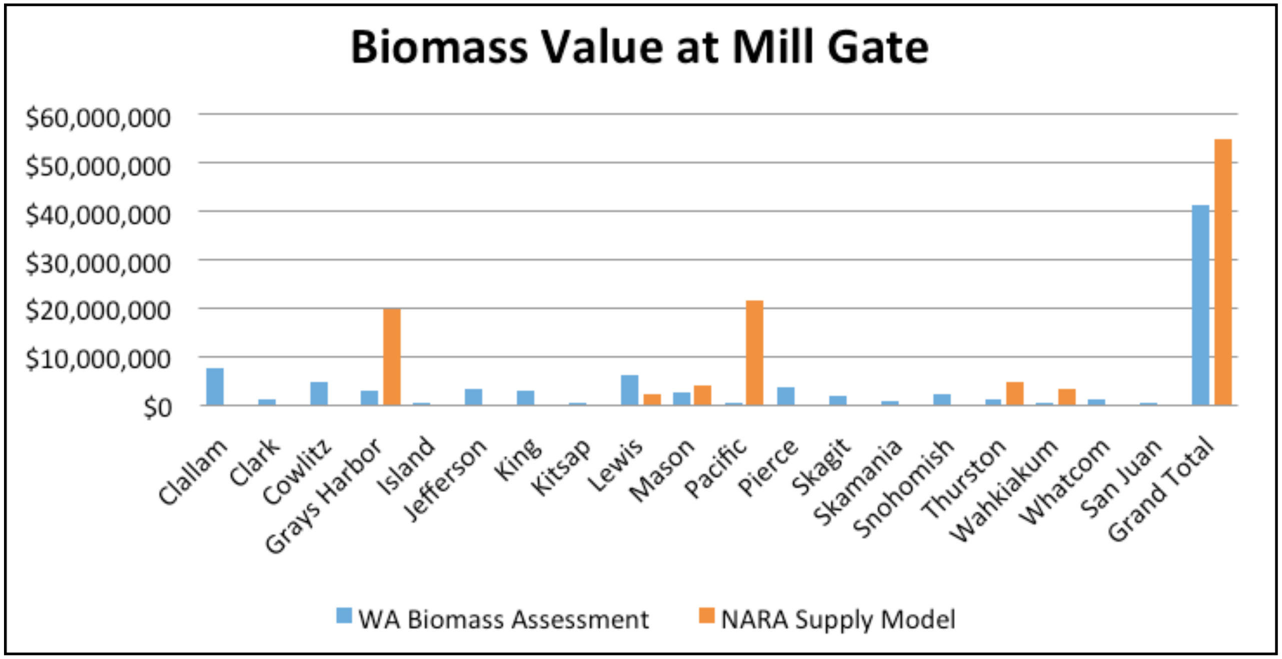

Figure SM-LCA-1.2. Comparison of the Washington Biomass Supply Assessment and NARA Supply Model data

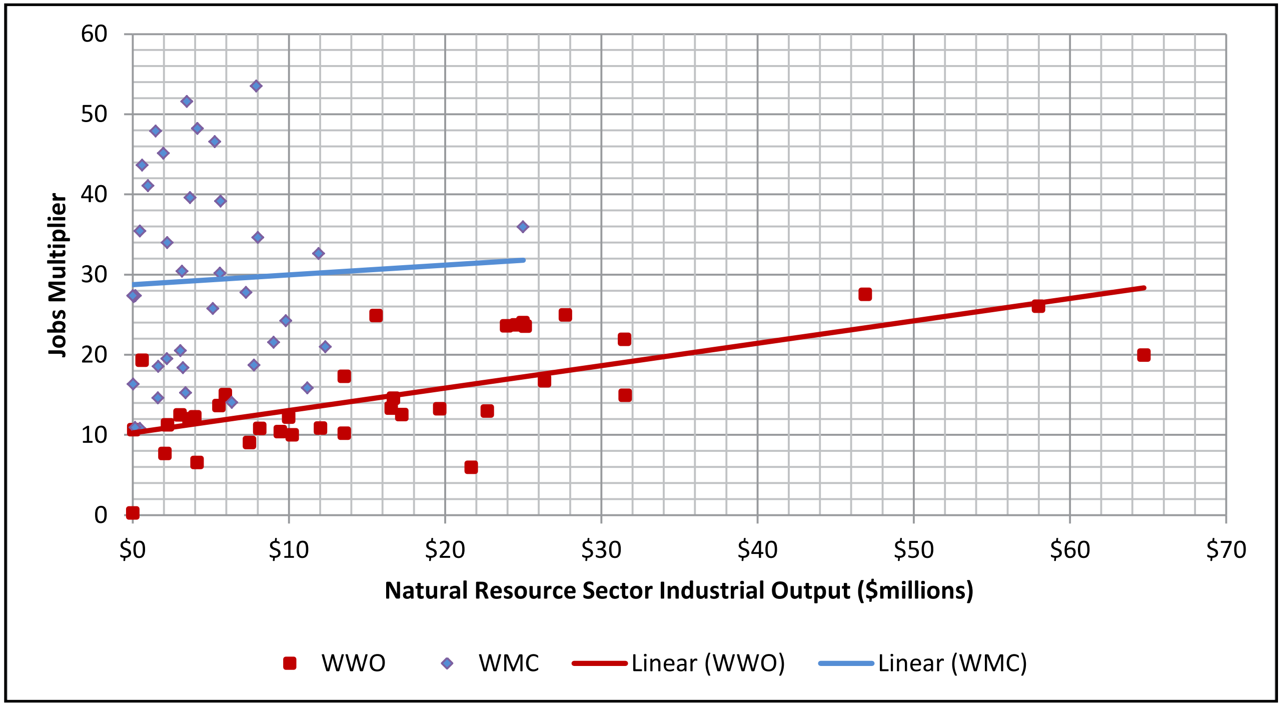

Figure SM-LCA-1.2. Jobs multiplier for WMC and WWO regions

NARA-related dissertation research, which is creating a biorefinery siting model for the WWO region.

Differences in the calculated county multipliers for the two regions (WMC and WWO) are being studied. For instance, Figures SM-LCA-1.3 and SM-LCA-1.4 below indicate significant differences in both job and induced-effect multipliers for the two regions. The figures relate these county level multipliers with the size of the natural resource sectors in each county and are colored coded for each region. Note the higher job multipliers associated with the smaller sized sectors found in the WMC counties versus those found in the WWO counties. Additionally, the WMC county induced-effect multipliers, while lower than WWO counties, show a potential increasing trend with sector size versus those counties in WWO.

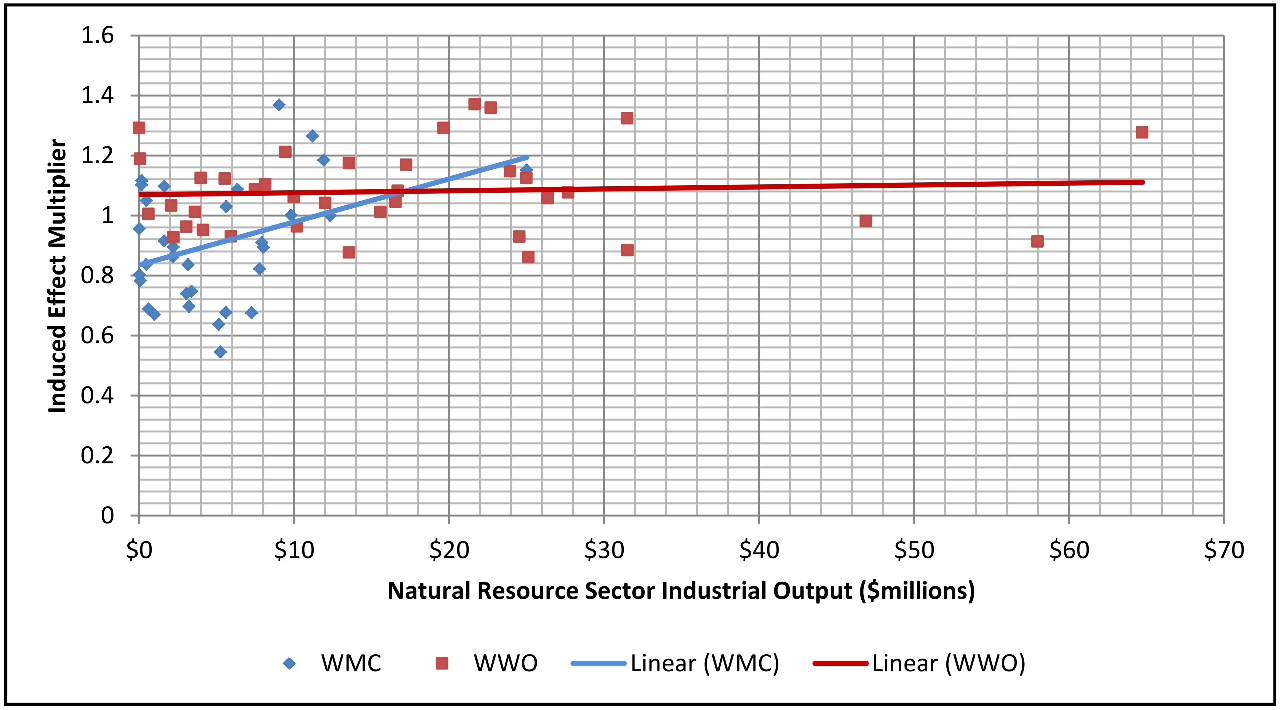

Figure SM-LCA-1.3. Induced effect multiplier for WMC and WWO regions.

Recommendations | Conclusions

Progress on the deep soils and sustainability analysis relative to nutrients, earlier recognized as a critical component of our assessment of sustained productivity of additional harvest for biofuels, is going well, with far greater than earlier anticipated progress, and we will continue to pursue this aspect of biofuel production. We have managed to leverage all of the graduate student stipends from other sources such as fellowships and teaching assistantships, and we should be able to continue this. Graduate students Jason James and Christiana Dietzen are the primary students, with Dr. Kim Littke and others working as well on the project.

We mentioned concern that the lysimeters at the NARA Long-Term Soil Productivity study do not seem to be collecting large amounts of percolating water. This is often a problem when they are first installed, so the fall rains arriving in September will hopefully solve this problem. Collections do not seem to be improving, and we will continue to try and improve this, but since they are in the ground, it is hard to understand why this is occurring. It may be that there is an incompatibility between soil properties and the porous media that is supposed to make intimate contact and allow water flow. Graduate student Marcella Menegale will continue work on this project, helped by Dr. Kim Littke and Dr. Scott Holub from Weyerhaeuser.

We will continue to expand the results of the four Long-Term Soil Productivity studies to the Pacific Northwest (PNW) region as a whole through our modeling effort using biogeoclimatic and stand factors as model inputs. These can also be used in a crude assessment of the impacts of climate change on potential productivity. Dr. Kim Littke will continue this effort. Dr. Marcia Ciol has contributed substantially to the direction of this effort, but has moved off of the grant for now.

The Stump Decomposition Project, after some problems, has made strong progress, and the data should prove highly useful in completing the carbon LCA. Graduate student Matt Norton will continue this work with help from Dr. Kim Littke, Dr. Indroneil Ganguly and others.

The preliminary research results obtained from the LCA, using NREL surrogate modules, show that under most scenarios, NARA-biojet fuel meets the required 60% global-warming potential (GWP) reduction criterion. The LCA team has already developed the individual modules necessary to be able to switch out the NREL surrogate pretreatment (dilute acid) process and incorporate the NARA-mild-bisulfite (MBS) pretreatment. The ASPEN modeling team has already provided the data to our corporate partners (Gevo, Inc.) responsible for the isobutanol (IBA) aspect of the modeling. As soon as Gevo Inc. is ready to share their data with the LCA team, a complete baseline NARA biojet fuel LCA will be made available. All the details have already been iron out, and the final LCA documents should be ready for submission for International Organization for Standardization (ISO) approval by the end of summer of 2015. Following are the planned action plan for the next 12 months, in chronological order:

1. Verify and cross-check all the data obtained from the ASPEN modeling group and make sure none of

the details have been overlooked.

2. Provide necessary input to Gevo Inc. so that they can integrate Gevo's black-box Life cycle inventory (LCI) with the rest of the process
   a. Provide pretreatment, boiler and utilities LCI to Gevo Inc.
3. Obtain Feedstock Scenario Logistics data from different groups at OSU and complete Feedstock Scenario Logistics Data with the selected (or hypothetical) pretreatment facility in the Mid Cascade to Pacific (MC2P) region.
   a. The data may include the following aspects:
      i. Logistics scenarios
      ii. Corresponding slash recovery rates (Kevin Boston)
      iii. Determination of supply zone assuming one million bone-dried tons (BDT) per year (Darius Adams)
4. Finalize the LCI of pre-treatment-gate to iso-pariffinic kerosene (IPK) in storage by integrating the LCIs provided by Gevo Inc.
5. Obtain activated charcoal and cement additive LCIs from Tim Smith's group and integrate it with the biofuels LCA
6. Complete the integrated LCA for ISO (add distribution LCA from Argonne's Greenhouse Gases, Regulated Emissions, and Energy Use model (GREET)
7. Complete the full ISO documentation for technical review, in collaboration with Gevo Inc.
8. Along the way publish peer reviewed journal articles.

Spatial economic impacts depend on the definition of the supply region. We will illustrate how economic impacts change as assumptions about the supplying region are formed. Changes in the supply region occur over time. The NARA Supply model develops supply data over several decades. We will compare changing supply regions over time between the Washington Biomass Supply Assessment data and the NARA Supply Model. We will continue to evaluate alternative locations for biomass facility sites in Washington and Oregon with the NARA Supply Model.

Regional economic impacts differences exist between WMC and WWO. We will continue to document these differences and how they are likely to affect community impacts. Also, we expect to see differences in the commodity by industry accounts. Further development of these accounts will be pursued, including insertion of the biofuels production sector in the input-output model. Finally, a further breakout of the sectors will allow more precise multiplier estimates associated with the forestry sector. We continue to develop spreadsheet models that allow for a sensitivity analysis of industry by industry multipliers versus commodity by industry multipliers. In addition, we have disaggregated the 67-sector model to a 440 sector model. We also have zip-code level data for Washington counties. Models built upon zip-code level data will be used to characterize the rural economic impacts that occur in Washington State and generalized for the NARA region. Current spreadsheet input-output models assume the traditional industry-by-industry matrix analysis with industries aggregated into standard U.S. Bureau Economic Analysis sixty-seven sectors. Given that outputs from the proposed bio-jet fuel process will include several commodities, we are developing the commodities by industry framework, as well as disaggregating the sixty-seven sectors. Discussions were held at the NARA annual meeting with Tom Spink, Gevan Marrs and the rest of the TEA team to share data that will allow measures of the production function for the different commodities to be produced. Data to construct the biofuels sector within the transactions table is expected to be available in April 2015.

Physical and Intellectual Outputs

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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 our 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. We address this issue 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.

Our 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. We propose to quantify typical LTSP objectives such as forest productivity, soil nutrient and carbon pools and fluxes, and soil compaction. This study is unique in that, through our collaborations, we also plan to investigate wildlife and water quality effects following biomass removal and compaction treatments to round out environmental sustainability objectives on site.

Activities and Results

The Sustainable Feedstock Production Systems team through our work at NARA LTSP has made significant headway toward our 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). We measured and recorded immediate post-treatment soil and biomass effects (Figure SM-SP-1.3). We installed weather stations 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. We have measured the trees after one growing season, but data has not been closely analyzed. 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.

This fiscal year we also measured another existing LTSP site, Fall River LTSP near Olympia, Washington, which has reached age 15. Those data provide a fast-forward view of what we might expect to see at the new NARA LTSP. So far results at Fall River LTSP indicate a small (and borderline-statistically-significant) decline in tree volume growth at the 3rd most severe biomass removal, but no significant decline was observed at the most severe biomass removal level (Figure SM-SP-1.4).

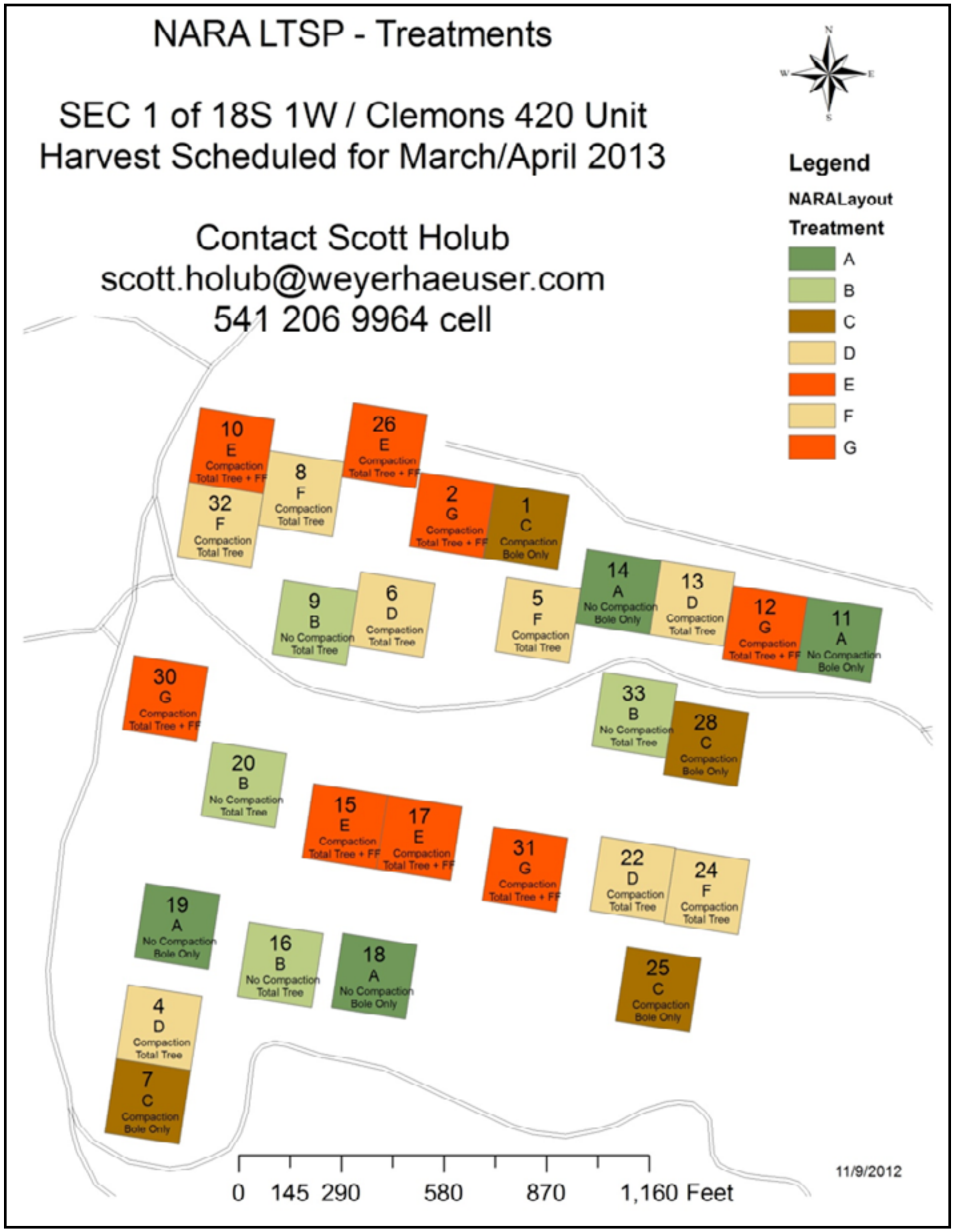

Figure SM-SP-1.1. NARA LTSP Treatment map

Figure SM-SP-1.2. NARA LTSP aerial photo June 2014

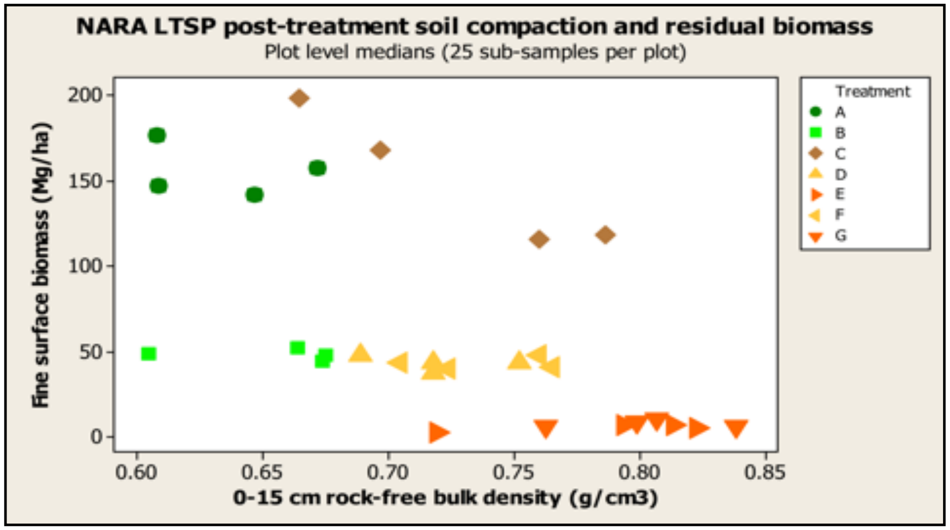

Figure SM-SP-1.3. Post-treatment assessment of compaction and remaining biomass – NARA LTSP

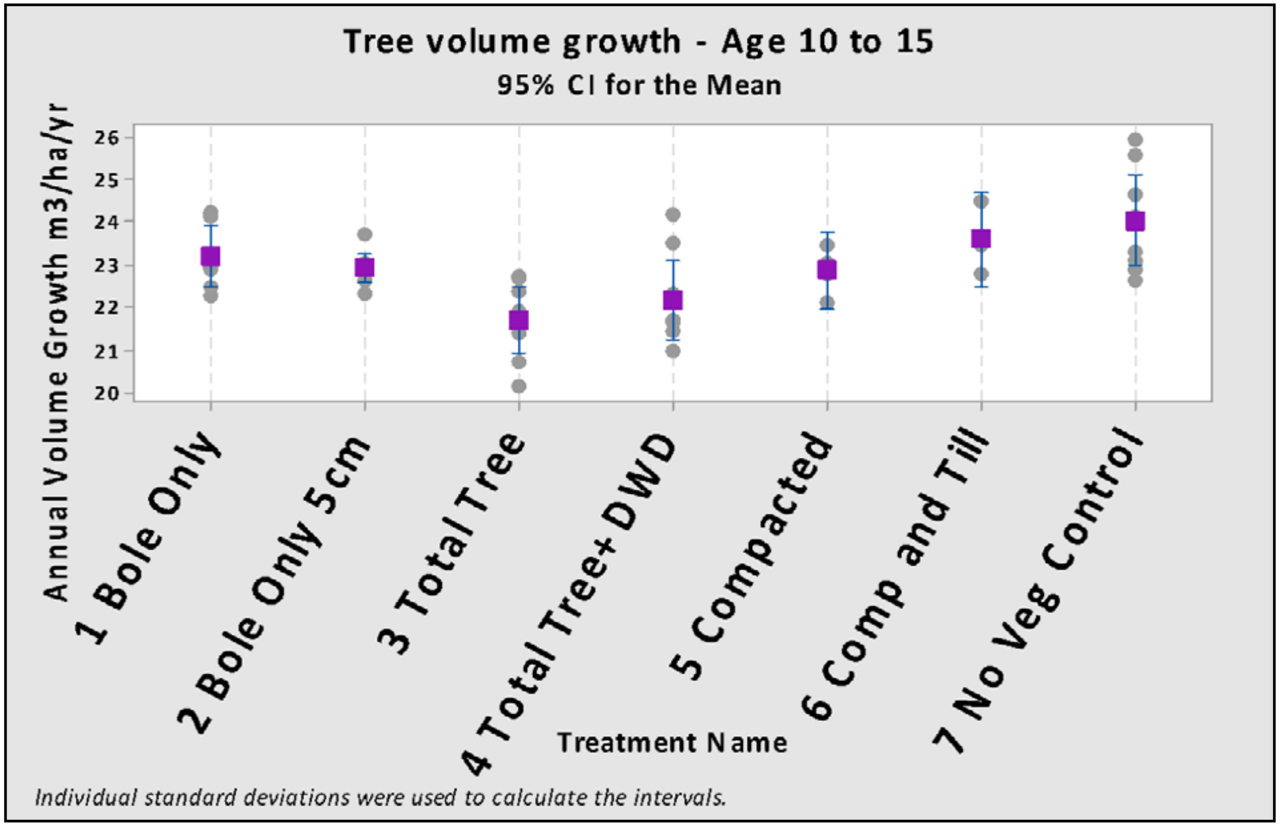

Figure SM-SP-1.4. Preliminary plot-level wood-volume annual growth rates by biomass removal and compaction treatment at the Age 15 Fall River LTSP near Olympia, Washington. Measurements were taken in Fall 2014. Note: All treatments had vegetation controlled with herbicide, except No Veg Control. All treatments were non-compacted, except Compacted and, Compacted and Tilled. No Veg Control, Compacted and, Compacted and Tilled were Bole Only biomass removal.

Recommendations | Conclusions

Preliminary findings indicate that the different treatments we implemented at NARA LTSP were successful at creating a range of conditions in residual biomass remaining and soil compaction. As the projects continue we will monitor environmental conditions, maintain the plots and fence, and support student projects to examine the effects of the treatments.

15-year results from the Fall River LTSP indicate that biomass removal effects on tree growth were small at that site so far. Additional sites and continued study and monitoring are still needed before firm conclusions can be drawn.

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.

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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

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-2.3. Establish Large-Scale ("iFLAMES")

We successfully established Site #1 (Warm Springs) of the integrated Fireshed-Level Adaptive Management Evaluation Sites (IFLAMES) network, with pre-treatment measurements completed and summarized; the nine areas, range from 125 to 270 ft2 of basal area/acre and are representative of mixed-conifer stands in this area. All stands are mixtures of Douglas-fir and ponderosa pine, and some of the stands have incense-cedar. We continue to plan for additional sites on tribal lands (e.g. Salish-Kootenai and Yakama tribal lands) and to coordinate with regional CFLRP projects over potential sites on federal lands (e.g. Lakeview). This requires regular attendance of meetings and conferences, site visits, and conversations.

Kevin Vogler's thesis work is moving forward to publication in two manuscripts:

- "Sustainable Biomass supply from Fuel reduction treatments: A Biomass Assessment of Forest Service lands in the Blue Mountains, USA" to be submitted to Biomass & Bioenergy
- "Wildfire hazard in dry forests of Eastern Oregon: Are fuel treatments appropriately scaled to address the problem?" to be submitted to Journal of Forestry

Along with other related research, as well as experiences with iFLAMES, we were able to foster greater participation from land managers and collaborators within the region; these efforts are supported by research examining:

- Ecosystem resiliency and fuel model recovery following fuels treatments in dry-forest ecosystems, primarily examining post-treatment regeneration within established plots. An analysis of the current state of previously treated stands should give an indication of the effective lifecycle for each treatment.
- Revision/expansion of our understanding of the historic role of fire, insects and climate variability in these ecosystems; reconstructions for approximately 500 years on ten different sites on the Malheur National Forest in central-eastern Oregon. Data about historical successional and disturbance dynamics over long periods of highly variable climate periods will inform restoration treatments that create resilient forest structure and composition in the face of future change.

Recommendations | Conclusions

Intensity and extent of silvicultural treatments across an expanse of Eastside federal lands (in need of restoration) influences the amount of material available for biomass/bioenergy, and there are compelling reasons to pursue those ventures to support restoration and sustainable land management; however, our analysis concludes that available supply is insufficient to support the NARA facility currently envisioned.

Physical and Intellectual Outputs

REFEREED PUBLICATIONS

Spies, T. A., E. M. White, J. D. Kline, A. Paige Fischer, A. Ager, J. Bailey, J. Bolte, J. Koch, E. Platt, C. S. Olsen, D. Jacobs, B. Shindler, M. M. Steen-Adams and R. Hammer. 2014. Examining fire-prone forest landscapes as coupled human and natural systems. Ecology and Society 19(3): 9.

CONFERENCE PROCEEDINGS AND ABSTRACTS FROM PROFESSIONAL MEETINGS

J.D. Bailey. 2014. Overuse and misuse of “thinning” in modern silviculture. Presentation at: Society of American Foresters National Convention. October 8-11 in Salt Lake City, UT.

RESEARCH PRESENTATIONS

James Johnston gave presentations to the Blue Mountains Forest Partners and the Malheur National Forest on August 21 and October 16 about historical successional and disturbance dynamics on forests targeted for restoration treatments under the CFLRP program.

Vogler, K. and J. Bailey. Sustainable Biomass Supply from Fuel Reduction Treatments: A Biomass Assessment of Federally Owned Land in Eastern Oregon. Oral Presentation at Large Wildland Fires Conference, April 19-23, 2014, Missoula, MT.

Vogler, K. and J. Bailey. Sustainable Biomass Supply from Fuel Reduction Treatments: A Biomass Assessment of Federally Owned Land in Eastern Oregon. Poster prepared for Central Oregon Fire Science Symposium, April 7-10, 2014, Bend, OR.

TRAININGS, EDUCATION AND OUTREACH MATERIALS

“Living with Fire” Pacific Northwest Science and Management Team Retreat, June 5-6, 2014 in Skamania, WA. (Speaker)

THESIS AND DISSERTATIONS

Vogler,K. Sustainable Biomass Supply from Fuel Reduction Treatments: A Biomass Assessment of Federally Owned Land in Eastern Oregon. Masters Defense, June 20, 2014, Corvallis, OR.

TASK SM-SP-3: BIOMASS MODELING AND ASSESSMENT

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

Task Description

Develop expanded biomass volume/weight accounting from existing measurements on regional 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 silvicultural 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

We further refined the NARA biomass supply model and began preparation of a manuscript for submission to a peer-reviewed journal documenting the model and applying it to develop projections of supply curves for biomass suitable for use in liquid biofuel production. We also examined the impacts of variation in supply functions with changes in two key public policies: (i) RIN credits expanded to include material from federal lands, (ii) changes in public harvests.

Recent work also includes preparation of a manuscript refining the NARA-based work from Mindy Crandall's doctoral thesis for submission to a peer-reviewed resource economics journal. The work is based on a variant of the NARA biomass supply model adapted to utilize specific potential depot locations along with transport, processing, capital establishment, and operating costs to determine optimal depot locations and capacities and market clearing biomass flows from woods to the depots. Portions of this work was also presented at the Southern Regional Science Association Annual Meeting March 26 - 28 in Mobile, AL and accepted for oral presentation at the combined Western Forest Economists and International Society of Forest Resource Economics meeting May 31 – June 2 in Vancouver, BC.

After meeting with Indroneil Ganguly and Ivan Easton, we expanded our Forest Vegetation Simulator (FVS) yield and biomass model to provide additional outputs for the Mid Cascade to Pacific (MC2P) region under an array of silvicultural options for use in their Life Cycle Inventory analyses. We continue to work on final development of FVS yield and biomass data for eastern OR and WA along with ID and MT enabling completion of biomass supply relations for example refinery areas in the Missoula Corridor area.

Work continues in partnership with Natalie Martinkus shifting our transportation cost computation methods to a new ARCGIS Network Analyst-based approach. This new approach promises to be faster and more flexible than the scheme we have used to date.

Recommendations | Conclusions

Work will begin this summer on a multi-NARA group synthesis paper covering the sustainability of the use of forest residuals for bio-fuel production. This work will require:

- incorporation of completed John Sessions led Collection, Processing, and Transport Logistics group findings into the NARA biomass supply model (Task SM-SP-3.2).
- inclusion of wildlife metrics from Matt Betts led Wildlife Impacts group into the FVS growth and yield generation program.
- evaluation for potential inclusion of Doug Maguire and Jeff Hatten led Long-Term Site Productivity group findings into the FVS growth and yield generation program.
- Refinement of FVS growth and yield output to provide Indroneil Ganguly and Ivan Eastin of the Life Cycle Assessment group detailed data for use and input in their modeling.

We are also in the process of submitting a proposal for an AFRI Foundational Program Grant in the Agriculture Economics and Rural Communities (AERC) program area. The proposal's Duke University led research team seeks to coordinate, leverage and extend three NIFA Bioenergy Bioeconomy Bioproducts (B3) projects. The proposed project seeks to align two AFRI "Policy Options for, and Impacts on, Regional Biofuels Production Systems" program area projects:

- CRIS Number 229908 "The Effect of Existing and Novel Policy Options on the Sustainable Development of Regional Bioenergy Systems" and
- CRIS Number 230883 "Regional Bioenergy Policy Effectiveness: Compatibility, Innovation, and Coordination across the Supply Chain",

plus the proposed project will investigate the applicability of identified policy options to AFRI large cap projects. In addition to utilizing existing established forest sector models to simulate emerging bioenergy opportunities across the U.S., the project would use the NARA biomass supply model to evaluate the potential effectiveness of project identified novel policy options for fostering development of bioenergy markets in the U.S. Pacific Northwest. The proposed project timeline for integration of the NARA biomass supply model with these policy-based AFRI efforts includes an overlap with NARA year 5 providing additional bioenergy policy support through leading up to our final reporting for the Sustainable Feedstock Production Group.

Physical and Intellectual Outputs

REFEREED PUBLICATIONS

Crandall M, DM Adams, CA Montgomery. The potential for biomass use and increased federal harvests to aid rural development in western Oregon. (in preparation)

RESEARCH PRESENTATIONS

Crandall, M., C. Montgomery, and D. Adams. 2015. Potential Rural Development Impacts of Increased Utilization of Forest Resources. Presented at Southern Regional Science Association Annual Meeting, March 26 - 28, Mobile, AL

THESIS AND DISSERTATIONS

Crandall, Mindy. "The effects of increased supply and emerging technologies in the forest products industry on rural communities in the northwest U.S." Doctoral dissertation in the Department of Forest Engineering, Resources and Management, submitted to the Graduate School, Oregon State University, September 26, 2014. https://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/52556/CrandallMindyS2014.pdf

TASK SM-SP-4: LONG TERM PRODUCTIVITY STUDIES

Key Personnel	Affiliation
Doug Maguire	Oregon State University

Task Description

We will 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 both 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 silvicultural 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-4.2. Estimate nutrient and carbon removals under various levels of biomass harvesting

This task has been completed. Tree lists from four SMC type 1 plantations (~15 yrs plantation age), representing a range of site productivities (SI50=78.3, 99.7, 124.7, and 143.6 ft) were grown to 80 years of age using the geographically appropriate version of ORGANON, a regional growth model. Examining fire-prone forest landscapes as coupled human and natural systems

Task SM-SP-4.3. Determine sustainable levels of bioenergy feedstock under range of silvicultural intensities

We have accumulated estimates of soil nutrient replenishment rates, atmospheric deposition rates, and nutrient release rates of various parent materials found within westside Douglas-fir stands. Based on the soil nutrient capital at the four SMC-type 1 sites sampled during the construction of soil biomass equations, and application of the Evans stability ratio, we have determined sustainable levels of bioenergy feedstock production.

Task SM-SP-4.4. Estimate changes in long-term site productivity under different climate change scenarios

Based on future estimates of climate change (using climate-FVS) at the four SMC type-1 sites that were sampled during the construction of biomass equations, Douglas-fir is predicted to be a non-viable species in the future. This would suggest that there is no long-term Douglas-fir productivity on the basis of that specific model. We are currently exploring the use of other models in answering this question.

Recommendations | Conclusions

Differences in nutrient removals by harvest intensity are most pronounced in low productivity stands, where a bole-only harvest takes a much smaller % of aboveground nutrient content relative to a whole-tree harvest. Given that low productivity stands have greater nutrient limitations than their high productivity counterparts, and also due to inherently greater biomass production, biomass harvesting would be best focused within high productivity stands.

Of the five macronutrients for which published rates of weathering, deposition, and leaching are available (N, P, K, Ca, Mg), calcium is the nutrient that has the highest percentage of its initial pool depleted by biomass harvesting. This is especially true in coastal regions, where older sandstones are particularly lacking in calcium, and where atmospheric deposition is the primary source.

Physical and Intellectual Outputs

THESIS AND DISSERTATIONS

Coons, K.L. (2014). Douglas–fir (Psuedotsuga menziesii) biomass and nutrient removal under varying harvest scenarios involving co-production of timber and feedstock for liquid biofuels. M.Sc. Thesis, Oregon State University.

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

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 both positive and negative air quality impacts that biofuel harvesting may have on short- and long- term changes in air pollution within the project airsheds at scales ranging from field scale to regional scale. The specific objectives of this project are:

1. to develop supply chain emission scenarios and use these for a regional analysis of the impact of the supply chain on air quality.
2. to assess the reduction in air pollution levels associated with the reduction in prescribed burning which will occur when woody residues are harvested for biofuel production.

Activities and Results

During the past year, we have completed a series of regional air quality simulations to investigate the impact of prescribed fires on local and regional air quality. These simulations show that harvesting woody biomass for biojet fuel production will decrease the amount of slash burning that occurs in the region and result in a positive benefit for air quality. This impact is mostly confined to the fall and spring months when prescribed fire activity occurs. Figure SM-SP-5A.1 shows the benefits associated with reduction of prescribed fire activity by 70%. Also shown is PM2.5 concentration averaged for the prescribed fire season- October and November. It was also found that prescribed fire contribution to 8-hour average ozone concentration is negligible.

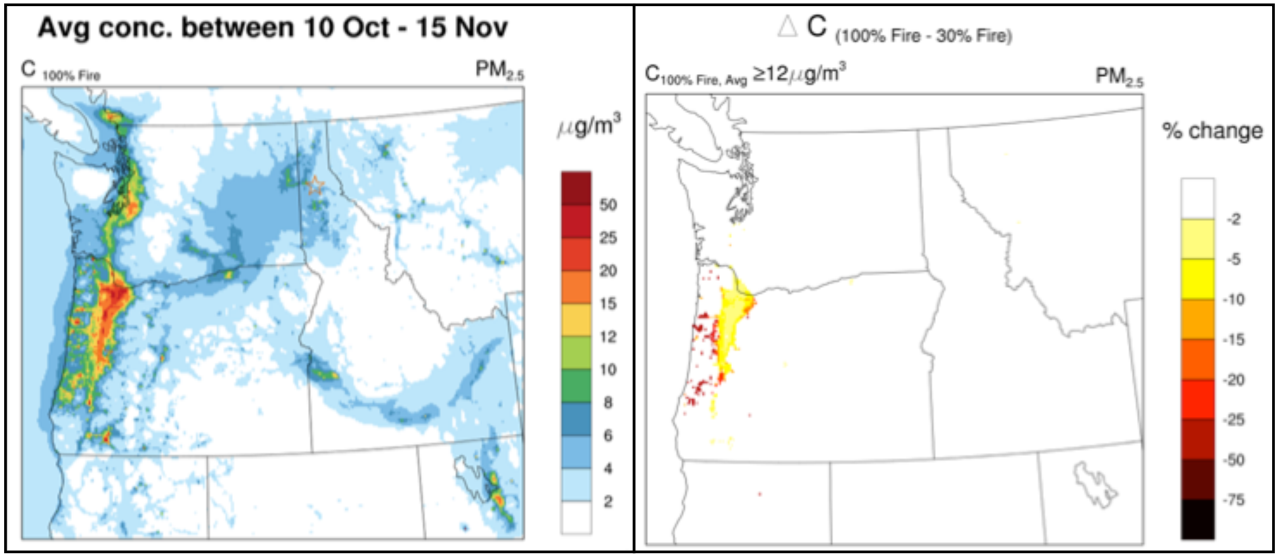


Figure SM-SP-5A.1. (left) average PM2.5 concentration for the simulation period and (right) % change in concentration observed when prescribed fire emissions were reduced by 70%

Recommendations | Conclusions

Our focus for the next year is on simulations of biorefinery and supply chain emissions. However, we are dependent upon the other design groups to provide emissions data and scenario cases. This continues to be an area of concern for our analyses.

Physical and Intellectual Outputs

Primary outputs are model simulation files and associated powerpoints and posters.

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.

The University of Utah will primarily conduct Items 1-3, 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

Soil samples were collected in May 2014 from Long-Term Soil Productivity (LTSP) plots to perform DNA extraction test in the laboratory. Nine samples were collected from each plot. The samples were taken at a depth of 0-20 cm using a hand shovel.

Microbial population data was collected from 28 one acre plots subject to different land treatments and statistically analyzed to evaluate a null hypothesis that changes in biomass removal do not impact subsurface environment. Four DNA extraction test for each soil sample i.e. 144 for each treatment and 16 for the control one, concluding a total of 1024 test has been performed. Two sample t-tests assuming equal variances has been performed to find out the correlation between DNA concentration and different treatments. The results of the hypothesis tests were not able to make any decision about the null hypothesis for which a biological analysis has been performed using finger printing analysis (ARISA).

Forty samples out of 1024 DNA samples, five from each treatment including the control one has been selected for the ARISA finger printing analysis, in such a way so that those can be considered as the representative sample for each treatment. Community fingerprinting is used to profile the diversity of microbial community. These techniques show how many variants of a gene are present instead of counting individual cells in a sample. The results of ARISA tests are shown in Figure SM-SP-5W.1 and Table SM-SP-5W.1.

1197 intergenic spacer sequences out of 3211 were examined and 56 genera were found; the majority of which are from taxa belonging to either the gram positive or gram-negative phyla. Table SM-SP-5W.2 shows the diversity indices results calculated by the Shanon–Weaver and Simpson's Diversity Index method.

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

We have performed a literature review on stream channel response to forest practices and selected models to simulate hillslope and stream channel impacts. A methodology was developed to use hillslope models to provide sediment supply data to a model of flow and sediment transport in streams. Preliminary work indicates that changes to peak flows and sediment supply are the most critical parameters for quantifying channel response. Cat Spur Creek, located in a logged watershed in northern Idaho, was selected as the field site. Data collection was conducted in July 2014 to characterize channel elevation, streambed material, and streambank vegetation. Based on the Cat Spur Creek watershed, the FS Disturbed WEPP hillslope model was used to provide sediment supply rates to Nays2DH, a two-dimensional stream model capable of predicting sediment transport and changes to bed material. Impacts from biomass removal have been conservatively estimated to increase sediment yield from the hillslope by 35 to 60% beyond the initial sediment yield due to timber harvest. This estimate is dependent upon the area disturbed by biomass removal. The increased sediment yield predicted by the FS Disturbed WEPP model was then used as input to Nays2DH. Biomass removal impacts predicted by the stream model were: 1) a decrease in average bed material diameter by up to 3 mm, and 2) increase in bedload transport by up to 5% as shown in Figure SM-SP-5W.2.

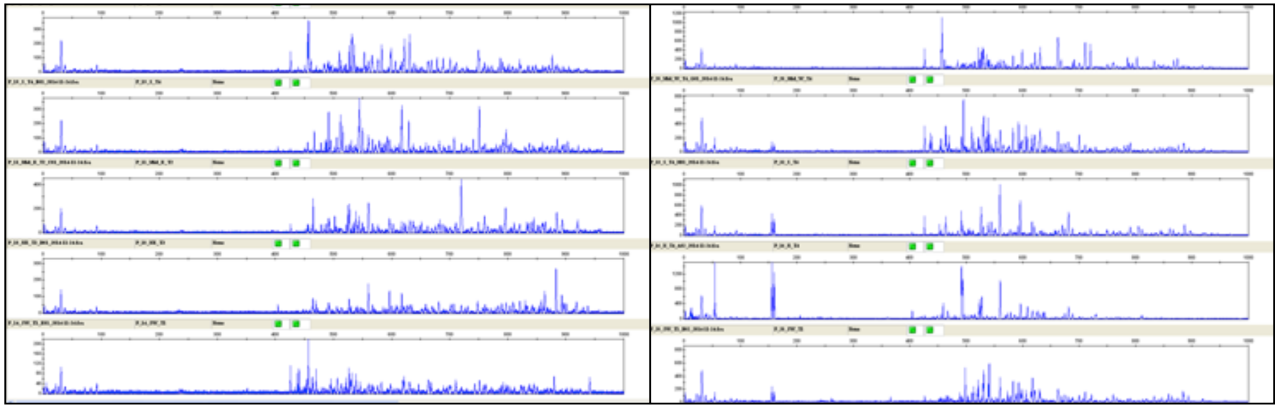


Figure SM-SP-5W.1. ARISA test run result for treatment A and B

Table SM-SP-5W.1. Range of Peak Number and sizes in the ARISA Profiles for Different Treatments

Treatments	No. of Peaks	Range of peak size (bp)	Range of spacer size (bp)
Treat A	397	208.46 – 920	86.46 – 798
Treat B	464	208.46 – 950.59	86.46 – 828.59
Treat C	404	208.48 – 917.79	86.48 – 795.79
Treat D	442	226.69 – 1002.1	104.69 – 880.1
Treat E	288	220 – 934.01	98 – 812.01
Treat F	337	208.62 – 921.7	86.63 – 799.7
Treat G	438	208.59 – 971.53	86.59 – 849.53
No Treatment	441	208.58 – 941.52	86.58 – 819.52
Total	3211		

Table SM-SP-5W.2. Diversity Index Results

Treatments	A	B	C	D	E	F	G	Unharvested
Shanon – Weaver Index (H)	2.98	3.13	3.03	3.30	3.21	3.19	3.30	3.22
Shanon's Equtability Index (EH)	0.85	0.84	0.83	0.87	0.86	0.86	0.86	0.85
Simpson's Index (D)	0.084	0.075	0.084	0.059	0.069	0.074	0.065	0.071

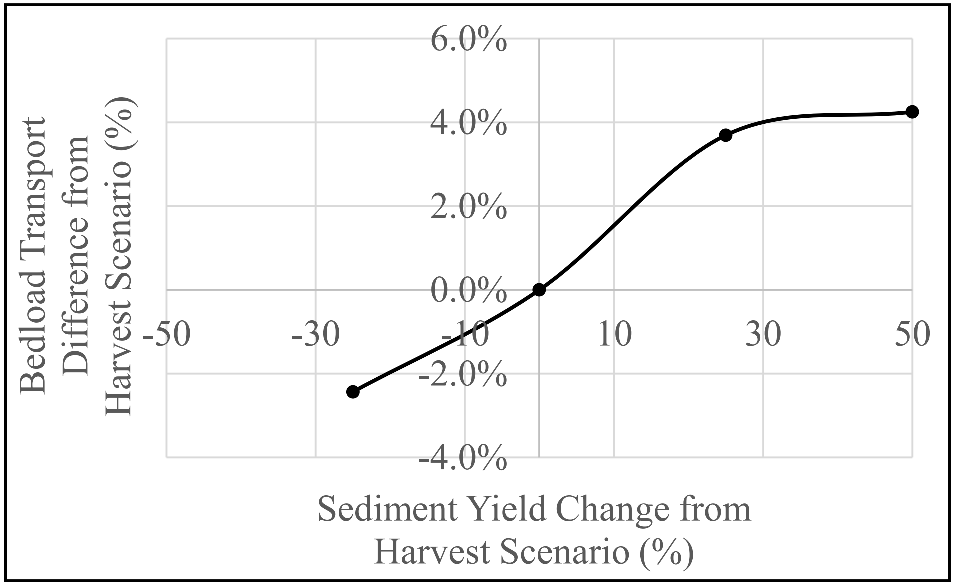


Figure SM-SP-5W.2. Correlation of sediment yield increases from hillslope to bedload transport in stream

Recommendations | Conclusions

- From all these analysis, it has been found that the biomass removal from the field does not have any detrimental impact on the long-term flux of nutrient populations and microbial ecology.
- To find out the impact on water quantity specifically on runoff, infiltration and evapotranspiration a water balance model has to be developed in near future by using Windows version of UNSAT-H model. All necessary data and literature review has already been done. Developing the water balance model will help to understand the impact of ground residual removal from hydrologic point of view.
- Future work is needed to improve hillslope sediment and runoff predictions from watersheds impacted by traditional logging and biomass removal. This work should focus on sites representative of expected field conditions. Additional data collection within the stream channel will also provide further insight into stream channel processes. A sustained monitoring and measurement campaign through cycles of watershed disturbance would be most beneficial. Such a dataset would provide important validation data for numerical models as well as quantitative metrics for stream channel impacts.

Physical and Intellectual Outputs

PHYSICAL

- Nine soil samples from each plots and four soil samples from unharvested sites were collected.
- Four DNA extraction tests from each soil sample were performed which concluded a total of 144 DNA extraction for each treatment and 1024 for the whole LTSP sites.
- Fifty-six genera were identified from the ARISA results for these LTSP sites.

CONFERENCE PROCEEDINGS AND ABSTRACTS

In progress: Hasan, M.M., Barber, M.E., Goel, R., and Mahler, R.L. (abstract and paper accepted). Understanding the consequences of land use changes on sustainable river basin management in the Pacific Northwest, USA. River Basin Management 2015, 8th International Conference on River Basin Management including all aspects of Hydrology, Ecology, Environmental Management, Flood Plains and Wetlands, A Coruna, Spain.

In progress; Wickham, R. and J. Petrie (abstract and paper accepted), Quantifying the spatial variability of stream bed grain size distributions and the influence on sediment transport modeling, ASCE EWRI Congress 2015, World Environmental & Water Resources Congress, Austin, TX, May 17-21, 2015.

RESEARCH PRESENTATIONS

Sorensen, E., R. Wickham, and J. Petrie. Spatial Distribution of Grain Sizes in Sampling Heterogeneous Stream Beds. Poster presented at the 2014 NARA Summer Undergraduate Research Experience Poster Session, Pullman, WA, August 1, 2014.

Hasan, Mohammad M., Michael E. Barber and Scott M. Holub. Microbial Population as a Function of Woody Biomass Removal Treatments. Poster presented at the 2014 NARA Annual Meeting, Seattle, WA, September 15-17, 2014.

Wickham, Ross S. and John Petrie. Response of Flow and Sediment Dynamics in Mountain Streams to Biomass Removal. Poster presented at the 2014 NARA Annual Meeting, Seattle, WA, September 15-17, 2014.

Wickham, R. and J. Petrie, Response of Flow and Sediment Dynamics in Mountain Streams to Biomass Removal, Poster Presentation at Climate, Land Use, Agriculture and Natural Resources: Activities in Interdisciplinary Research, Education and Outreach, October 7, 2014. Pullman, WA

VIDEOS AND WEBINARS

Petrie, J. Rivers Channel Changes: Impacts of Forest Management, MOSS imagine tomorrow webinar (McCall Outdoor Science School, University of Idaho), March 11, 2015

THESIS AND DISSERTATIONS

Wickham, R. The Effect of Grain Size Heterogeneity on Sediment Transport Modeling, MS Thesis, to be defended on April 20, 2015.

Hasan, M.M. Evaluating the Environmental Impact of Woody Biomass Removal for Biofuel Production, MS Thesis, to be defended on April 24, 2015.

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

Key Personnel	Affiliation
Matthew Betts	Oregon State University

Task Description

We will review silvicultural regimes proposed 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, we will conduct a meta-analysis that tests the influence of species life-history traits on sensitivity to proposed silvicultural regimes. Review landscape patterns resulting from regional models of biomass collection and removal. We will test for potential population-level consequences of biofuel harvest 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

Task SM-SP-6.1. Analysis of preliminary regional models completed to provide metrics for regional runs and to inform future regional model runs

The manuscript submitted by Betts and to Journal of Forestry has been conditionally accepted. In this manuscript, we describe the range of management practices used to harvest biomass, and the types of forest organisms known or expected to be impacted. We review the tradeoffs between habitat alteration and potential for global climate change mitigation. Furthermore, we place biomass harvesting in a landscape context and discuss the potential for thresholds in species responses to biomass management at stand and landscape scales. After framing the issues and current knowledge, we propose a research plan for the future.

We are continuing to conduct a meta-analysis examining the effects of intensive forest management practices on bird communities across North America. We have compiled 14,000 bird community observations from Oregon, California, Ontario, New Brunswick, British Columbia, Saskatchewan, and Alberta. Preliminary occupancy models have been run for stand-level and landscape-level impacts of intensive forest management on species richness, cavity-dwellers, and individual bird species from 8 study regions, including 2 in the Pacific Northwest. Heather Root was hired as an Assistant Professor 6 months ago, which has slowed progress on this data analysis. Jim Rivers does not have the statistical background to continue with this aspect of the project, so our intention is to hire a new postdoc to complete the analysis. The postdoc will not start until late Fall 2015, so we are requesting a no-cost extension on 2015 funds to enable that hire. With this no-cost extension, our target completion date for this task is June 2016.

As mentioned in previous updates, we have determined there are insufficient data available to develop population viability analyses for indicator species as proposed originally. As a result we are focusing our work on (1) the review above and (2) collection of field data on the impacts of biofuel removal (Task SM-SP-6.2 below).

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

Betts and Rivers (in collaboration with former postdoc Root) established a field study in western Oregon for spring/summer 2014 to examine the relationship between White-Crowned Sparrow fledglings and slash at sites with experimentally manipulated management intensity. Casual observation suggests that fledglings are using fine and coarse slash as cover between the times that they leave the nest and gain the ability to fly. This effort will dovetail with an AFRI-supported project investigating the effects of intensive forest management. During June-August 2014 we collected juvenile sparrow telemetry data to identify habitats used by fledglings and measure the association between survival and woody debris. Data are currently undergoing the QA/QC process, followed by data analysis with survival models.

In addition to our research on birds, we also initiated a field study during summer 2014 to examine the influence of biomass removal and site prep on invertebrate pollinators. Ground-nesting bees, which provide important ecosystem services in regenerating forests, are among the wildlife likely to respond to slash manipulation on small-scale plots like those established in the LTSP experiments and will be continue to be a focus of our field studies at the LTSP sites during summer 2015. Our initial field work used a combination of (1) emergence traps to quantify emergence of ground-nesting bees and (2) blue-vane traps that sample a wide array of insects to quantify presence of invertebrate pollinators in LTSP stands (Figure SM-SP-6.1). During summer 2014 we captured a large number of bees (>1900 individuals) and we are currently processing individuals so that they can be identified to species. Following lab work, we will test whether species diversity (i.e., species richness and abundance) differs relative to experimental treatments.

Figure SM-SP-6.1. Examples of a ground-nesting bee emergence trap (left) and a blue vane trap (right) used to trap invertebrate pollinators in the LTSP sites on Weyerhaeuser land during summer 2014. Emergence traps are exclosures with an open bottom that capture ground-nesting bees that overwinter in the soil and emerge as adults. In contrast, blue vane traps capture free-flying adult bees that vary widely in the type of substrates used for nesting.

Recommendations | Conclusions

Our review manuscript examines current knowledge about the utilization of dead wood by wildlife. We summarize the abundant literature on the importance of coarse woody debris for wildlife within a stand and identify knowledge gaps in the areas of fine woody debris and impacts at a landscape scale, which may be more important than local impacts. In the coming year, we will complete the meta-analysis of intensive forest management effects on bird communities, the survival analysis of White-Crowned Sparrows in relation to fine and coarse woody debris, and continue our study of the bee communities captured at the WY LTSP site.

Physical and Intellectual Outputs

PEER-REVIEWED PUBLICATIONS

Root, H. and Betts, M.G. In Revision. Biofuel and Biodiversity in Mesic Forests. Journal of Forestry

RESEARCH PRESENTATIONS

Betts, M.G. 2014. Why do species occur where they do? Land-use, Climate and Behavioral Drivers of Species distributions in a changing world. University of Georgia, April 2014.

Betts, M.G. 2014. Why do species occur where they do? Land-use, Climate and Behavioral Drivers of Species distributions in a changing world. University of York, York, United Kingdom, August 2014.

Betts, M.G. 2015. Conserving Forest Biodiversity from Moncton to Monte Verde. Université de Moncton, New Brunswick, Canada, February 2015.

Betts, M.G. 2014. Introduction to the Intensive Forest Management Experiment. Wildlife in Managed Forests: Songbirds and Early Seral Habitats of the Oregon Forests Research Institute, Albany, OR.

Rivers, J. W., and M. G. Betts. 2014. Intensive forest management practices reduce nest survival and offspring production: evidence from a landscape-scale experiment 132nd meeting of the American Ornithologists' Union, Estes Park, CO.

Rivers, J. W., J Verschuyl, A. J. Kroll, C. J. Schwarz, and M. G. Betts. 2014. Assessing herbicide impacts on songbird demography in early seral forests of the Pacific Northwest. Wildlife in Managed Forests: Songbirds and Early Seral Habitats of the Oregon Forests Research Institute, Albany, OR.

Mathis, C. L., J. W. Rivers, and M. G. Betts. 2015. Assessing the influence of organic biofuel removal on bee diversity in early seral production forests. Oregon Chapter of The Wildlife Society, Eugene, OR.

Rivers, J. W., J. Verschuyl, A. J. Kroll, and M. G. Betts. 2015. The influence of intensive forest management practices on breeding success of the white-crowed sparrow, an early seral songbird. Oregon Chapter of The Wildlife Society, Eugene, OR.

Rivers, J. W., J. Verschuyl, A. J. Kroll, and M. G. Betts. 2015. Quantifying tradeoffs between biodiversity and timber production in western Oregon: an overview of the Intensive Forest Management Study. Washington Chapter of The Wildlife Society, Grand Mound, WA.

Rivers, J. W., J. Verschuyl, A. J. Kroll, and M. G. Betts. 2015. Influence of intensive forest management on the breeding success of an early seral songbird. Washington Chapter of The Wildlife Society, Grand Mound, WA.

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 (BBER) Forest Industry Research Program will characterize the composition, quantities, spatial distribution, and other characteristics 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 and annual timber harvest in the 4-state region.

Activities and Results

The University of Montana's BBER Forest Industry Research Program has provided fellow NARA researchers with forest industry and timber products output (TPO) data for modeling and 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.

After attending the NARA annual meeting in September 2014 and meeting with other members of the Team, we assembled information on felled tree breakage, stump height, and small end diameter for our colleagues at OSU and UW. We thank them for their interest in our research and look forward to informing other NARA investigators on how to use our logging utilization and mill residue data sets.

BBER currently has 2002 through 2012 timber harvest data (in MBF Scribner) by county and ownership available for the entire 4-state region; 2013 data for all ownerships in Washington are available; and 2013 data for several but not all owners are available for Oregon, Idaho and Montana. This timber harvest info should be useful for updating models of potentially available feedstock and measures of sustainability (e.g., growth-to-harvest ratios). These data are updated on an ongoing basis as new information is released by reporting agencies (e.g., USFS, BLM, ODF, WA-DNR, IDL, and MT-DNRC).
BBER has made a 5-state timber harvest by county and ownership database available for each year 2002 thru 2012. This has been provided to several NARA researchers, including Adams and Martinkus, and is available online: http://www.bber.umt.edu/FIR/H_Harvest.asp.

BBER researchers are now completing 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 3 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 (2011), Oregon (2008), Montana (2009), Washington (2010), with new (2013) Oregon data now posted to our BBER website. We can provide estimates of mill residues produced (and used/not used) annually for each of the 4 NARA states based on our mill census data, annual lumber production, and other information.

Mill residue and other production information:
Oregon- 2008 mill study available at: http://www.

Table SM-SP-7.1.Logging utilization field work progress through March 31, 2015

State	Sites	percent complete (based on 35 per state)	percent complete (based on 30 per state)
Idaho	20	57	67
Montana	22	63	73
Oregon	30	86	100
Washington	28	80	93
Total	100	71	83

bber.umt.edu/pubs/forest/fidacs/OR2008.pdf)

Montana- 2009 mill study available at: http://www.bber.umt.edu/pubs/forest/fidacs/MT2009.pdf)

Washington- 2010 mill study (provided by WA-DNR) available at: http://www.dnr.wa.gov/BusinessPermits/Topics/EconomicReports/Pages/obe_washington_state_millsurvey.aspx

Idaho- 2011 mill study available at: http://www.bber.umt.edu/pubs/forest/fidacs/ID2011.pdf)

Above four-state mill residue TPO data available on request from BBER and at: http://srsfia2.fs.fed.us/php/tpo_2009/tpo_rpa_int1.php

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 100 sites across the region (Table SM-SP-7.1).

Table SM-SP-7.1. Logging utilization field work progress through March 31, 2015

We can provide logging residue estimates for each NARA state at the state and county levels based on our logging utilization fieldwork and ancillary information. We can also supply summarized annual county-level timber harvest data obtained from other sources.

Logging residue information:
Idaho- 2008-2011 logging residue report available at: http://www.bber.umt.edu/pubs/forest/util/ID_logging_util_2014.pdf

Oregon (2008), Montana (2009), Washington (2010), and Idaho (2011) logging residue TPO data available on request from BBER and at: http://srsfia2.fs.fed.us/php/tpo_2009/tpo_rpa_int1.php

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 4-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.
- The BBER and the US Forest Service Forest Vegetation Management staff (Ft. Collins Service Center) are jointly modifying 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.

Recommendations | Conclusions

CONCLUSIONS

1. Mill Residues: BBER's recent TPO research (Simmons et al. 2015; McIver et al. 2012; Simmons et al. 2013) confirms preliminary observations: virtually all mill residues currently produced in the NARA 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 pre-treatment 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 new home construction; and if the trend of pulp mill closures in the U.S. continues, opportunities for new or expanding uses of mill residue by the biomass sector may increase.

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. land ownership- federal, state, private industrial, or nonindustrial private (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 generally declined over the past 20 years across all four NARA states (McIver et al. 2012; Simmons et al. 2014; Simmons et al. 2015; 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. However, substantial recovery of private lands harvest has been observed since 2010 in western Oregon and Washington as a result of increased log exports to Asia. As domestic demand for housing and wood products increases, private and state-owned timber harvest is also expected to rise. We believe it unlikely that federal lands will substantially increase timber harvest levels in the near future, regardless of wood products demand. Public support for forest restoration and fire hazard reduction treatments has fostered hope that we will see minor increases in federal harvest. However, current legal, policy/budget, 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: Focus on completing collaborative research in the last year of the NARA project. In particular, we need to wrap-up our cooperative OSU-BBER residue pile and logging utilization research. We also need to seek 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. We hope that the Adams-Latta models will make full use of our updated TPO and logging utilization work. Research products will enable land managers to accurately predict residue quantities and availability as a function of timber harvest volume and simple covariates, such as logging system employed.

3. Logging utilization studies: Continue collecting logging utilization data across the NARA project area through Year-5 of the project. The overall BBER logging utilization study plan calls for sampling 5 to 7 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 five 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-5 logging utilization sampling efforts on Washington, Oregon, and Montana. Obtaining additional west-side samples will help ensure success of our cooperative OSU-BBER project.

BBER researchers continue to sample logging utilization, report on timber harvest, and maintain information on mill residue production and mill capacity across the 4-state NARA area. We offer several ways that our NARA colleagues can use the results of this work. Specifically:

- BBER will continue to update state-level summaries of mill and logging woody residue information. Several NARA researchers, e.g. Darius Adams and Greg Latta, Natalie Martinkus, Indroneil Ganguly, and the IDEX student groups, have used this data to estimate feedstock availability.

- Using the results of BBER's logging utilization research, U.S. Forest Service Forest Vegetation Simulator (FVS) staff and BBER investigators have developed improved FVS estimates of post-harvest residues. This work has far-reaching consequences, including improved FVS user forecasts of: woody feedstock availability, fuels loading, and fire behavior. We hope our NARA colleagues will make full use of this new capability.

- BBER researchers have developed a biomass prediction tool. This easy to use application can be web-based and will enable land managers to quickly assess the gross quantities of logging residue (i.e., slash) produced from commercial timber harvesting activities for use in biomass feedstock and wildfire fuel load analyses.

- We are developing models for the entire NARA project area that predict the ratio of logging residue volume to mill delivered volume as a function of readily available covariates, such as logging systems employed.

- NARA researchers can learn timber harvest volumes by county throughout the 4-state NARA area and California by accessing BBER's web-based cut by county tool: http://www.bber.umt.edu/FIR/H_Harvest.asp.

- State-level forest industry reports are available at: http://www.bber.umt.edu/FIR/H_States.asp. and http://www.dnr.wa.gov/BusinessPermits/SchoolFundingTrustBeneficiaries/Pages/Home.aspx

- Brief summaries of forest industry outlooks for Idaho and Montana: http://www.bber.umt.edu/FIR/H_Outlook.asp.

- Capacity studies can be accessed at: http://www.bber.umt.edu/FIR/H_Capacity.asp.

- Past logging utilization studies: http://www.bber.umt.edu/FIR/L_Util.asp.

- Forest economic data (log and hauling costs, employment, production, and wages, log prices): http://www.bber.umt.edu/FIR/ForEcon.asp.

THE FUTURE

In NARA Year 5, the BBER team will complete logging utilization field work, analyze and report logging utilization and other forest industry data, wrap-up ongoing collaborative research, 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-5 efforts will include:

- Measuring logging utilization at active logging sites in coastal Oregon and Washington;
- Processing, summarizing, and sharing 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 western Oregon and western Washington. We anticipate being able to complete 5-6 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 needed to ensure NARA modeling tools have sufficient data to accurately forecast outcomes.

We suggest that all NARA organizations, including the BBER, craft manager-friendly publications and internet-based tools in year 5. We need to ensure we leave land managers and bioenergy specialists a suite of practical, user-friendly outputs by the end of the NARA project. Dr. Vik Yadama's Outreach Team has already produced many useful science delivery products. But we cannot expect the Outreach team to solely shoulder the technology transfer burden.

Physical and Intellectual Outputs

REFEREED PUBLICATIONS

Simmons, E., E. Berg, T. Morgan, C. Gale, S. Hayes. Biomass prediction tool. Manuscript in preparation.

RESEARCH PRESENTATIONS

Berg, E., E. Simmons, T. Morgan, S. Hayes, and S. Zarnoch. 2014. Improving Forest Vegetation Simulator (FVS) estimates of logging residues. Presentation to the Society of American Foresters 2014 national convention, October 6, 2014.

Berg, E., T. Morgan, E. Simmons, and S. Hayes. 2014. Logging Utilization: Decision Support Tools for Land Managers. Poster presented at the 2014 NARA Annual Meeting, Seattle, WA, September 15-17.

Berg, E., T. Morgan, E. Simmons, S. Hayes, S. Zarnoch. 2014. Logging Residues: Tools for Land Managers. Poster presented at the Seattle Biomass Conference. Seattle, WA. April 28-30, 2014.

OTHER PUBLICATIONS

Simmons, E., Berg, E., Morgan, T., Zarnoch, S., Hayes, S. & Thompson, M. (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

Simmons, E., Scudder, M., Berg, E., Morgan, T. & Hayes, S. (2015). Oregon's Forest Products Industry and Timber Harvest, 2013. Draft tables at: http://www.bber.umt.edu/pubs/forest/fidacs/OR2013.pdf

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 the work that Dr. Jeff Hatten (OSU) will do in collaboration with 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-, 1 yr post- and 2 yr post for elemental contents stable isotopic ratios, 3) examine whole soils pre-, post-, 1 yr post- and 2 yr 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. Hatten will be ultimately responsible for all work completed under this scope of work and he will oversee one MSc level student that will be conducting most of the work on the project with the assistance of undergraduate workers.

1) Soil moisture and temperature.

We will monitor 32 soil locations in all treatment plots (7 treatments (A, B, C, D, E, F, and G)* 4 replicates) and additional stations installed in the uncut forest (4 replicates). These soil monitoring stations will include Decagon data loggers with 1 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.

Will examine composited soils from the <2.0mm size fraction collected pre-, post-, 1 yr post- and 2 yr post-harvest from 5 treatments (A, B, C, D, and E) + the uncut forest. (6 treatments * 4 replicates = 24 plots). Pre- and post-harvest soils have been collected to 100cm and will be analyzed to that depth. We will collect soils from 25 locations in plot from the 0-15cm horizon and forest floor for the 1 yr post- and 2 yr post-harvest assessment. We analyze the carbon (C) and nitrogen (N) content and stable isotopic composition of whole soils, three density fractions, and roots (from pre-harvest sample collection only).

3) Exchangeable nutrient pools.

We will examine the available nutrient pools of the surface soil and O-horizons for pre-, post-, 1 yr post- and 2 yr post-harvest assessments in 5 treatments (A, B, C, D, and E) and the uncut forest. We will examine exchangeable nitrate and ammonium using KCl extractions and Bray extractable P. These extracts will be analyzed by our team in the IWW collaboratory. Exchangeable cations will be extracted using ammonium acetate and analyzed using an ICP in the central analytical lab.

4) Pan lysimeters.

We will develop, construct, and install two pan lysimeters into each replicated of 5 treatments (A, B, C, D, and E) and the uncut forest. We will also collect atmospheric deposition and throughfall deposition from this apparatus and a limited number of locations. Soil solutions from these lysimeters will be collected and analyzed once per month (when present). We will examine these solutions for nitrate, ammonium, total N (DON by difference), TOC, ortho-phosphate in the IWW collaboratory. Cations will be analyzed using an ICP in the central analytical lab.

5) Foliar response.

During year 2 will assess tree heights and foliar concentrations of nutrients in 5 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). Will collect and composite 1 year old foliage from 5 trees. Foliage will be analyzed for Total C, N, P, Ca, Mg, K, and Al. We will also send foliage to be analyzed for 13C and 15N.

6) Soil respiration.

We will take soil respiration measurements once per month in 5 treatments (A, B, C, D, and E) and the uncut forest from 4 locations per plot. These measurements will be made for at least 2 growing seasons. Soil respiration measurements will be made with a LiCor 8100 and 10cm soil respiration chamber. At each location will install two kinds of soil collars: 6cm inserted 1 cm into mineral soil with no O horizon and 35 cm inserted 30cm into mineral soil to exclude roots. From each location will collect three kinds of soil respiration: 1) total soil respiration + O horizon respiration – soil respiration chamber set directly on soil surface, 2) total soil respiration – soil respiration chamber set on 6cm soil collar, and 3) heterotrophic soil respiration + O horizon respiration – soil respiration chamber set on 35cm soil collar.

Activities and Results

We approached the study of soils and long-term site productivity with a set of questions that had not been directly approached in the scientific literature: Do higher soil temperature and moisture after harvesting and organic matter removal result in higher heterotrophic activity? Does this higher activity result in higher than expected nutrient (i.e. N) availability that subsidizes early tree nutrition? To this end we have installed soil moisture and temperature probes, pan lysimeters, and soil respiration collars. These data have been collected since about December 2012 and continue to be collected. We have also performed density fractions that will be analyzed for 13C and 15N to examine relative rates of soil C and N cycling. Preliminary results support our hypothesis that these OM removal experiments result in warmer soil temperatures (Figure SM-SP-8.1). Interestingly, we have found that the effects of organic matter removal have propagated to 100cm depth, a phenomena that has not been reported in the literature. However, the effect of soil temperature has not caused a subsequent increase in periodic measures of heterogenic activity (i.e. soil respiration), but we still need to examine trends in an accumulated signal of heterotrophic activity (e.g. 13C and 15N of soils). We will continue this research by performing density fractionations on soils collected during the early part of this summer (2015). These density fractions will be examined for stable isotopes which will elucidate whether or not C and N are being cycled differently in the soil. Additionally, we have acquired funding to examine the hypothesis that roots from the previous stand subsidize regrowing stand and soil carbon. We will examine the whole soils and density fractions for biomarkers of lignin, cutin, and suberin in order to determine if these roots are contributing a significant amount of carbon to soil carbon pools in the first 2-years after harvest.

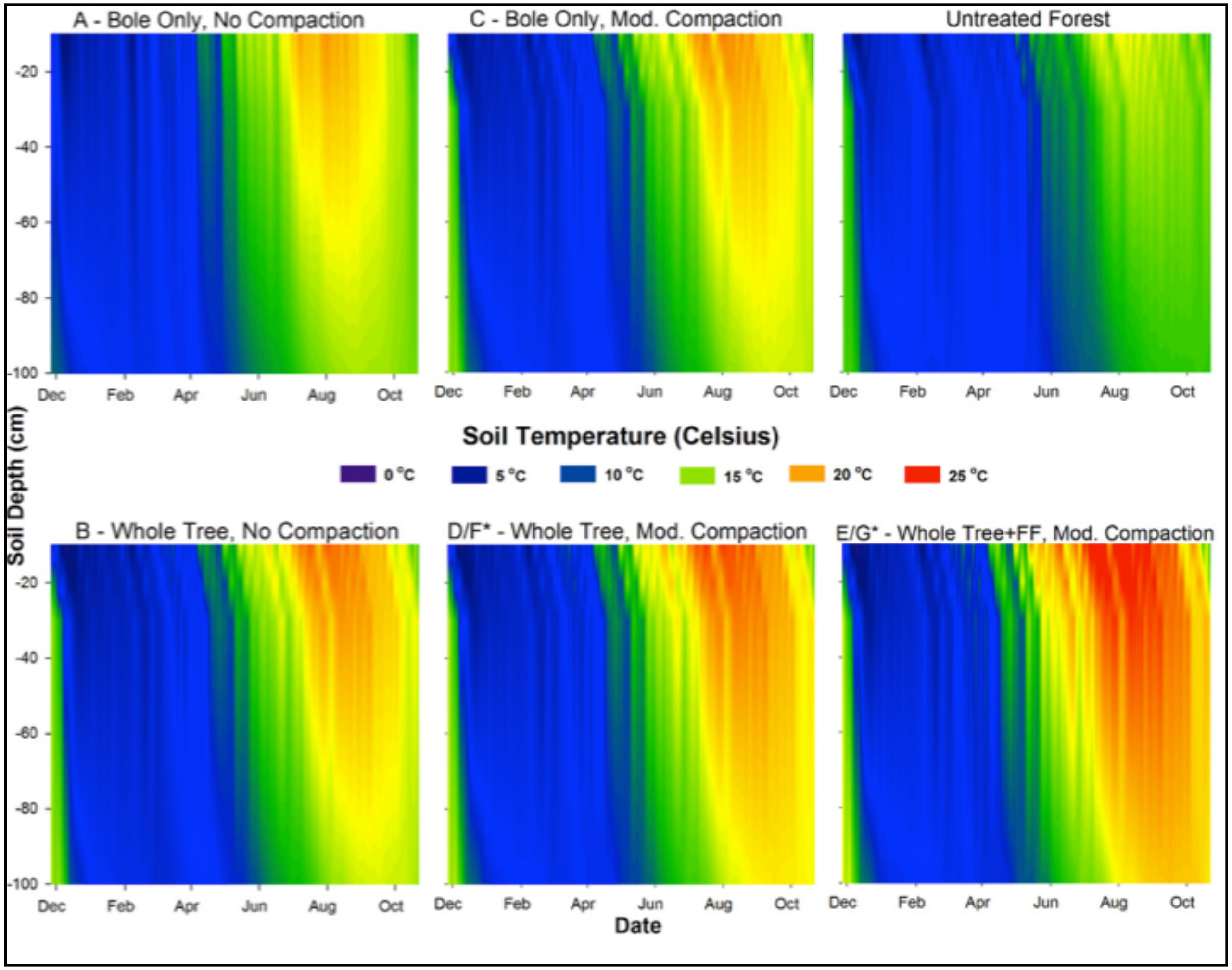


Figure SM-SP-8.1. Soil temperature heat maps across the first year after treatment (months 6-17).

Recommendations | Conclusions

We have found a significant change in soil temperature in the whole soil profile, including deeper portions of the soil. We are currently focusing on trying to determine if this change in soil temperature has resulted in any effect on heterotrophic activity. We will be examining periodic measurements of soil respiration. We will also examine the stable isotopic signature of soils to determine if N is cycling at a faster rate, which would suggest that these high soil temperatures drive higher mineralization rates that may prop up tree productivity.

Physical and Intellectual Outputs

RESEARCH PRESENTATIONS

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

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

Gallo, A., J.A. Hatten. 2014. Long-term soil productivity on managed forests: Mechanisms of apparent resilience after intensive biomass removal. Western Forestry Graduate Research Symposium. Corvallis, Oregon. April 21-22. (Poster)

Holub, S., R. Harrison, and J. Hatten. 2014. How do removals affect long-term productivity?: Long-term Soil Productivity (LTSP) studies. Seatac, Washington. September 16-18. (Oral)

Holub, S. N. Meehan, R. Meade, G. Johnson, R. Harrison, M. Menegale, J. Hatten, and A. Gallo. 2014. NARA Long-term Soil Productivity (LTSP) Project – 2014 Update. Northwest Advanced Renewables Annual Meeting. Seatac, Washington. September 16-18. (Poster)

Gallo, A., J.A. Hatten. 2014. Long-term soil productivity on managed forests: Mechanisms of apparent resilience after intensive biomass removal. Northwest Advanced Renewables Annual Meeting. Seatac, Washington. September 16-18. (Poster)

Gallo, A., J.A. Hatten. 2014. Immediate response mechanisms to account for sustained tree growth following intensive biomass removal on Long-Term Soil Productivity (LTSP) sites. Soil Science Society of America Annual Meeting. Long Beach, California. November 3-6. (Poster)

Gallo, A., J.A. Hatten. 2015. Immediate response mechanisms to account for sustained tree growth following intensive biomass removal on LTSP sites. Oregon Society of Soil Scientists. Hood River, Oregon. February 26, 2015. (Poster)

Gallo, A., J.A. Hatten. 2015. Immediate response mechanisms to account for sustained tree growth following intensive biomass removal on LTSP sites. Northwest Forest Soils Council. Hood River, Oregon. March 14, 2015. (Oral)

Gallo, A., J.A. Hatten. 2015. Biophysical responses in soil following intensive biomass removals. Western Forestry Graduate Research Symposium. Corvallis, Oregon. April 28, 2015. (Oral)

SYSTEMS METRICS

TECHNO-ECONOMICS TEAM

TASK SM-TEA-1: TECHNO-ECONOMICS ANALYSIS

Key Personnel	Affiliation
Gevan Marrs	Weyerhauser
Tom Spink	TSI

Task Description

Gevan Marrs and TSI will collaborate to construct a complete techno-economic (TEA) 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 (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. Perform 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.

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.

In year four the TEA team will refine and update the TEA for the one selected pretreatment process. The updated TEA will include details specific to a site identified in the NARA IDX process, and have refined process specifications from the one selected pretreatment process. It will incorporate improvements identified through on-going work in other teams, including feedstock logistics and pre-treatment, fermentation and alcohol-to-jet conversion steps, and lignin co-products development and market assessment. Additionally, the product take-away details will be incorporated such that the site-specific bio-jet arrives at specific PNW airport(s), and marketing details of other lignin residue co-products are improved.

An additional task assigned to the TEA team is to partner with Cosmo Specialty Fibers (CSF) in the development of scenarios that convert existing sulfite pulp mills into bio refineries. The result of this work for NARA is an educational opportunity for personnel in CSF and the publication of a generic paper by NARA personnel describing the retrofit possibilities to bio refineries for sulfite pulp mills.

These tasks are summarized and incorporated into the previous tasks as follows:

Task SM-TEA-1.7. Solicit process improvements in key areas and update economics on Mild Bisulfite (MBS) process

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

Task SM-TEA-1.11. Evaluate retrofits of existing sulfite mills to the NARA MBS process

Activities and Results

Figure SM-TEA-1.1 describes the selected NARA Mild Bisulfite (MSB) process as defined by joint work between the ASPEN team and the TEA team. There are eight distinct departments; Feedstock Preparation, Pretreatment, Enzymatic Hydrolysis, Gevo (fermentation to jet), Distribution, Boiler, Co-Products, and Utilities. Six departments are within ASPEN design (Gevo is ASPEN) and two (Utilities and Distribution) are not within ASPEN design.

A rough draft of an integrated bio refinery report (IBRR) is being completed that has the following chapters; Index, Executive Summary, Model Method, Integrated Model, Feedstock Preparation, Pretreatment, Enzymatic Hydrolysis, Gevo, Distribution, Co-Products, Boilers, Utilities, Environmental, Financial, and Appendix. Each chapter includes a process description and ASPEN diagram, Input/output data, Capex, Opex, and Environmental notes. A rough draft IBRR is posted to NARA Google Drive and is intended to be interactive to suggestions, corrections, and general educational purposes. The IBRR is intended as a foundation document for the TEA where ASPEN, and other economic details, are archived.

Figure SM-TEA-1.2 depicts a first draft economic sensitivity analysis of the NARA biorefinery. The four largest drivers in the sensitivity analysis are: Market value of bio-jet, Activated Carbon Market Price, Capex change from base case, and the impact of RINS.

One identified improvement opportunity remains to be quantified – repurposing of an existing asset. The benefit of this is of course dependent upon assumptions about avoided Capex due to re-using assets. Preliminary work has shown it to be very difficult to precisely determine the value, which can be placed on an existing asset, as both buyer and seller want to maximize return. It seems very likely that we will be forced to accept a convention of evenly splitting the difference between zero value and maximum potential value for any assets identified as useful in repurpose. This will dramatically reduce repurpose value compared to common assumptions in the literature, where assets are obtained at no cost.

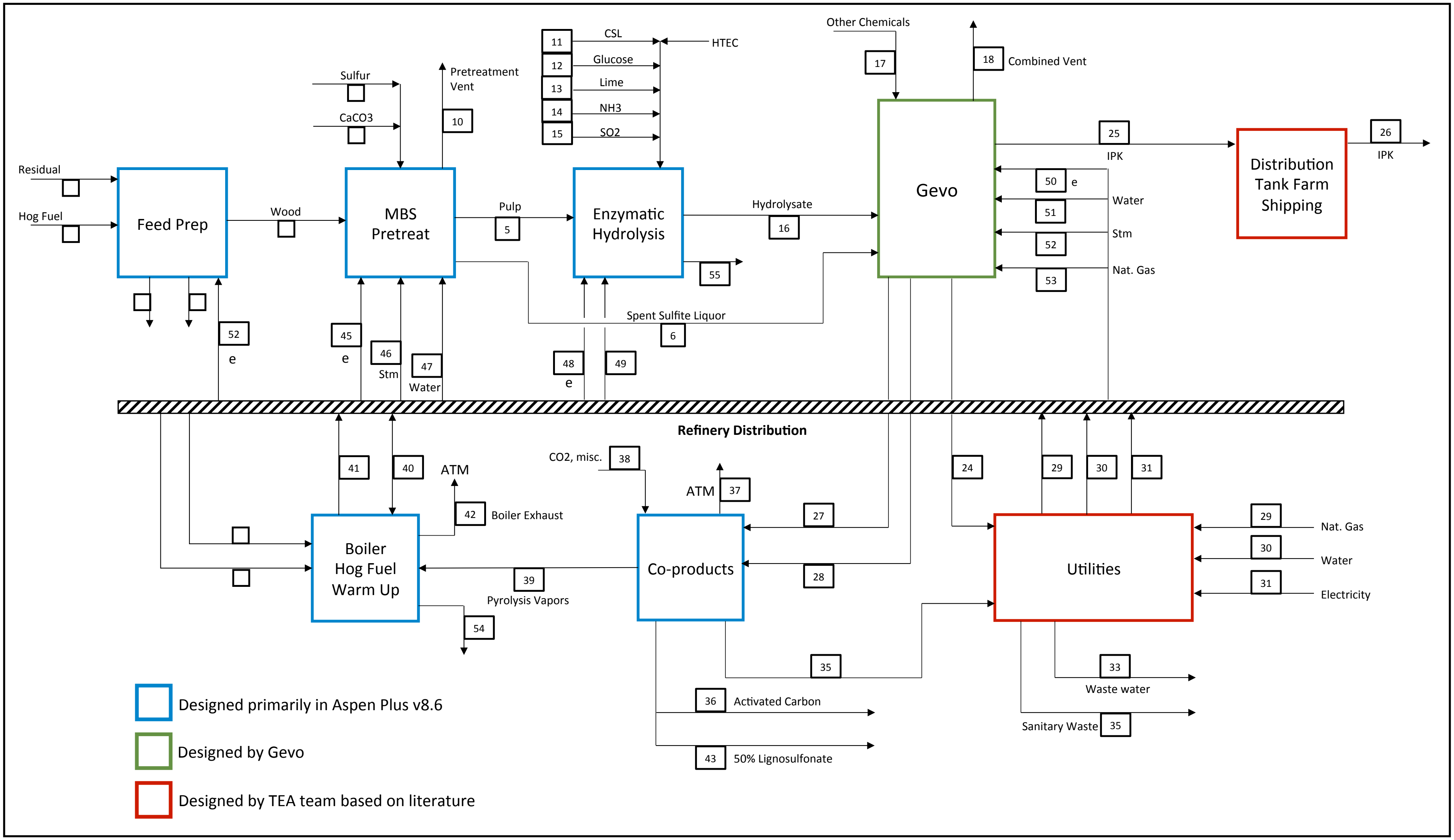


Figure SM-TEA-1.1. Integrated NARA Mild Bisulfite (MBS) Biorefinery Process

Figure SM-TEA-1.3 depicts the first draft for mass and economic value of revenue streams. From this portrayal, it can be seen how significant a large yield drop in activated carbon, and / or loss of RINs, will be to overall project economic return.

Updates to process during this fourth year, and not yet incorporated into Figure SM-TEA-1.3, are;

1) optimization by Gevo to eliminate the production of octane and produce the equivalent amount of iso-paraffinic kerosene (IPK). This increases the overall yield of IPK on wood to 52.4 gallons of IPK

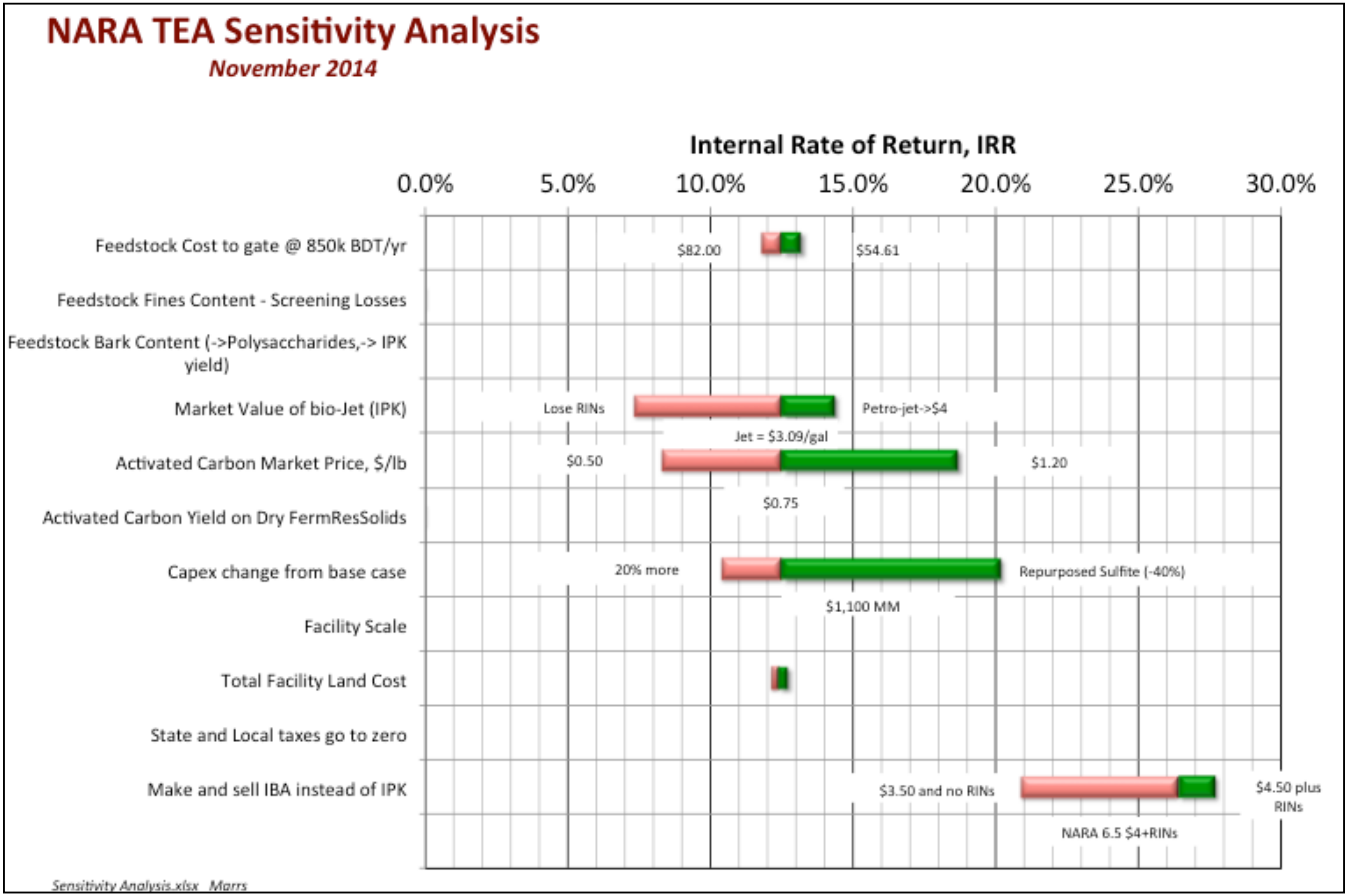
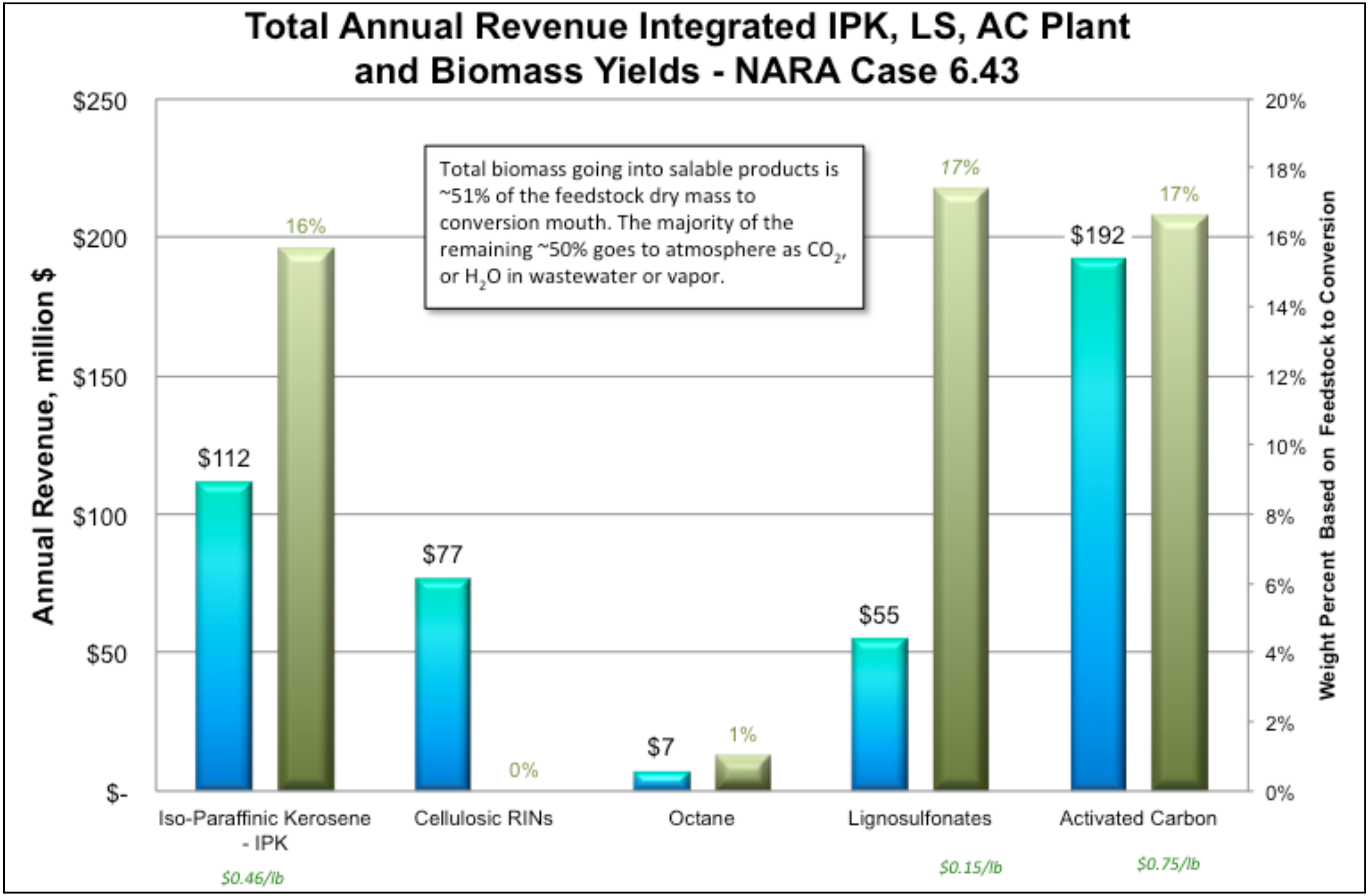


Figure SM-TEA-1.2. Sensitivity Analysis results for some key uncertainty factors showing impact on overall project Internal Rate of Return (IRR).

per bone-dried ton (bdt) feedstock. However, since the added IPK revenue is offset by octane not being sold, the net economic impact is quite small: and 2) further research on activated carbon (AC) has determined that the likely yield is 22.5%, rather then the initially assumed 40%. Because of the significance of AC revenue in the base case shown in Figure SM-TEA-1.3, such a yield reduction reduces annual revenue by about $84 MM, dropping the project initial rate of return (IRR) to about 6.6%. This is obviously a very significant reduction in project attractiveness.



Total biomass going into salable products is ~51% of the feedstock dry mass to conversion mouth. The majority of the remaining ~50% goes to atmosphere as CO_2, or H_2O in wastewater or vapor.

Figure SM-TEA-1.3. Revenue and product yield on feedstock for the major products in TEA Case 6.43.

Recommendations | Conclusions

1. Using the latest "base case" TEA, the expected return on investment is about 12%. For such a large capital investment (>$1 billion), and for a risky facility (having never been built before), this level of return is unlikely to induce investors to commit funds. An IRR somewhere greater than 20 to 25% is realistically required attract interest. Thus, very substantial cost reductions, and / or revenue increases to increase the IRR by such a large amount are required. At this time, no such substantial improvements are being considered by the TEA staff.

2. When the TEA is updated to reflect the now-likely activated carbon yield of 22.5% instead of 40%, the IRR will be substantially lower (about 6.5%). Clearly this makes it even a much greater improvement needed to get to 20-25% IRR.

3. The ASPEN model and Integrated Biorefinery Report (IBRR) is nearing completion of the rough draft. This draft has proven to be much more complex than expected. The draft is to be posted to NARA Google drive in the view only mode to encourage comments, corrections and possible modifications. There is guidance required on future use of the model as to intellectual property (IP) issues, access, and who operates the model. It is recommended that senior leadership be presented issues and options.

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 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 tradeoffs 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 R&D 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 is 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 team in the past three months has been working on completing a draft of the Integrated Biorefinery Report (IBRR). This document is intended to demonstrate the mass and energy flows in the NARA biorefinery as well as the capital and operating costs of each department. The biorefinery overview is seen below in Figure SM-AM-1.1. It is anticipated that this document can be shared with various members of NARA to assist in their work.

In addition, work has continued on the integrated ASPEN model, which is nearly complete. The integrated ASPEN model will contain a majority of the technical information gathered throughout the project, and is intended for use in optimization of the project.

Currently, work is being focused on updating and checking the capital costs of each of the departments and checking the values against known industry sources or publications. In particular, the utilities and enzymatic hydrolysis departments require more work.

Recommendations | Conclusions

The departmental models as is are nearing completion, and we have accurate information for the majority of departments. The co-products economics remains a great uncertainty. It appears that the volume of coproducts that we are producing would significantly saturate the current market (both for lignosulfonate and for activated carbon). As a result, these findings should be taken into consideration for the overall techno economic analysis (TEA) of the refinery.

Physical and Intellectual Outputs

RESEARCH PRESENTATIONS

Gao, Allan, Tom Spink and Shulin Chen. 2014. Aspen Plus Process Modeling of NARA Biorefinery Departments. 2014 NARA Annual Meeting, Seattle, WA, September 15-17 (poster).

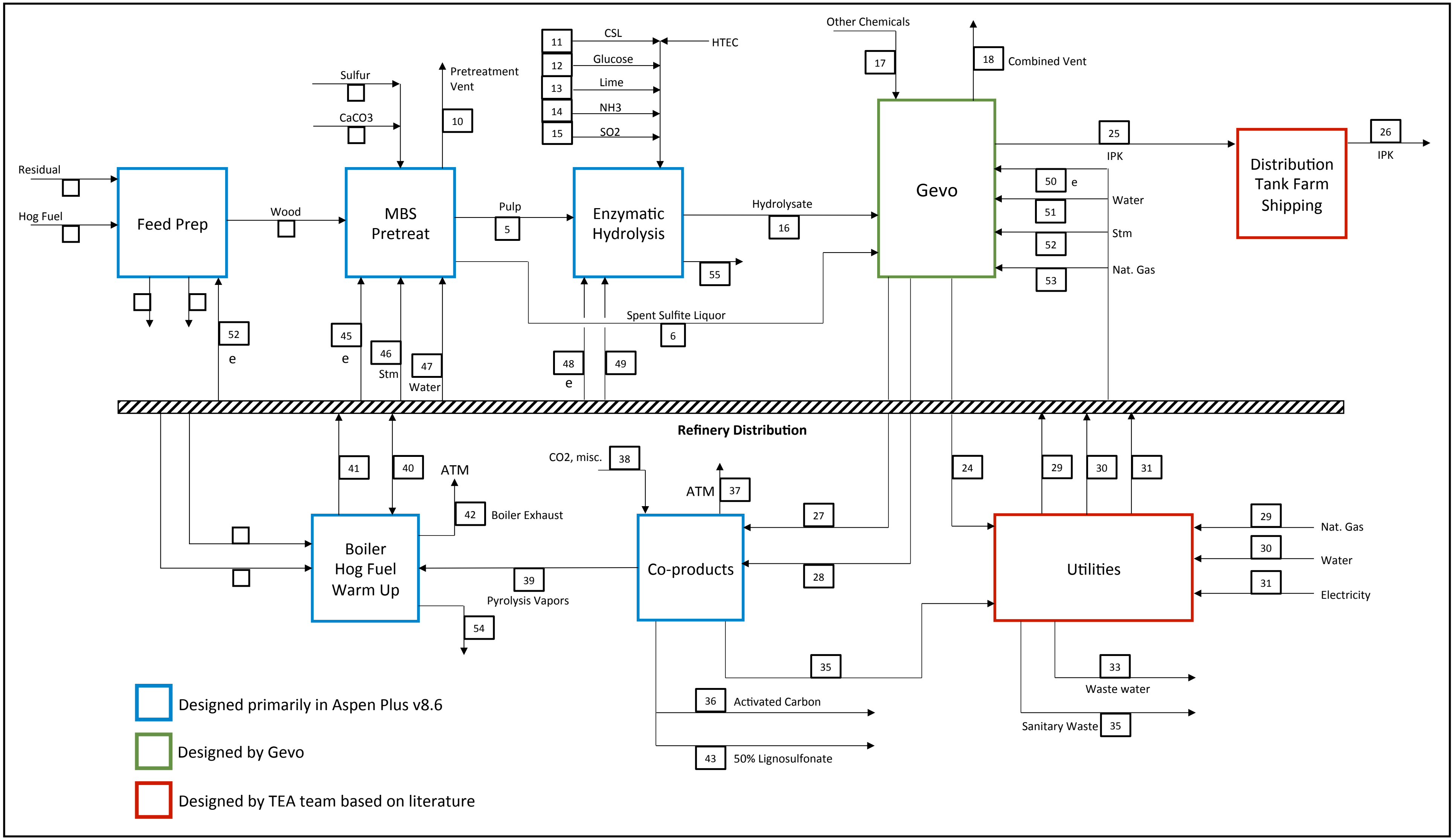
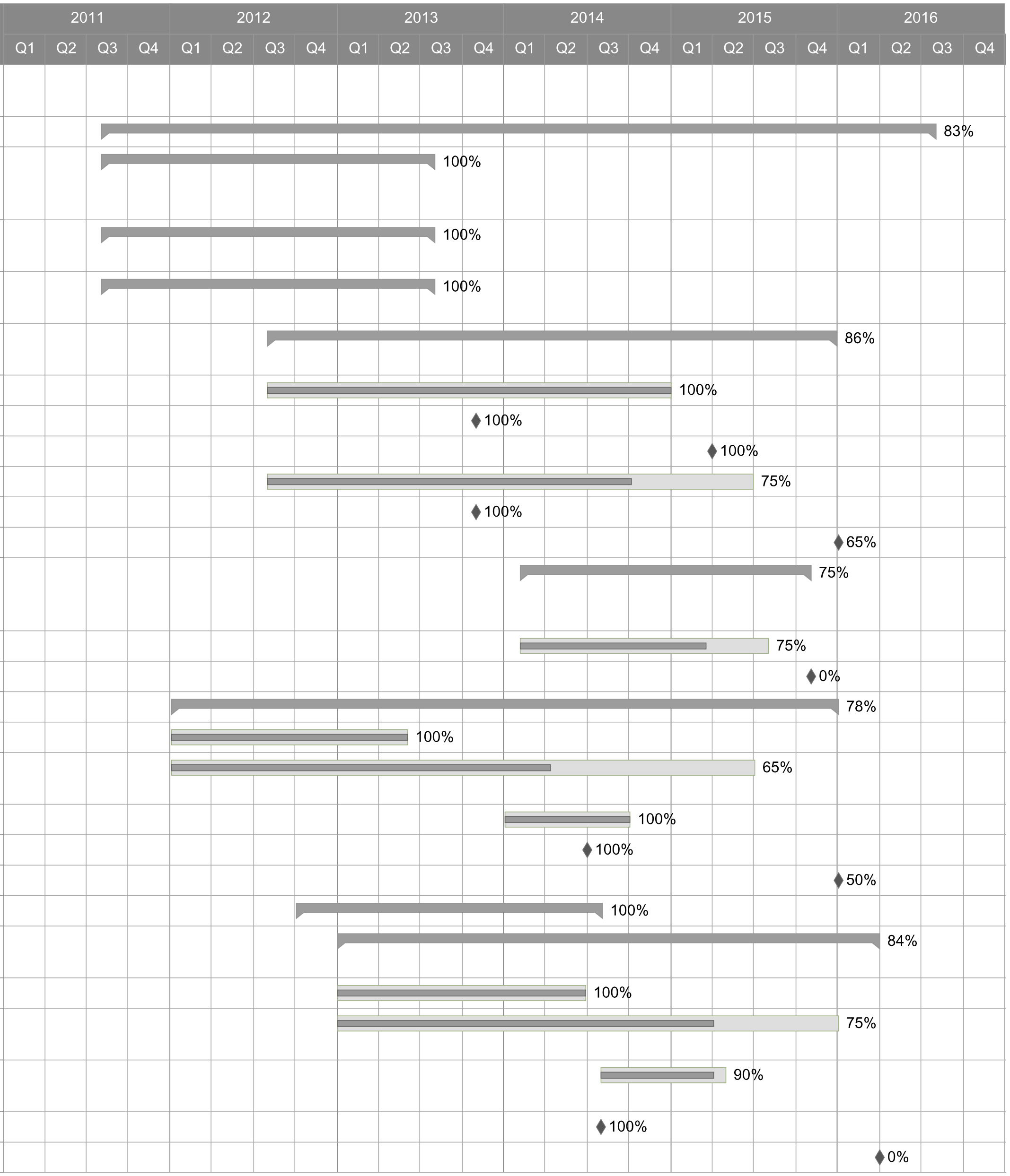


Figure SM-AM-1.1. Refinery overview with process streams

SystemsMetrics_EPP

	Task Name	
1	SYSTEMS METRICS - ENVIRONMENTALLY PREFERRED PRODUCTS TEAM	
2	⊟ SM-EPP-1. Environmentally Preferred Products	83%
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%
8	⊞ Task SM-EPP-1.2. Review Sustainability Approaches: ecolabels, stds., product claims, LCA/EIO data sources & models	100%
13	⊞ Task SM-EPP-1.3. Review Regional Bioenergy Stakeholder Perceptions: issues, influencial groups, etc.; NARA site personal/focus group interviews and analysis	100%
26	⊟ Task SM-EPP-1.4. "Informed" stakeholder interaction/operationalization (pop's., sampling, constructs, protocols)	86%
27	Western Montana Corridor (WMC)	100%
28	Preliminary Report	◆ 100%
29	Final Report	◆ 100%
30	West Side (WS)	75%
31	Preliminary Report	◆ 100%
32	Final Report	◆ 65%
33	⊟ Task SM-EPP-1.5. Refine Operationalization – pop's., sampling, constructs, protocols – select additional NARA community sites and provide Social Hotspot Analysis	75%
34	Nara community SH interviews	75%
35	Report	◆ 0%
36	⊟ Task SM-EPP-1.6. Techno-Market Assessment: Jet Fuels	78%
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	65%
39	Identify key channels, buyers & specifiers for select aviation fuels in the PNW	100%
40	Jet fuel products - data collection preliminary report	◆ 100%
41	Jet fuel products - data analysis report	◆ 50%
42	⊞ Task SM-EPP-1.7. Economic, Environmental & Social Assessment: Jet Fuels	100%
46	⊟ Task SM-EPP-1.8. Techno-Market Assessment: BioProduct Polymers (1-2 product categories)	84%
47	Examine & define market opportunities for select co-products	100%
48	Collect co-products data from U.S. biorefineries via secondary and primary data collection	75%
49	Identify key channel, buyers & specifiers for select bio-based polymer co-products in PNW	90%
50	Bio-based polymer co-products - data collection preliminary report	◆ 100%
51	Bio-based polymer co-products - data analysis report	◆ 0%



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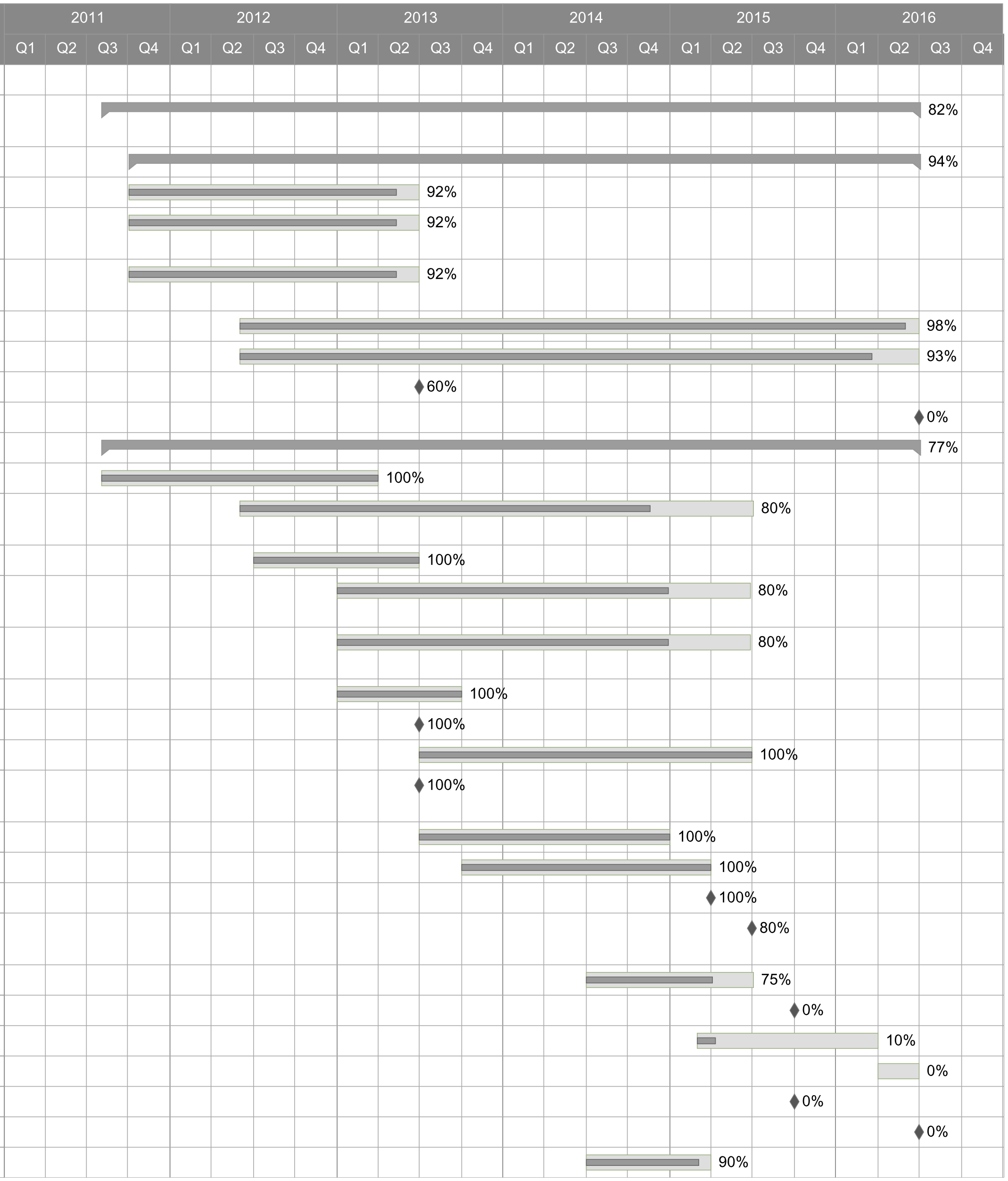
	Task Name
52	Task SM-EPP-1.9. Economic, Environmental & Social Assessment: BioProduct Polymers
53	Collaborate w/ LCA & SH NARA teams to develop env & social hotspot analyses
54	Define select "ideal" bio-based polymer co-products & substitutes in terms of properties, prices, & other attributes; Evaluate env/social criteria; Dev value props
55	Incorporation of co-product modules into parameterized biojet model
56	Task SM-EPP-1.10. Prototype Integrated EPP Protocol
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
58	Develop an EPP marketing and procurement decision support tool to integrate economic, environmental and social impacts of NARA biojet and co-products
59	Final EPP Report

SystemsMetrics_LCA

NARA

	Task Name	
1	SYSTEMS METRICS - LCA & COMMUNITY IMPACT TEAM	
2	SM-LCA-1. LCA Assessment of Using Forest Biomass as a Feedstock for Biofuels	82%
3	Task SM-LCA-1.1. Soil Carbon Analysis	94%
4	Review literature on carbon impacts of forest thinning and residual collection	92%
5	Review literature of carbon implications of alternate systems for harvest, collection and transport of forest thinnings and residuals	92%
6	Review literature of impacts of collecting forest thinnings and residuals on soil carbon and stand productivity including the soil impact of avoided wildfires	92%
7	Review impact of forest residual removal on soil carbon and stand productivity	98%
8	Collect soil carbon data	93%
9	Preliminary report	60%
10	Final report	0%
11	Task SM-LCA-1.2. LCA Analysis	77%
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)	80%
14	Develop framework LCA analysis for forest residuals (Inland Empire)	100%
15	Conduct framework LCA analysis for pretreatment (in conjunction with Gevo and Catchlight)	80%
16	Integrate framework forest residual and pretreatment LCA with biofuel LCA (with Gevo)	80%
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)	100%
20	Preliminary LCA framework with report for complete process (Inland Empire) (in conjunction with Gevo and Catchlight)	100%
21	Develop framework LCA analysis for forest residuals (NARA Community #2)	100%
22	Collect LCA data for NARA Community #2	100%
23	Preliminary LCA report for feedstock (NARA Community #2)	100%
24	Preliminary LCA framework with report for complete process (NARA community #2) in conjunction with Gevo and Catchlight	80%
25	Integrate LCA data into framework LCA (NARA Community #2)	75%
26	Complete LCA analyses for both locations	0%
27	Conduct peer review of LCA data and revise	10%
28	Upload LCI data to national databases	0%
29	Preliminary LCA report	0%
30	Final LCA Report	0%
31	Identify potential alternative pathways for biomass to alcohol/biofuel	90%



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	Task Name	
32	Develop LCA framework for selected alternative pathway	30%
33	Integrate LCA data into framework for alternative route	10%
34	Develop publications for alternate pathway LCA	10%
35	Task SM-LCA-1.3. Community Economic Impact Assessment	70%
36	Review literature on rural economic impact and infrastructure requirements	80%
37	Model community economic impacts of biofuel production for both locations	60%
38	Preliminary Economic Impact Report	50%
39	Final Economic Impact report	0%

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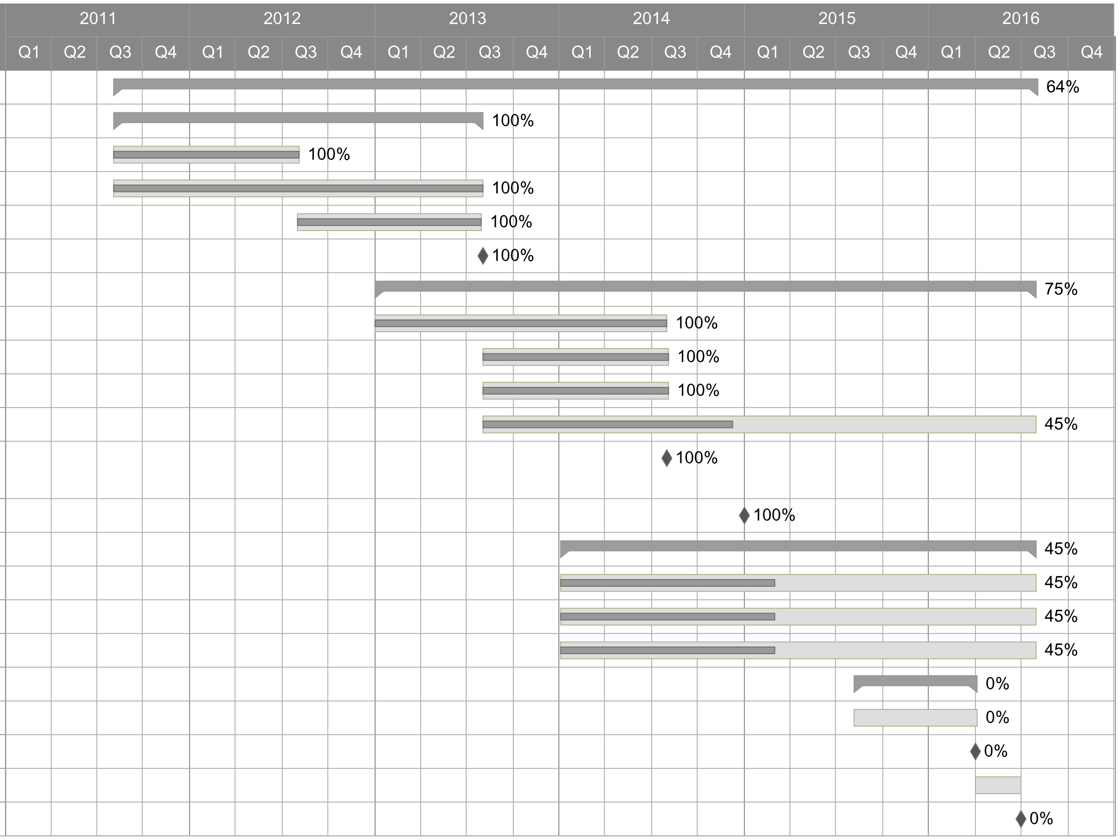
SustainableProduction_Holub

	Task Name	
1	SM-SP-1. Sustainable Feedstock Production Systems	64%
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	75%
8	Harvest stands and apply treatments	100%
9	Construct Fences	100%
10	Plant seedlings	100%
11	Post planting assessment and measurements	45%
12	Stands harvested and treatments applied, fences constructed, seedlings planted	100%
13	Establishment Report	100%
14	Task SM-SP-1.3. On-going plot maintenance	45%
15	Maintain fences and weed control	45%
16	Weather station monitoring and maintenance	45%
17	General site maintenance	45%
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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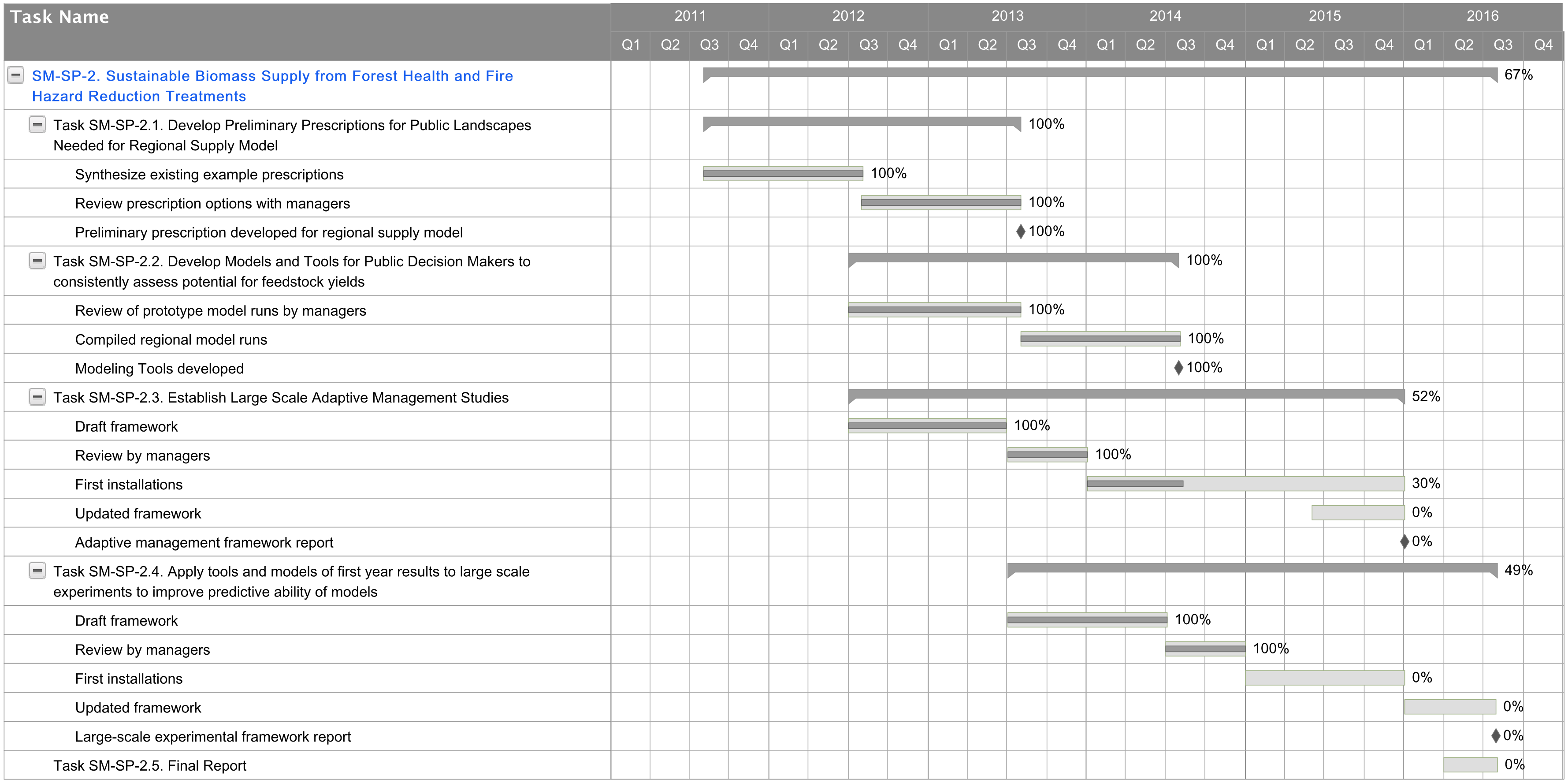

	Task Name	
1	SM-SP-2. Sustainable Biomass Supply from Forest Health and Fire Hazard Reduction Treatments	67%
2	Task SM-SP-2.1. Develop Preliminary Prescriptions for Public Landscapes Needed for Regional Supply Model	100%
3	Synthesize existing example prescriptions	100%
4	Review prescription options with 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	100%
10	Task SM-SP-2.3. Establish Large Scale Adaptive Management Studies	52%
11	Draft framework	100%
12	Review by managers	100%
13	First installations	30%
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	49%
17	Draft framework	100%
18	Review by managers	100%
19	First installations	0%
20	Updated framework	0%
21	Large-scale experimental framework report	0%
22	Task SM-SP-2.5. Final Report	0%

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SustainableProduction_Adams_Latta

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

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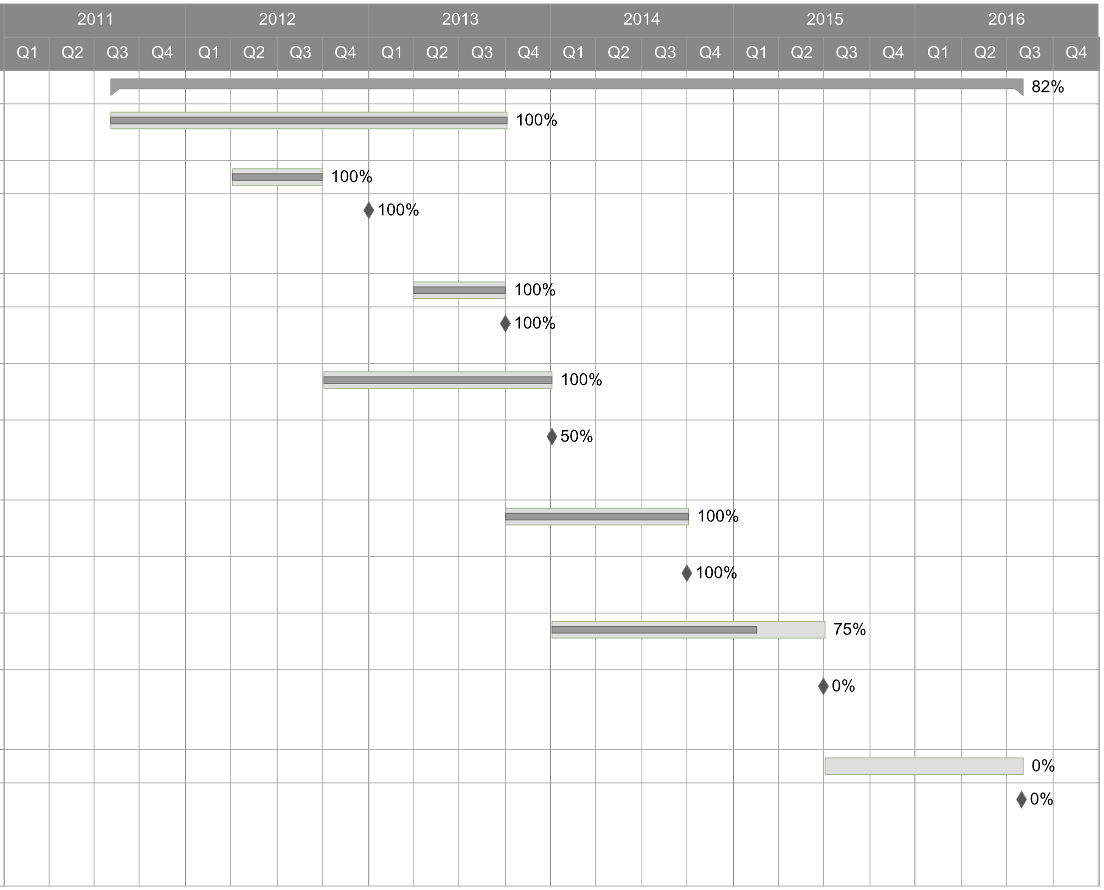
SustainableProduction_Maguire

	Task Name
1	SM-SP-4. Long Term Productivity Studies
2	Task SM-SP-4.1. Develop allometric equations for managed stands
3	First season of biomass sampling
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
5	Second season of biomass sampling
6	Complete second field season of biomass sampling; complete database for both field seasons of biomass sampling; develop biomass equations
7	Task SM-SP-4.2. Estimate nutrient and carbon removals under various levels of biomass harvesting
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
9	Task SM-SP-4.3. Determine sustainable levels of bioenergy feedstock under range of silvicultural intensities
10	Sustainable levels of bioenergy feedstock production determined under a range of silvicultural intensities using forest simulation models
11	Task SM-SP-4.4. Estimate changes in long term site productivity under different climate change scenarios
12	Changes estimated in long-term site productivity under different rates of biomass removals and different climate change scenarios using forest simulation models
13	Task SM-SP-4.5. Synthesis of Results & Final Report
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



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SustainableProduction_Petrie_Lamb

	Task Name	
1	SM-SP-5. Environmental Impact Analysis to Support NARA Biofuel Development in the Pacific Northwest	61%
2	Task SM-SP-5.1. Water Resources Component	58%
23	Task SM-SP-5.2. Air Component	63%
24	Task SM-SP-5.2.1. Regional analysis of supply chain scenarios for air quality	49%
25	Develop scenarios for evaluation of air quality	25%
26	Set-up, evaluate multi-scale air models	80%
27	Run and appraise model, evaluate future impacts	50%
28	Task SM-SP-5.2.2 Assessment of the positive impact of reduced prescribed fires	100%
29	Analysis of prescribed fire impacts on air quality	100%
30	Base case (no fire emissions)	100%
31	Prescribed fire case (with all prescribed fire emission data from NFEI 2011)	100%
32	Sensitivity analysis case	100%
33	Final report	20%

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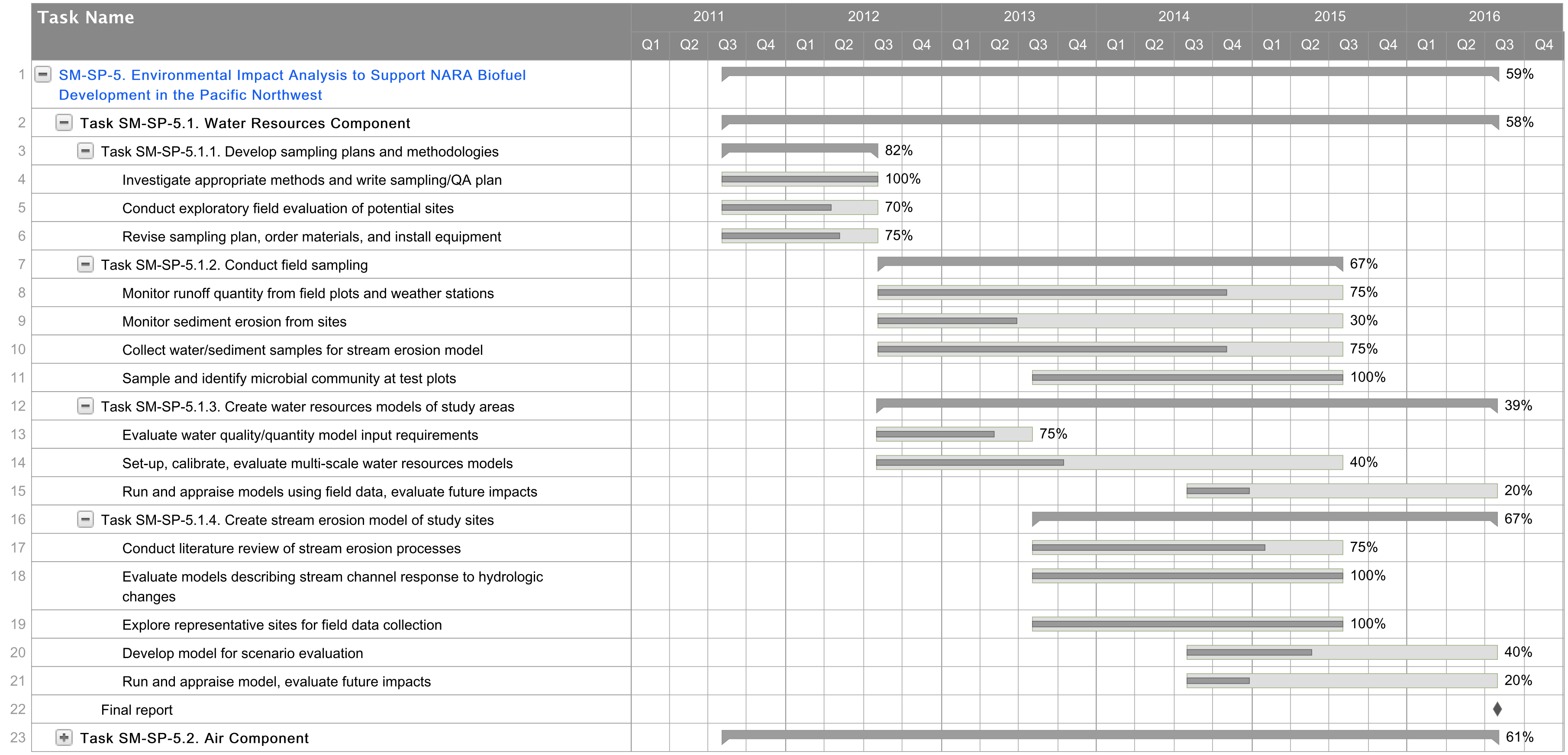
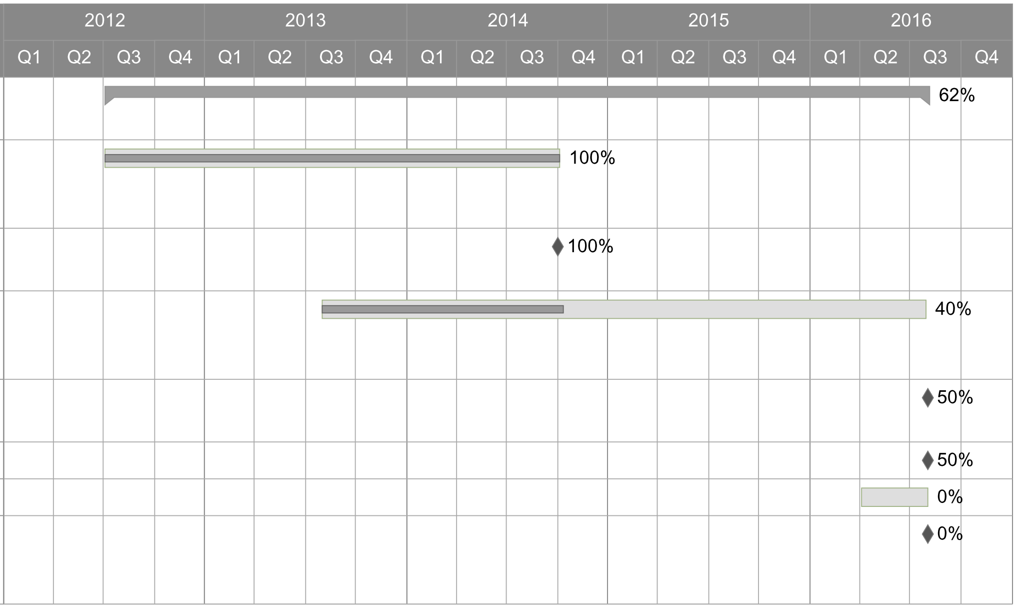
SustainableProduction_Petrie_Lamb



	Task Name	
1	SM-SP-5. Environmental Impact Analysis to Support NARA Biofuel Development in the Pacific Northwest	59%
2	Task SM-SP-5.1. Water Resources Component	58%
3	Task SM-SP-5.1.1. Develop sampling plans and methodologies	82%
4	Investigate appropriate methods and write sampling/QA plan	100%
5	Conduct exploratory field evaluation of potential sites	70%
6	Revise sampling plan, order materials, and install equipment	75%
7	Task SM-SP-5.1.2. Conduct field sampling	67%
8	Monitor runoff quantity from field plots and weather stations	75%
9	Monitor sediment erosion from sites	30%
10	Collect water/sediment samples for stream erosion model	75%
11	Sample and identify microbial community at test plots	100%
12	Task SM-SP-5.1.3. Create water resources models of study areas	39%
13	Evaluate water quality/quantity model input requirements	75%
14	Set-up, calibrate, evaluate multi-scale water resources models	40%
15	Run and appraise models using field data, evaluate future impacts	20%
16	Task SM-SP-5.1.4. Create stream erosion model of study sites	67%
17	Conduct literature review of stream erosion processes	75%
18	Evaluate models describing stream channel response to hydrologic changes	100%
19	Explore representative sites for field data collection	100%
20	Develop model for scenario evaluation	40%
21	Run and appraise model, evaluate future impacts	20%
22	Final report	♦
23	Task SM-SP-5.2. Air Component	61%

SustainableProduction_Betts

	Task Name	
1	SM-SP-6. Local and Regional Wildlife Impacts of Biomass Removals	62%
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	100%
3	Literature review summarizing impacts of biofuel extraction on biodiversity and identifying empirical research needs	100%
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	40%
5	Report summarizing demographic effect of biofuel extraction on songbirds (from empirical study)	50%
6	Report summarizing pollinator impacts from WY LTSP field work	50%
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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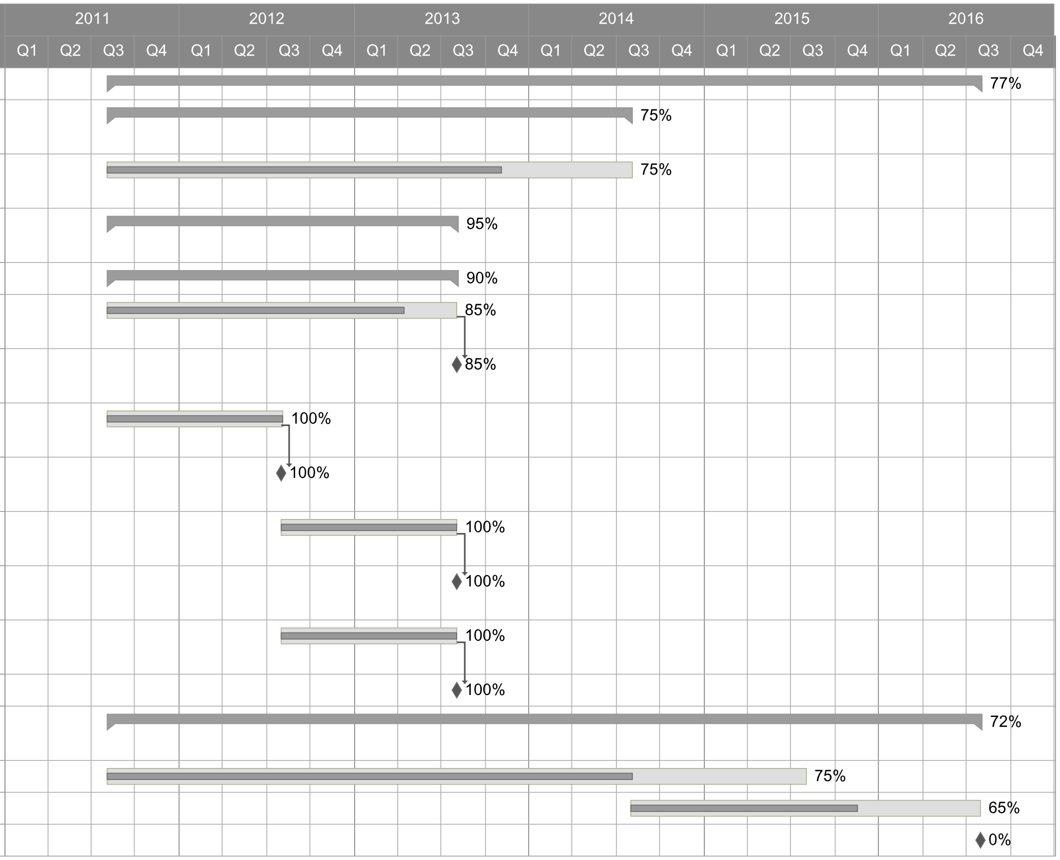
SustainableProduction_Morgan



	Task Name	
1	SM-SP-7. Supply Chain Analysis	77%
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	75%
3	Coordinate with "west-side" modeling team on data needs and standards for Idaho & Montana	75%
4	Task SM-SP-7.2. Enhance and update primary mill residue and capacity information for 4-state region	95%
5	Task SM-SP-7.2.1. Survey of primary mill facilities in Washington and Oregon	90%
6	Cooperate with Washington DNR on mill surveys to collect mill residue and capacity information	85%
7	Washington primary mill (residue, wood use, capacity, etc.) data available for modeling	85%
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	72%
15	Conduct logging utilization studies in Idaho, Montana, Oregon and Washington	75%
16	Incorporate updated logging residue data into woody supply analysis	65%
17	Final report on forest/logging residue and primary and secondary mill residue	0%

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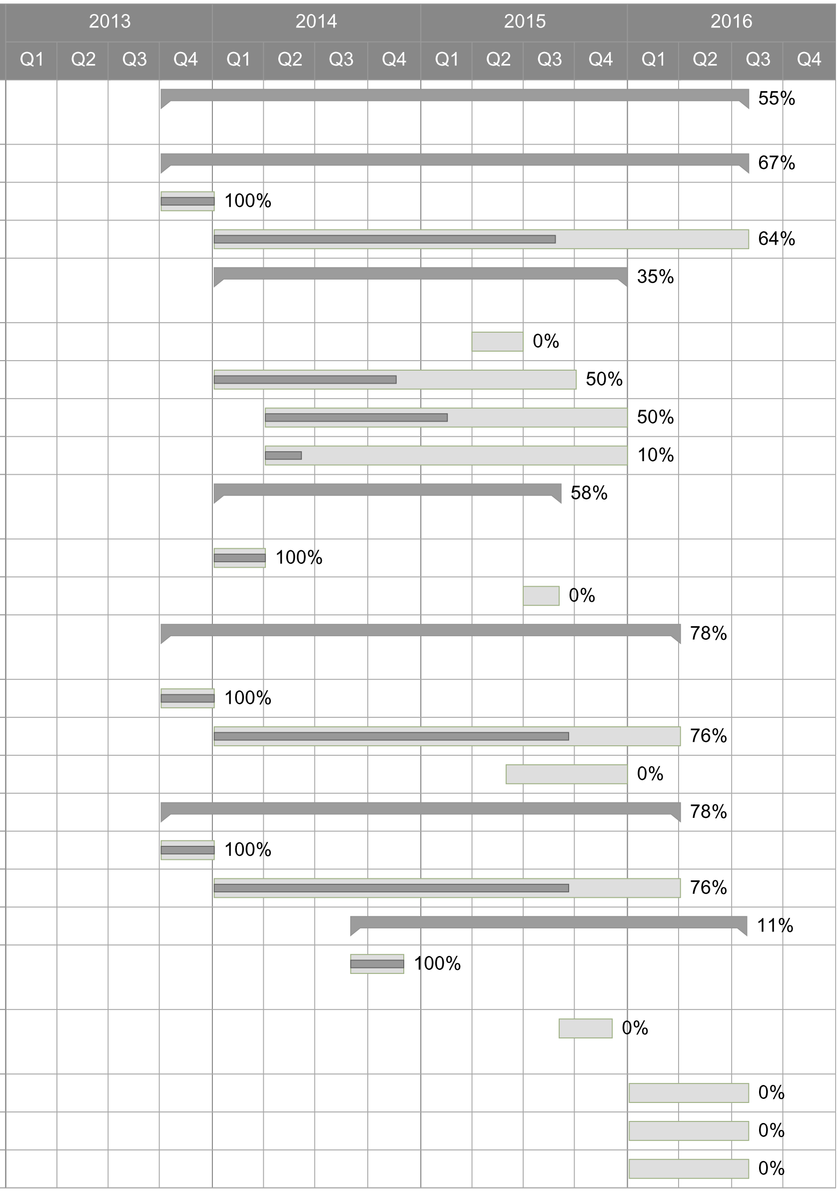
SustainableProduction_Hatten

NARA



	Task Name	
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	55%
2	Task SM-SP-8.1. Monitor and report on soil moisture and temperature data	67%
3	Soil Moisture Installation	100%
4	Soil Moisture and Temperature Measurements	64%
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	35%
6	Soil Collection - Year 2 after treatment	0%
7	Density Fractionations	50%
8	Elemental Determinations	50%
9	Stable Isotope Determinations	10%
10	Task SM-SP-8.3. Examine whole soils pre-, post-, 1 yr post- and 2 yr post for exchangeable nutrient pools	58%
11	Available Nutrients pre- and post-treatment	100%
12	Available Nutrients 2 yr post-treatment	0%
13	Task SM-SP-8.4. Examine inputs of carbon and nutrients into mineral soils using pan lysimeters	78%
14	Pan Lysimeter Installation	100%
15	Pan Lysimeter Solution Collection	76%
16	Task SM-SP-8.5. Foliar response to soil changes	0%
17	Task SM-SP-8.6. Examine soil carbon cycling through soil respiration	78%
18	Respiration Collar Installation	100%
19	Soil Respiration Measurements	76%
20	Task SM-SP-8.7. Manuscript, Report Preparation, Data Archive	11%
21	Milestone/Deliverable 1: Conference presentation on effect of compaction on distribution of soil carbon and nutrients	100%
22	Milestone/Deliverable 2: Conference presentation on the effect of organic matter removal on soil carbon and nutrients	0%
23	Milestone/Deliverable 3: Manuscript preparation on soil carbon	0%
24	Milestone/Deliverable 4: Manuscript preparation on soil nutrients and site productivity	0%
25	Milestone/Deliverable 5: Final Report preparation	0%

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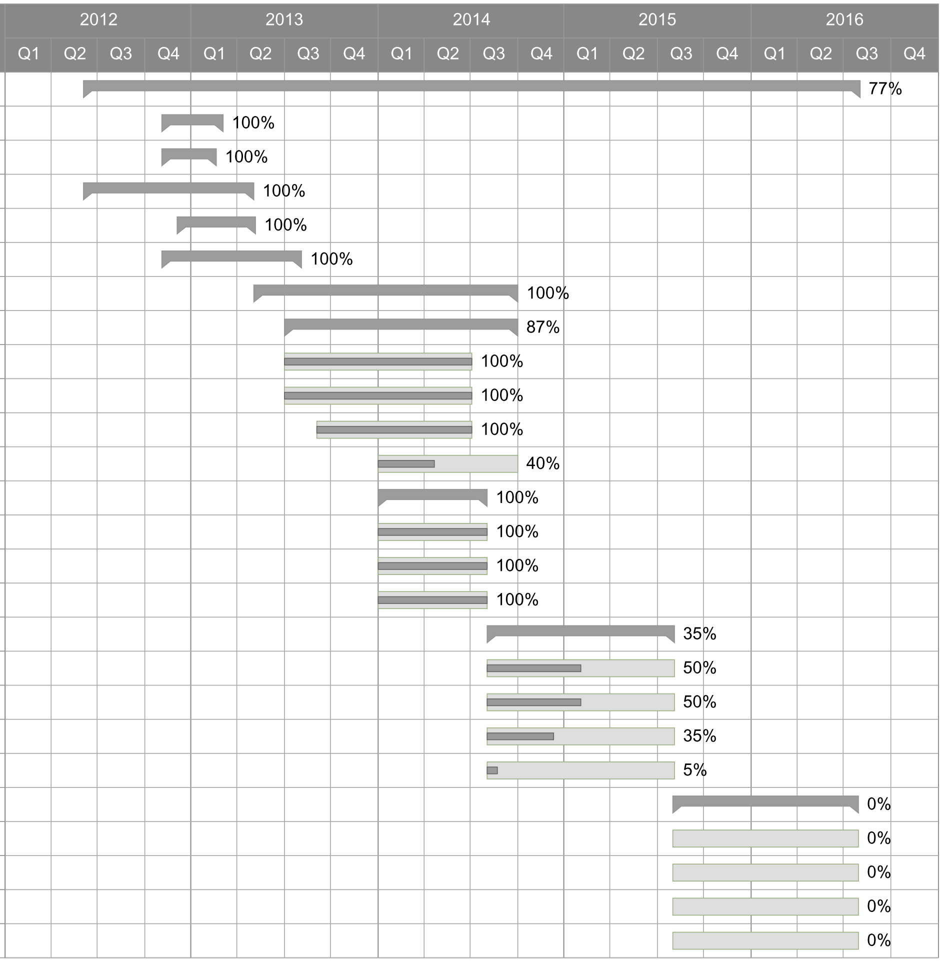
SystemsMetrics_TEA

	Task Name	
1	SM-TEA-1. Techno-Economic Analysis	77%
2	Task SM-TEA-1.1. Build and populate first-cut NARA project TEA model framework	100%
4	Task SM-TEA-1.2. Obtain and Assemble first-cut Capital Cost Estimates	100%
7	Task SM-TEA-1.3. Obtain and Assemble first-cut Process Flow and Operating Cost Estimate	100%
18	Task SM-TEA-1.4. Construct first-cut pass at overall economics	100%
23	Task SM-TEA-1.5. Summarize reporting elements and communicate with stakeholders	100%
29	Task SM-TEA-1.6. Evaluate the Pretreatment options on an equitable basis	100%
33	Task SM-TEA-1.7. Solicit process improvements in key leverage areas and update economics	87%
34	Hold communications meetings with key NARA task elements and explain results	100%
35	Work with NARA staff to identify key improvement possibilities	100%
36	Modify TEA model to incorporate speculative improvements and quantify impact	100%
37	Document key findings and recommend path(s) forward	40%
38	Task SM-TEA-1.8. Refine and update model for process and siting specificity	100%
39	Identify key process improvement possibilities	100%
40	Quantify and incorporate key feedstock cost reduction discoveries	100%
41	Increase specificity about facility scale, siting, and product off-take plans	100%
42	Task SM-TEA-1.9. Further refine and update model for process and siting specificity	35%
43	Identify additional key process improvement possibilities	50%
44	Quantify and incorporate key feedstock cost reduction discoveries	50%
45	Increase specificity about facility scale, siting, and product off-take plans	35%
46	Investigate specific siting incentives to add to economic feasibility (state, local, etc.)	5%
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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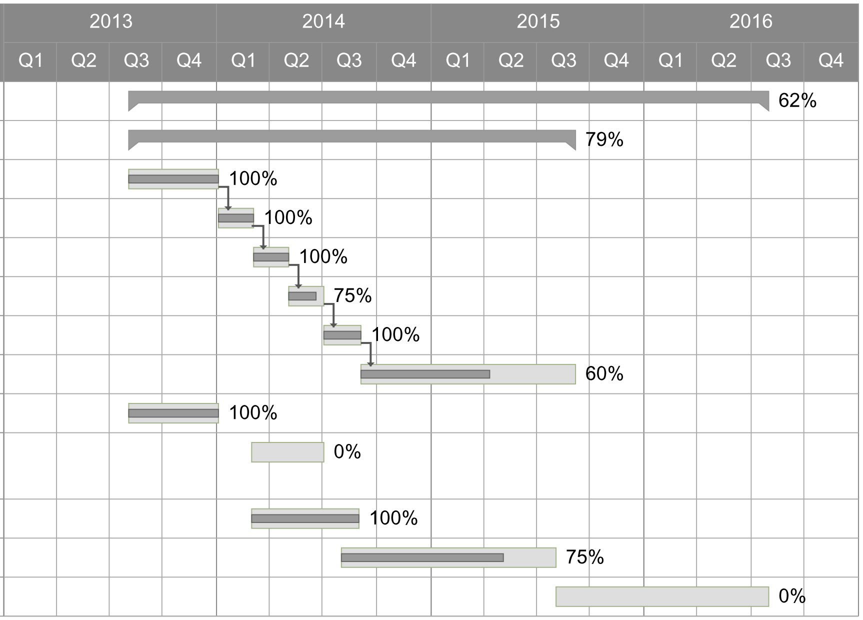
	Task Name
1	⊟ SM-AM-1. ASPEN Modeling of the NARA Conversion Process
2	⊟ Task SM-AM-1.1. Develop integrated ASPEN model for entire plant
3	Feedstock, pretreatment and enzymatic hydrolysis
4	Fermentation, separation, purification
5	Coproduct
6	Multi-functional boiler/utilities
7	IPK, Distillation
8	Integrated model
9	Task SM-AM-1.2. Perform TEA for different pretreatment processes
10	Task SM-AM-1.3. Cost estimation of distributed sugar depot (in coordination with Task E-8 Distributed Sugar Depot, Jinwu Wang & X.Zhang group)
11	Task SM-AM-1.4. Coproduct evaluation and model refinement
12	Task SM-AM-1.5. Directing process improvements in key areas based on TEA
13	Task SM-AM-1.6. Refining and updating models with inputs from other team members



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