NARA | GOAL THREE

August 2011 - March 2013 Cumulative Report

RURAL ECONOMIC DEVELOPMENT

Northwest Advance Renewables Alliance

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

Goal Three: Rural Economic Development:

Enhance and sustain rural economic development

Summary

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

The **Techno-Economic Analysis (TEA) Team** assesses the overall economics of the biofuels production process from feedstock delivered to the mill gate through to biojet sale. This analysis includes the overall production mass and energy balance as well as the value needs for co-products. The TEA models the capital requirement plus the variable and fixed operating costs for producing biojet from forest residuals using our chosen pathways**.**

The **Life Cycle Assessments (LCA) and Community Impact Team** assesses the environmental impact of producing aviation biofuels with our chosen pathway and compares it to the petroleum products for which it will substitute. This assessment covers harvesting options, as well as options for the various production steps. Regional options for harvesting and transportation models are considered. These regional scenarios provide the context to assess the impact of the industrial development on local communities.

To provide more specific information regarding the influence of harvesting forest residuals on sites, soil, and water, the **Sustainable Production Team** evaluates the influence of biomass harvesting scenarios, develops potential forest management prescriptions, assesses forest residual availability from harvest of highly managed stands, and 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 this new industry.

The **Environmentally Preferred Products Team** evaluates the social viability of the industry. This analysis of social sustainability investigates stakeholder needs and perceptions, community social assets, market opportunities for biojet and co-products, and governmental regulations and incentives for renewable products.

To determine future production costs (capital required plus fixed and variable operational costs), the **Techno-economic Team** has constructed a complete techno-economic model for the NARA softwood-to-biojet production. An initial analyses generated from this model includes techno-economic spreadsheets with variable products produced (biojet, isobutanol, lignin co-products) and an "improvement opportunities" analysis spreadsheet (waterfall chart) that shows estimated potential gains with 3-year

improvement ideas at a 50% probability level. Flow diagrams for the 10 key unit operations in the process, including material costs, were constructed. A yield chain spreadsheet for a key metric—gallons of IPK per BDT feedstock—(including all intermediate stage yields as well) was created (Task SM-TEA-1; each task progress is detailed in progress reports following this summary). Significant internal outputs to date for this team are listed below. Additional outputs are listed at the end of each progress report.

- An initial techno-economic model has been prepared that provides 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 analysis identifies key leverage points where resources and alternative thinking can be applied to lower the cost of production.

The **Life Cycle Assessment (LCA)** efforts have been primarily devoted to reviewing previous LCA models, conceptualizing an appropriate LCA model for the NARA project, accumulating input data, and generating assessments. To provide baseline data for nitrogen and carbon content in forest soils, soil analyses have been completed at numerous forested sites in the Pacific Northwest. An assessment of 73 sites in the coastal Douglas-fir region from North Vancouver Island to Southern Oregon compares nitrogen levels to harvest activity (Figure 1; Task SM-LCA-1). An assessment of soil carbon levels in 26 sites was conducted and a complementary study of carbon levels in working forests relative to vegetative control was completed (Figure 2; Task SM-LCA-1). Three environmental assessments were generated. One examined the avoided environmental burdens due to a reduction of slash pile burning (Table 3; Task SM-LCA-1); another assessed the relative environmental burdens of various aspects of biomass harvest and transportation (Figure 4 and 5; Task SM-LCA-1); and a preliminary LCA of the forest to fuel process using secondary data has been completed (Table 4; Task SM-LCA-1). An preliminary comparative analysis was completed that compares aircraft emissions impact on ozone depletion, global warming and fossil fuel depletion when burning biojet and fossil fuel (Tables 5 and 6; Task SM-LCA-1).

To assess the level of economic impact to supply chain communities, the **Community Impact** group has completed preliminary social accounting matrices (SAM) that contain the intra-industry relationships. In addition, the capital and labor flows needed to assess the impact from biojet fuel production have been constructed and populated with data from IMPLAN data covering the NARA region (Tables 1 and 2; Task SM-LCA-1).

Significant internal outputs to date are:

- A preliminary Social Accounting Matrix for the Inland Empire region has been completed.
- NARA has developed a significant partnership with Potlatch Corporation which is currently pursuing an Affiliate Member status. As part of this partnership, Potlatch has donated a dataset of a major biomass and pulpwood thinning trial for use in the LCA analysis.
- A collaborative relationship with researchers at the University of Idaho was established that enables access to the IMPLAN economic data (UI work supported under NIFA; grant # 2010-04759) needed to facilitate the community impact assessment for the Inland Empire region.
- The preliminary results of the LCA emissions comparison of aircraft burning biojet or fossil fuel suggest that the overall global warming potential of the NARA bio-jet fuel, measured in kilograms of CO2 emissions, is just 38.4% that of fossil fuel-based jet fuel (Table 5; SM-LCA-1). In addition, the ozone depletion potential of the NARA bio-jet fuel is approximately 12% that of fossil fuel-based jet fuel while the fossil fuel depletion potential is 39.1% of fossil-based jet fuel. In other words, our preliminary analysis suggests that there is a 61.6% reduction in the global warming

potential, an 88.1% reduction in the ozone depletion potential and a 60.7% reduction in fossil fuel depletion by substituting bio-jet fuel for fossil fuel-based jet fuel. This preliminary result is significant in that it exceeds the mandated 60% emission reduction criterion specified in the US Energy Independence Act guidelines.

To evaluate the environmental effects of biomass harvest and use, the **Sustainable Production Team** has established a new Long Term Soil Productivity (LTSP) site in the southern Willamette Valley of Oregon. Site data for pre-harvest conditions have been collected. Harvesting for implementing the various prescribed treatments has begun. (Task SM-SP-1)

To evaluate the potential effects of biomass harvesting on water quality, erosion and water quality, models are being established and an experimental design for validation is underway. The influence of biojet conversion process on regional air quality, emissions data from a regional sulfite pulp mill has been compiled. This mill utilized a sulfite pulping process, fermented sugars in the spent pulping liquor into ethanol, and produced lignin co-products. The stack data from this mill were separated in process steps and will be used as a step in airshed modeling to understanding how changes to the wood product industry due to new biofuel processing might affect air quality. In addition, air emissions produced from the SPORL pretreatment process have been analyzed under laboratory conditions. (Task SM-SP-5)

Silvicultural prescriptions have been developed for various regions, forest types, and owner groups. These tools are aimed at assessing available biomass feedstock supply from these management objectives and to inform biomass estimates generated for a regional supply model. Preliminary predictions of forest growth and quality control of the method have been completed. To direct the silvicultural prescriptions, baseline fire hazard modeling has been completed across Oregon. These models will inform the effectiveness of thinning regimes and biomass utilization to alter landscape level fire hazard. The framework for several dozen Integrated Fireshed-level Adaptive Management Evaluation Sites (iFLAMES) has been developed. (Task SM-SP-2)

The Forest Inventory and Analysis (FIA) plot data for the NARA study region has been assembled, modified and used to estimate log demand elasticity for Oregon and Washington. The Forest vegetation Simulator (FVS) model has been adapted to allow rapid generation of 100-year projections of timber volumes and biomass under user-specified silvicultural regimes. The model has been used to examine both single and multiple hypothetical biomass destination scenarios. An example biomass supply curve has been generated for a single site case. (Task SM-SP-3) To inform this forest econometrics model, primary mill residue and capacity information has been updated for the NARA region and supplied to NARA researchers for model development and GIS applications. To provide logging residue estimates, 1300 felled trees were measured at 56 sites across the region. (Task SM-SP-7) To provide data used to determine sustainable levels of bioenergy feedstock production, components from 199 trees were sampled and chemical analysis is nearly complete. (Task SM-SP-4)

Significant internal outputs to date are:

- A study location for the LTSP experiment was identified and plotted. Pre-harvest data was collected and treatments have begun. This site will be instrumental in determining the effects of biomass removal on soils, vegetation and wildlife. (Task SM-SP-1)

- A series of regional, forest type, and owner group specific silvicultural prescriptions have been developed in order to better inform biomass estimates generated from the regional supply model. (Task SM-SP-2)

- Baseline fire hazard modeling has been completed across Oregon to measure effectiveness of thinning regimes and ability of the utilization of biomass material to alter landscape level fire hazard. (Task SM-SP-2)

- FVS (Forest Vegetation Simulator) variants in the NARA study region were converted to a composite model based on simplified C++ code, allowing rapid generation of 100-year projections of timber volumes and biomass under user-specified silvicultural regimes. A western Oregon example market projection has been run with the model using timber yield inputs from the C++ code and assumptions about biomass extraction and haul costs. The model has been used to examine both single and multiple hypothetical biomass destination scenarios and an example biomass supply curve has been generated for a single site case. (Task SM-SP-3)

- Numerous tree attributes have been measured from 199 trees originating in highly managed stands. This sampling ranged in breast height age from ~9 to ~90 years, in diameter at breast height (dbh) classes from 10-85 cm, and in height classes from 5-58 m. Understory vegetation sampling has been completed across a chronosequence of sites ranging in age from 0-20 years. Biomass equations have been fit to data collected during the first sampling season. These new equations overcome known biases in existing biomass equations with tree size and treatment history (Task SM-SP-4).

- Air emission data have been compiled from the wood products industry and from pretreatment simulations (Task SM-SP-5).

- Forest residual datasets for Idaho (2006), Oregon (2008), Montana (2009), Washington (2010), with updated Idaho sampling (2011) have been compiled and provided to NARA researchers conducting supply chain assessment. In addition, this data is being used to developed tools for predicting woody biomass in landing residue piles (Task SM-SP-5).

To evaluate stakeholder needs and perceptions, the **Environmentally Preferred Products** Team developed a stakeholder survey used to measure their knowledge, concerns, and level of trust related to issues concerning forest management, biomass, and liquid biofuels. With the assistance of the NARA Outreach Team, 325 potential interviewees were identified and data collection is underway. To evaluate community social assets, a preliminary biogeophysical and social asset assessment to inform plant siting and predict public bioenergy behaviors has been completed. The information will be used to identify communities and regions that are viable to development considering a number of factors including biomass availability, physical infrastructure, potential workforce development, and ability to activate social capital for the common good. To assess market opportunities for biojet, this team, with assistance from Gevo, Inc., supervised MBA student projects at Penn State University to generate market opportunities for biojet. In addition, they have generated preliminary data on primary US airports, supply chain alliances and regulatory/environmental impacts. Key governmental policy drivers, voluntary initiatives and standards and aviation biofuels LCA's were thoroughly reviewed and this information are used to structure the NARA LCA and model future environmental assessments. (Task SM-EPP-1) Significant internal outputs to date are:

- A preliminary biophysical and social asset assessment has been completed and is instrumental in developing selection criteria for strategic communities in the supply chain.

- A review of environmental policies, standards, and disclosure/labeling initiatives has been completed. Knowledge gained impacts future work throughout the Systems Metrics Program.

Outcomes/Impacts:

Events that cause a change of knowledge, actions or conditions for stakeholders and society.

- BBER's logging utilization researchers have provided forest landowners customized reports of the quantities of logging residue left on their lands after timber harvesting. This information has enabled landowners to gauge the efficiency of their forest management operations, learn of woody biomass energy opportunities, and help them predict the impacts of logging operations on wildlife habitat and coarse woody debris inventories. These data will be used by the USDA Forest Service Forest Inventory and Analysis (FIA) Program to update estimates of woody biomass residue inventories in the Resource Planning Act (RPA) Timber Products Output (TPO) database and will result in financial savings to taxpayers and enhanced biomass inventories at varied spatial scales. (Task SM-SP-7)

Training

Name	Affiliation	Role	Contribution
Katie Gagnon	PSU, Dept. of Agr. & Biol. Eng.	Staff – 20-hrs./wk. (wages)	Coordinating stakeholder assessment efforts
Wenping Shi	PSU, Dept. of Ecosystem Sci. & Mgmt. (ESM)	PhD Student – part-time on the NARA project	Coordinating social asset dataset development, management, and analysis
Stephen Wertz	PSU, Dept. of Agr. & Biol. Eng.	PhD Student – to start Sept. '13	Techno-Market Assessment: Jet Fuels
Min Chen	PSU, Dept. of Agr. & Biol. Eng.	PhD Student – started Jan. '13	Techno-Market Assessment: BioProduct Polymers
Stephen Cline	PSU, Dept. of ESM	Undergrad. - 10 hrs/wk. (wages)	Techno-Market Assessment: BioProduct Polymers
Jill Maroney	UI, Dept. of Environmental Science	PhD Student – started with EPP Jan. '13	Stakeholder assessment primary data collection activities and triangulation of CAAM refinements
Natalie Martinkus	WSU, Dept. of Civil & Env.Eng.	PhD Student	Biogeophysical asset assessment and mapping via GIS
Rylie Olson	UMN, Dept. of Bioproducts & Biosystems	PhD Student	Life cycle and hotspot analyses; Literature review
Holly Lahd	UMN, Dept. of Applied Econ	PhD Student	EEIO Assessment of Biopreferred alternatives

Warren Devine	UW, SEFS	Post-Doc	synthesis, data analysis, writing
Paul Footen	UW, SEFS	PhD student	field, sampling, lab work, writing
Tait Bowers	UW, SEFS	PhD student	LCA surveys, LCA framework analysis, data collection and analysis, writing
Austin Himes	UW, SEFS	MS student	field, sampling, lab work, writing
Jason James	UW, SEFS	MS student	field, sampling, lab work, writing
Marcella Menegale	UW, SEFS	PhD student	field, sampling, lab work, writing
Kim Littke	UW, SEFS	PhD student	field, sampling, lab work, writing
Erika Knight	UW, SEFS	MS student	field, sampling, lab work, writing
Kevin Vogler	OSU, Department of Forest Engr, Resources & Mgmt	Graduate Student	Literature synthesis, GIS layers and model formulation
Mindy Crandall	OSU, Applied Economics, Sustainable Forestry	Graduated (PhD)	Developing profit function estimates for WA, ID and MT. Will run alternative biomass processing scenarios and assist in developing biomass supply equations. Examine alternatives for intermediate processing of biomass between forest and refinery.
Isabel Guerrero	OSU, Applied Economics	Graduated (MS)	Developed initial estimates of profit functions and associated log demand parameters for Oregon lumber and plywood industries
Abraham Rodrigo Gonzalez	WSU, CEE)	Grad Student	Wood product air pollution emission inventory
Mark Mettler	WSU, CEE	Undergrad	Evaluation of Biolog system for nutrient evaluation
Chad Warren	WSU, CEE	Undergraduate	Initial WEPP model evaluation.
Madeline Fuchs	WSU, CEE	Undergraduate	Summer REU student
Mohammed Hasan	WSU, CEE	Grad Student	Currently modeling hydrology and soil erosion in targeted watersheds.
Vikram Ravi	WSU, CEE	Grad Student	Air quality emissions and simulations
Heather Root	Oregon State University	Post-Doc	Beginning modeling and review efforts.
Andy Bluhm	OSU, Forest Ecosystems and Society	Research Tech	lab work

Junhui Zhao	OSU, Forest Engr, Resources & Mgmt (FERM) Department	Post-Doc	field work
Alexis Danley	OSU FERM	Research Tech	lab work
Evelyn Idzerda	OSU FERM	Research Tech	lab work
Fantasia Freedom	OSU FERM	Research Tech	lab work
Andrew Rose	OSU FERM	Research Tech	lab work
Shannon Cox	OSU FERM	Research Tech	lab work
Kristin Coons	OSU FERM	FERM Grad Student	field/lab work
Nicole Rogers	OSU FERM	FERM Grad Student	field/lab work
Mike Shettles	OSU FERM	Undergraduate	lab work
Jeremy Mitchell	OSU FERM	Undergraduate	lab work
Becky Brenton	OSU FERM	Undergraduate	lab work
Brian Pickett	OSU FERM	Undergraduate	lab work
Rebecca Burson	OSU FERM	Undergraduate	lab work
Georgia Hall	OSU FERM	Undergraduate	lab work
John Crandall	OSU FERM	High School student	lab work
Tynan Granberge	OSU FERM	Research Tech	lab work
Peter Antico	OSU FERM	Research Tech	lab work
Charles Gale	Univ. of Montana, Resource Conservation	Undergraduate	Gale served as lead analyst and author for "Oregon's forest products industry and timber harvest, 2008…" (PNW-GTR-868); this manuscript has provided timely and vital information on mill residues, timber harvest, and other critical Oregon TPO data. Gale worked as a NARA logging utilization field crew member in 2011 to 2012.

Micah Scudder	Univ. of Montana, Forestry	MS Student (note- Scudder received his MS degree in December 2012- he now works as a full time research assistant at BBER).	Scudder worked as a logging utilization field crew member across the 4 state NARA area in 2012. Micah has served NARA as our resident wood export specialist- his skills have been particularly useful in understanding the export and substitution effects of wood flows throughout the northwest. Scudder (in collaboration with Josh Meek) has developed a tool that summarizes timber harvest by year by county in MT, , ID, OR, WA, and CA. This innovative web-based application will enable users to quickly understand the spatial and temporal dynamics of timber harvest.
Josh Meek	Univ. of Montana, Forestry	MS Student	Meek worked as a logging utilization field crew member across the 4 state NARA area in 2012. Meek (in collaboration with Micah Scudder) has developed a tool that summarizes timber harvest by year by county in MT, , ID, OR, WA, and CA. This innovative web-based application will enable users to quickly understand the spatial and temporal dynamics of timber harvest.

Resource Leveraging

Resource Type	Resource Citation	Amount	Relationship or Importance to NARA
A Grant-In-Aid (GIA) commitment to a PhD candidate (Stephen Wertz)	September 2012 through May 2015, Penn State's College of Agricultural Sciences, Dept of Agricultural and Biological Engr	Approx. $49,000	The GIA provides matching funds for a NARA grant assistantship
Grant-In-Aid (GIA) commitment to a PhD candidate (Min Chen)	January 2013 through December 2015, Penn State's College of Agricultural Sciences, Dept of Agricultural and Biological Engr	Approx. $49,000.	The GIA provides matching funds for a NARA grant assistantship
Grant, Becker,	USDA AFRI	Approx.	State-based BioEnergy Policies in the

D. & Smith, T.		$350,000.	Supply Chain
Grant, Smith, T.	Global Environmental Management Initiative	Approx. $100,000.	Sustainable Supply Chain & Sourcing Tool
Grant, Smith, T.	USDA McIntire-Stennis funds awarded through UMN College of Food, Ag. & Natural Resource Sciences	Approx. $30,000.	Bioenergy Hotspot Assessments and Policy Integration
Grant, Barber, M. (PI), et al. (21 others – including P. Smith, M. Gaffney, J. Perez-Garcia, and M. Wolcott from the NARA team).	NSF Hazards SEES Type 2: Advancing local, regional, and national adaptive capacities for wildfire resilience in an altered climate. Submitted Feb. 2, 2013.	$3,000,000.00.	Plan to leverage development and application of the Community Asset Assessment Model (CAAM) initially derived under NARA. The CAAM will be further refined and recalibrated to examine community adaptation and response to fire hazard.
Grant, Cavalieri, R.P. et al.	FAA-COE - Proposal to the Federal Aviation Administration Center of Excellence for Alternative Jet Fuels and Environment. Submitted March 18, 2013 to FAA & Office of Env. & Energy.	$19,897,252.00	Plan to leverage the NARA work investigating biorefinery intermediate and co-product supply chains.
A two-day advanced LCA training session was organized at the University for Washington.		All the cost associated with the training session was borne by funds outside the NARA project.	All the NARA-LCA team members, including graduate students working on the project, were trained by a SimaPro specialist on the advanced features of the software (SimaPro). With this advanced training, a Simapro database and project has been created and updated. The additional data needed from the NREL database will be implemented over the next six months to one year. The software allows multiple projects to be set up simultaneously, and with this initial set up of processes in the LCI, it will streamline data entry and the analysis of impact assessments in the later stages.

Funding & Fellowship Support	School of Environmental and Forest Sciences, Univ. of Washington		Substantial leveraging from funding of the Pacific Northwest Stand Management Cooperative, and graduate student fellowship support
Data Sharing Agreements	Potlatch, Inc.		Over the past several years Potlatch Inc. has collected and analyzed various aspects of biomass harvest, collection and its economic implication in the northern ID and Western MT region. Agreements with Potlatch Inc. are being undertaken leveraging data collected by the LCA team through primary data collection techniques. Moreover, Potlatch is in the process of being considered as a NARA member enhancing the role of industry within the NARA project.
Contact	Dr. Jennifer Adam		Dovetailing BioEarth project with respect to nutrient modeling efforts at watershed scale
Contact	Bob Bilby at Weyerhaeuser		Using Trask Creek watershed project as a means of expediting baseline data for runoff and nutrient information
	Weyerhaeuser Company		Utilized existing infrastructure, research equipment, knowledge, and expertise
Funding, Maguire	BLM		Thirty of our young sample trees (<25 yrs of age) were from sites from an existing study being sampled in a manner similar to NARA protocols. Additional funding has been obtained from BLM to cover the cost of sampling older trees (>40 yrs of age). Data from this sampling will be useful for elements of a BLM-funded study, as well as expand the NARA database for producing new biomass equations
Funding, Morgan	Logging Utilization, sponsored by USDA-Forest Service-Rocky Mountain Research Station, 07-JV-11221684-326		This agreement assisted in paying for measurement of logging residues generated during timber harvest in Idaho and for reporting of findings. The logging residue information will be a component of woody feedstock analysis, and the reports and contacts made with landowners and land managers in Idaho will increase the awareness of the NARA project

Funding, Morgan	Pacific States Forest Industry and Timber Harvest Analysis, sponsored by USDA-FS-Pacific Northwest Research Station, 08-JV-11261979-355		Agreement has assisted with gathering and reporting of data related to timber harvest volumes, mill residues, and forest industry infrastructure in OR and WA, and provided various opportunities to share NARA results and discuss NARA project with forest industry as well as private & public forest management professionals
Funding, Morgan	On-going Timber Product Output and Forest Industry Analysis for the Interior West States, by USDA FS-Rocky Mtn Res Station, 11-JV-11221638-091		This agreement will assist with the gathering and reporting of data related to timber harvest volumes, mill residues, and forest industry infrastructure in Idaho and Montana, and will provide opportunities to share NARA results and discuss NARA with mill & forest owners & managers.

SYSTEMS METRICS

Environmentally Preferred Products Team

Task SM-EPP-1: Environmentally Preferred Products

Key Personnel	Affiliation
Paul Smith	Pennsylvania State University
Timothy Smith	University of Minnesota
Tammi Laninga	University of Idaho
Michael Gaffney	Washington Sate University
Andrew Hawkins	Gevo

Task Description

A socio-market perspective of biorefinery value chain outputs requires an integrated, multi-faceted approach. 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 and/or co-products including supply chain perceptions and issues; and (9) examine select intermediate products, co-products, and allocation methods influencing the environmental assessment and reporting of aviation fuels.

Task SM-EPP-1.1 “Public” stakeholders:

Examination of opportunities and barriers for a regional approach to bio-aviation fuels and co-product system requires an assessment of public and informed regional bioenergy stakeholders to develop a social license. The EPP group will develop multiple empirical quantitative measures for core dimensions of creative capacity and social capital to measure community-level resilience and adaptability to change.

In addition, EPP will contribute to the analysis of physical asset constraints through GIS application, and explore potential NARA community concerns to better understand key supply chain community issues with regard to regional bioenergy infrastructure projects.

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

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

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

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

Task SM-EPP-1.4

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

Task SM-EPP-1.5

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

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

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

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

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

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

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

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

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

Activities and Results

To fulfill task EPP-1.1, a preliminary biogeophysical and social asset assessment of the NARA region to predict public bioenergy behaviors has been completed. This work has resulted in two proceedings papers focusing on: (1) the Western Montana Corridor – presented at an international conference of the Society of Wood Science & Technology in Beijing, China (Fall 2012); and (2) the 4-state NARA region – presented at the 2012 Sun Grant Conference in New Orleans, LA, USA. A refined analysis is in progress to target a journal article. Accordingly, we are currently refining the biogeophysical criterion and the social asset dataset which currently contains 525 column variables for all 3,108 US counties. Initial retrospective analysis (RA) is underway. RA utilizes studies previously conducted in the NARA region to demonstrate how the various NARA datasets may provide predictive capacity with respect to high and low sites. Further analysis, validation, refinement and calibration of the NARA region biogeophysical and social assets are in progress. Specifically, RA will be expanded for Community Asset Assessment Model (CAAM) weightings and "ground truthing" via primary data collection (quantitative and qualitative) as required for model validation and calibration. A completed CAAM will assist the NARA project in identifying communities and sites relevant to a biojet supply chain in the Pacific Northwest (PNW) (Figure 1). Identified communities may be viewed as more "physically" and "socially" receptive to potential biojet infrastructure economic development activities.

Task EPP-1.2 has been successfully accomplished. A thorough review of the literature has been completed. Specifically, 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 were reviewed. This review suggests overwhelming evidence of 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.

Task EPP-1.3 has been successfully accomplished. A thorough review of the literature has been completed, relevant constructs developed and pre-tested, and stakeholder populations within the NARA region identified.

Task EPP-1.4 calls to operationalize informed stakeholder surveys. From the identified informed stakeholder populations derived from multiple sources with expert assistance from NARA Outreach Team members, purposive sampling using maximum variation through touch point coding was employed. Mixed method primary data collection instruments have been developed and pretested in the Western Montana Corridor and the I-5 Corridor (West Side). Approximately 325 potential interviewees have been identified and data collection is currently underway. The data will include demographics plus various psychographic measures, including knowledge, concerns, and trust related to forest management, biomass, and liquid biofuels issues. The EPP team is scheduled to complete informed stakeholder data collection in the second quarter, 2013 with analysis, report and publication writing and presentations in year three. Efforts have been made to coordinate constructs with similar USDA-NIFA AFRI CAP projects underway by Drs. Saul (UI), Dasmohapatra (NCSU - IBSS), and Asah (UW-AHB) with the hope of integrating a "National Biomass to Biofuels SH Assessment" meta-analysis.

Task EPP-1.5 is scheduled to begin in the first quarter, 2014 but we hope to jump-start this activity to commence in the fourth quarter, 2013. Triangulation of stakeholder assessment data is anticipated to further refine, validate and calibrate the biogeophysical and social asset mapping efforts (Task EPP-1.1). In this regard, additional primary data collection in year three may be warranted.

Task EPP-1.6 is to provide a Techno-Market Assessment for Jet Fuels. A poster presentation outlining the work of the Bio-APEX team was prepared for the 2012 Annual NARA Conference in Missoula, MT (Adeniran, et al., 2012) including an updated view of regional aviation fuel demand centers in the NARA region (Fig. 3). An updated, but still preliminary literature review of "Biojet in the US" was provided in the Oct.-Dec. '12 quarterly report and included a context and background on biofuel and biojet market opportunities, supply chains, environmental impacts and governmental regulations. Preliminary data on primary US airports is being assembled, supply chain alliances examined, and the regulatory/ environmental impacts studied. Due to a variety of concerns with traditional petro-based aviation fuels, the biojet segment has received tremendous attention by various industrial and governmental stakeholders. This research effort specifically targets the supply chain, from the biorefinery-to-flight. Opportunities for utilizing petroleum industry supply chain networks, and the challenges that need to be overcome to bring biojet to commercial scale, are under examination.

Task EPP-1.7 was altered following the year one annual meeting and commenced in the fourth quarter, 2012. Parameterization is scheduled to begin the third quarter 2013, but we hope to jump-start this activity earlier in the summer of 2013. While collaboration with SH NARA toward social hotspots has begun, no efforts are currently planned to include social dimensions from an LCA perspectives (subtasks 43 & 54). However, this integration will be re-visited within Task 10 (years 4 & 5). Similarly, subtasks 45 & 55 will likely be delayed, given more rapid development of co-product LCA models and parameterization. A preliminary model of the isobutanol life cycle using woody biomass has been completed. The model is based on data obtained in the literature, with the exception of the wood harvest stage, which used measured data developed by the NARA LCA team. The model is structured such that measured data taken within other NARA project teams can be substituted as it becomes available, thus improving the accuracy and applicability to the NARA project. This model of the isobutanol production pathway will serve as a baseline technology platform by which variant process design pathways, intermediate product diversions and co-product production modules will be integrated through parameterization

Task EPP-1.8 is scheduled to begin Q3–'13; however, due to leadership requests, we are using a graduate course at Penn State to jump-start this effort beginning Spring semester '13. [NOTE: We also jump-started Task 6 Spring semester '12 through a Penn State graduate class 6 months early.] We are currently conducting a review of the literature to examine biorefinery intermediate and co-products with the greatest potential for commercial success with special applications to the NARA project. World bioplasitcs capacity is projected to quadruple from 2011 to 2016. Bio-PET 30, expected to have an 80% market share in 2016, will be driven by branded beverage companies. Other low-hanging bioplastics products, such as PLA and PHA, will likely remain key bioplastic product categories.

Task SM-EPP-1.9 was altered following the year one annual meeting and is scheduled to commenced in the third quarter 2013, however, efforts toward this task began in the first quarter '13. No efforts are currently planned to include social dimensions from an LCA perspectives (subtasks 43 & 54). Similarly, subtasks 45 & 55 will likely be delayed, given more rapid development of co-product LCA models and parameterization. Comparisons across intermediate products, co-products and end-use fuel are anticipated to commence in the second quarter, '14 for both Tasks SM-EPP-1.7 and SM-EPP-1.9, once parameterized models are further developed.

Based on preliminary findings emanating from the NARA Techno-Economic Assessment (TEA), co-product development (and/or intermediate product diversion) has surfaced as an increasingly important driver of economic viability. In light of these findings, the development of environmental impact modeling for likely co-products has been pushed forward into our current work. In particular, we have begun to explore the development of an LCA module for processes associated with the conversion of lignin to activated carbon. Lignocellulose represents approximately 50% of the wastes from agriculture, municipal sources, forest and agricultural-based industries, yet, less than 2% of the produced lignin is used in commercial applications. Thus, within the last several decades, a variety of researchers have focused interest on lignin as a potential raw material for the chemical industry. Activated carbon is a high-porosity material, very useful in the adsorption of both gases and solutes. Therefore, it has been widely used for the separation of gases, recovery of solvents and removal of organic pollutants from drinking water, as well as a catalyst carbon. As environmental pollution is becoming an issue of increasing concern, the need for activated carbon is growing.

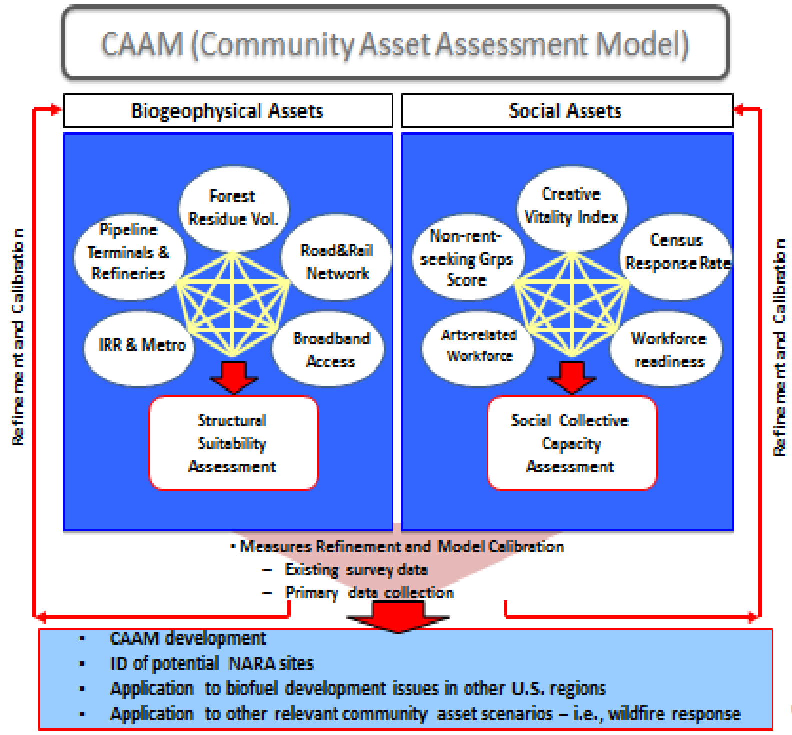

Figure 1. Community Asset Assessment Model Concept.

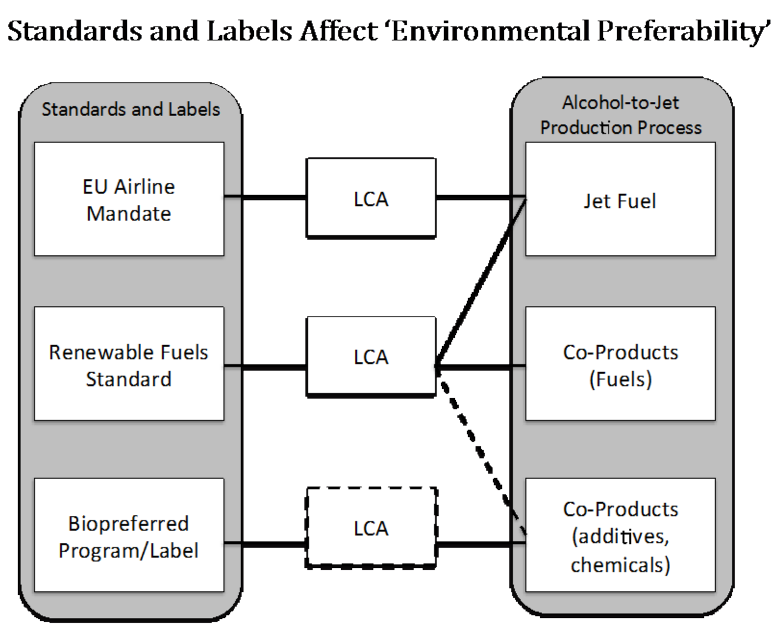

Figure 2. Fuel and product standards influence varying aspects of the alcohol-to-jet fuel production process.

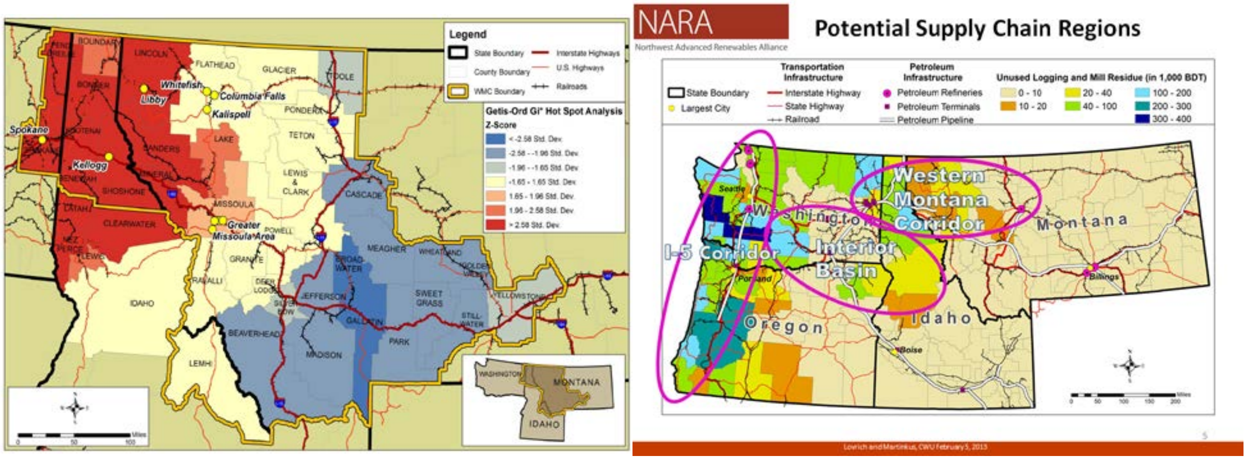

Figure 3. Potential NARA Region Supply Chain Configurations.

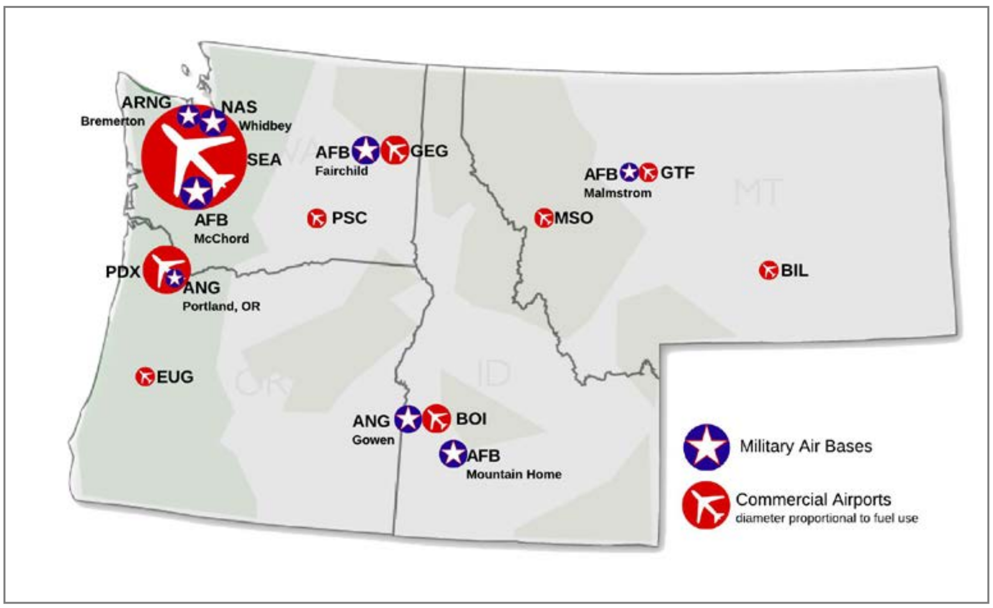

Figure 4: Regional demand centers in the NARA Region in 2011 (circle size represents relevant market size) (Map provided by Martinkus, N., M. Wolcott, P. Smith, and S. Wertz).

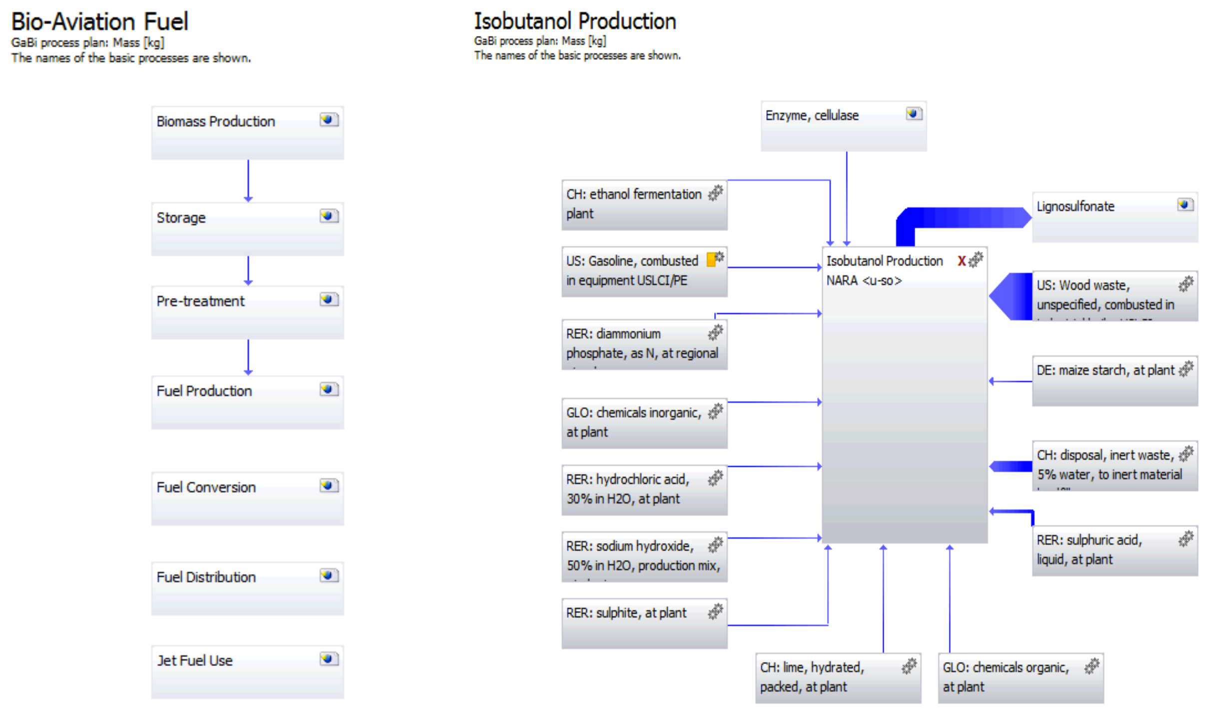

Figure 5. Initial structure of the isobutanol-to-fuel production pathway.

Recommendations/Conclusions

Tasks EPP-1.1, 1.3, 1.4, and 1.5: This work has built an extensive national social asset dataset at the county level. Validation of this dataset has led the EPP team toward retrospective analysis utilizing additional datasets available within the NARA region. Validation work is in progress. A thorough literature review of biofuel-to-energy stakeholder studies has been completed, resulting in the operationalization of a mixed method survey instrument. Data collection from approximately 325 informed stakeholders in the NARA region is in progress. Results will: (1) aid our understanding of the region's knowledge, concerns, and trust related to forest management, biomass, and liquid biofuels issues; (2) provide valuable validation, refinement, and calibration to the Task EPP-1.1 Community Asset Assessment Model (CAAM); and (3) combine with similar USDA-NIFA efforts in other regions of the US for an integrated meta-analysis.

Task EPP-1.2: Our review of policies, standards, and disclosure/labeling initiatives have informed future work planned and under developed by EPP. Specifically, the socio-technical nature of renewable energy development in the U.S. will undoubtedly require the integration of mandatory compliance (local direct regulation to state [RSP] and national mandates [RFS]), voluntary market standards (industry emissions reduction targets to governmentally sanctioned voluntary labeling standards), technical viability (cost drivers, resource constraints, supply and distribution compatibility, etc.) and market adoption (pre-commercialization procurement, environmental preference, price, etc.). Our review also informs future environmental assessment methodologies important to determining the viability of advanced biofuels and products in key policy and standards (access to RIN and REC markets, for example). Results have aided in the development of LCA-based methodologies useful to pre-commercialization procurement policies and renewable energy standards.

Task EPP-1.6: A definition of the market opportunity for select aviation fuels in the NARA region provided scope and strategic insight into target segments within the aviation market. This led to a more complete literature review of state-of-the-art US biojet including insight into biojet market opportunities and cost drivers, petroleum and biojet supply chain designs, refineries, pipelines, and fuel farms, and environmental impacts and government regulations impacting biojet, capital availability and technology adoption-diffusion (as contained in the Oct. – Dec. '12 quarterly report). As a result, the EPP team has developed a preliminary dataset of primary airports in the US to begin a more in-depth examination of key supply chain issues, from the biorefinery-to-flight, that impact this market space.

Task EPP-1.7: Initial work on this task has set the stage for several analyses regarding potential process design pathways and co-product selection. The isobutanol-to-fuel production pathway has several areas where inputs or processes that could be altered (e.g. pretreatment options, pre-process options, feedstock choices, etc.), which have been shown in the literature to potentially, and materially, affect environmental impacts. While current LCA-based models affecting policy implementation (i.e. GREET and EPA-RFS2) provide excellent assessment of individual fuel pathways, they currently do not allow for detailed 'plug-and-play' capabilities, reflective of the complexities of advanced and cellulosic production – particularly biochemical pathways. The streamlined approaches suggested in this task will help inform more in-depth analysis of key process technologies and provide a simplified comparative assessment of fuels to market actors voluntarily seeking lower impact fuels.

Task EPP-1.8: A thorough literature review of biorefinery intermediate and co-products, leading to a market definition for these biorefinery value chain ouputs, is in progress.

Task EPP-1.9: This task has only recently begun. A central focus of this task is to develop appropriate modified process maps of likely aviation biofuels and parameterized (streamlined) modules for comparison. These comparisons will be instrumental to private voluntary standards, the development of public policy rulemaking and to emergent policy interaction between energy and non-energy products. Our modeling work in this area will focus heavily on the integration of different allocation methods (with regard to co-product development) and "consequential" LCA approaches (with regard to decisions associated with intermediate product diversion).

Physical and Intellectual Outputs

Physical

- Stakeholder research instruments have been created and pre-tested, and are currently being operationalized.
- A US biojet market overview has been developed. This document includes insight into biojet market opportunities and cost drivers, petroleum and biojet supply chain designs, refineries, pipelines, and fuel farms, and environmental impacts and government regulations impacting biojet, capital availability and technology adoption-diffusion.
- An isobutanol-to-fuel LCA module, developed in the GaBi software suite. This module will be instrumental to both the EPP and LCA groups and serves as a baseline model for parameterization.

Intellectual

- A social asset dataset containing 525 columns of data has been developed and is currently being validated via retrospective analysis.
- An "outside-in" hotspot methodology for LCA-based product comparisons (see Pelton et al. 2013).

Refereed Publications (accepted or completed)

Fischlein, M., Smith, T. 2013. Revisiting renewable portfolio standard effectiveness: policy design and outcome specification matter, Policy Sciences, DOI 10.1007/s11077-013-9175-0.

Smith, T.S., Molina, S., Anderson, B. 2013. Toward the Convergence of Public and Private Forest Policy, in Green Forest Policies, Taylor & Francis. *In press*.

Pelton, R.E.O, Smith, T.M. , Lahd, H. 2013. Assessing Hotspot Assessment: A Procurement Perspective. Journal of Industrial Ecology. *In review*.

Conference Proceedings and Abstracts from Professional Meetings

Lovrich, N., W. Shi, N. Martinkus, P. Smith, J. Pierce, A. Kulkarni, M. Gaffney, M. Wolcott, and S. Brown. Integrating Social Capital In Biojet Feedstock Facility Siting Decisions. In Proceedings of the Sun Grant Initiative 2012 National Conference: Science for Biomass Feedstock Production and Utilization, Oct. 2-5, 2012 in New Orleans, LA, USA. *In-press.*

Martinkus, N., A. Kulkarni, N. Lovrich, P. Smith, W. Shi, J. Pierce, M. Wolcott, and S. Brown. 2012. An Innovative Approach to Identify Regional Bioenergy Infrastructure Sites. In Proceedings of the 55th International Convention of Society of Wood Science and Technology, August 27-31, 2012, Beijing, CHINA.

Research Presentations

Gagnon, K., P. Smith, I. Eastin, I. Ganguly. 2012. Stakeholder Perceptions. Presented at the Western Montana Corridor NARA Community Roadmap Development Meeting. University of Montana, Missoula, MT. 13 June.

Martinkus, N., A. Kulkarni, N. Lovrich, P. Smith, W. Shi, J. Pierce, M. Wolcott, and S. Brown. 2012. An Innovative Approach to Identify Regional Bioenergy Infrastructure Sites. Presented at the Western Montana Corridor NARA Community Roadmap Development Meeting. University of Montana, Missoula, MT. 13 June.

Adeniran, P., A. Chatterjee, C. Grassi, A. Kulkarni, J. Quezada, A. Hawkins, J. Scheib, and P. Smith. 2012. Strategic Marketing Plan for Biofuels in the NARA Region. Presented at the Western Montana Corridor NARA Community Roadmap Development Meeting. University of Montana, Missoula, MT. 13 June.

Martinkus, N., A. Kulkarni, N. Lovrich, P. Smith, W. Shi, J. Pierce, M. Wolcott, and S. Brown. 2012. An Innovative Approach to Identify Regional Bioenergy Infrastructure Sites. Presentation to the

Society of Wood Science and Technology International Convention at the International Centre for Bamboo and Rattan, Aug. 27-31 in Beijing, China.

Lovrich, N., W. Shi, N. Martinkus, P. Smith, J. Pierce, A. Kulkarni, M. Gaffney, and M. Wolcott. 2012. Physical and Social/Community Asset Mapping in the NARA Region. Presentation at the NARA Annual Meeting, Sept. 14 in Missoula, MT.

Gagnon, K., P. Smith, T. Laninga, J. Marotz-Maroney, M. Vashon, M. Gaffney, I. Ganguly, I. Eastin, and V. Yadama. 2012. Stakeholder Perceptions. Poster presentation at the NARA Annual Meeting, Sept. 14 in Missoula, MT.

Adeniran, P., A. Chatterjee, C. Grassi, A. Kulkarni, J. Quezada, P. Smith, A. Hawkins, J. Scheib, M. Wolcott, and S. Wertz. 2012. Strategic Marketing Plan for Biofuels in the Pacific Northwest. Poster presentation at the NARA Annual Meeting, Sept. 14 in Missoula, MT.

Nicholas Lovrich, N., W. Shi, N. Martinkus, P. Smith, J. Pierce, A. Kulkarni, M. Gaffney, M. Wolcott, and S. Brown. The Physical and Social Assets Mapping in the NARA Region. Poster presentation at the NARA Annual Meeting, Sept. 14 in Missoula, MT.

Martinkus, N. GIS as a Decision Support Tool for Supply Chain Analysis in the Western Montana Corridor. Presentation at the NARA Annual Meeting, Sept 14 in Missoula, MT.

Martinkus, N., T. Morgan, M. Wolcott. GIS as a Decision Support Tool for Supply Chain Analysis in the Western Montana Corridor. Poster presentation at the NARA Annual Meeting, Sept. 14 in Missoula, MT.

Smith, P. 2012. NARA and Environmentally Preferred Products (EPP). Presentation at the Penn State Dept. of Agricultural and Biological Engineering Fall Seminar Series. Sept. 25.

Smith, P., P. Adeniran, A. Chatterjee, C. Grassi, A. Kulkarni, J. Quezada, A. Hawkins, J. Scheib, S. Wertz and M. Wolcott. 2012. Strategic Marketing Plan for Biofuels in the NARA Region. Presentation at the Penn State Dept. of Agricultural and Biological Engineering Fall Seminar Series. Sept. 25.

Lovrich, N., W. Shi, N. Martinkus, P. Smith, J. Pierce, A. Kulkarni, M. Gaffney, M. Wolcott, and S. Brown. Integrating Social Capital Into Biojet Feedstock Facility Siting Decisions. Presentation at the Sun Grant Initiative 2012 National Conference: Science for Biomass Feedstock Production and Utilization, Oct. 2-5 in New Orleans, LA, USA.

Lovrich, Nicholas and N. Martinkus [with assistance from: P. Smith, J. Pierce, W. Shi, A. Kulkarni, M. Gaffney, M. Wolcott and S. Brown]. 2013. Cultural Assets and Sustainable Economic Development. Presentation at Central Washington University, Hal Holmes Center, Co-sponsored by Kittitas Environmental Education Network (KEEN), Forterra, the Ellensburg Public Library, CWU's College of Arts and Humanities, Academic Service Learning-Faculty Fellows, and the Departments of Political Science, Anthropology, Geography, and the Resource Management Program. Feb. 5.

Smith, T.M., Pickens, R. The Role of Private Governance in the Emergent Global Green Technology Policy Regime, Transnational Governance Interactions (TGI) – Theoretical Approaches, Empirical Contexts and Practitioners' Perspectives, Research Workshop, at the European University Institute in Florence, Italy, May 23, 2011.

Smith, T.M., Lahd, H., Olson, R. Using Life Cycle Assessment to Evaluate Ecolabel Claims, 23rd Annual POMS Conference: Socially Responsible Operations, Chicago, IL, April, 22, 2012.

Other Publications

Smith, T.M. 2013. Climate Supply Chain Risks: Bringing corporate sustainability out of the basement and into the supply chain, Bulletin of the Atomic Scientists. *In press*.

Olson, R., Smith, T.M. 2012. Exploring the Long-Term Feasibility of Pursuing Bio-Aviation Fuels Land Constraints and the Environmental Implications. Bioproducts and Biosystems Engineering and Institute on the Environment, UMN.

Videos and Webinars

Initiative in Focus Webinar, "Procurement in Sustainability: from buying green products to creating green solutions," with Kevin Dooley, Chief Research Officer, The Sustainability Consortium, Nancy Gillis, Director, GSA Federal Supply Chain Emissions Program Management Office (PMO), Timothy M. Smith, Director, NorthStar Initiative for Sustainable Enterprise. February 21, 2012. https://umconnect.umn.edu/p21956633/

Trainings, Education and Outreach Materials

- Bio-Based Sustainable Transformations & Resilient Technologies. Duke University, in collaboration with Yale University and Arizona State University. February 16-17. Approximately 50 people in attendance.
- LCA Modeling Workshop. Julie Sinistore (UW-Madison/Virent Inc.), Dr. Jason Hill, Dr. Tim Smith and Holly Lahd hosted a day-long workshop on LCA Modeling, February 24, 2012. Approximately 20 students, faculty, and local policy makers attended.
- Business Roundtable (~20 participants) and National Security & Our Energy Future Forum (~75 attendees) with Admiral Neil Morisetti, United Kingdom's Climate and Energy Security Envoy. Co-hosted by former State Representative, Jeremy Kalin.
- Biomass Feedstocks: Supply Chain Risks and Rewards, Nov. 29-30, 2012, American Chemical Society, with Duke U. (J. Golden) and Yale U. (P. Anastas), Invitation only: approx. 50 people.

LCA and Community Impact Team

SM-LCA-1: LCA Assessment of Using Forest Biomass as a Feedstock for Biofuel

Key Personnel	Affiliation
Ivan Eastin	University of Washington
Robert Harrison	University of Washington
John Perez-Garcia	University of Washington
Elaine O-Neil	University of Washington
Indroneil Ganguly	University of Washington
Tait Bowers	University of Washington
Tim Smith	University of Minnesota
Tom Spink	TSI
Gevan Marrs	Weyerhaeuser
Glenn Johnson	Weyerhaeuser
Junyong Zhu	USDA-Forest Products Laboratory

Task Description

This research module will provide a definitive Life Cycle Assessment of using woody biomass for the production of bio-jet fuel. Understanding the environmental consequences of this technology is necessary if woody 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 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 greenhouse gases (GHG) and other environmental performance indices for comparisons between cellulosic jet fuel and fossil jet fuels. Alternative technologies, and their impacts on the value chain, will be compared for different forest treatments, harvesting and collection equipment and processing alternatives. Feedstock qualities will be matched with processing alternatives and regional feedstock scales of availability matched with efficient scale processing infrastructure. Alternative configurations and policy assumptions covering a range of scenarios will be used to project potential regional reductions in GHG emissions and energy dependence as well as rural economic impacts. The impacts of different policies and other alternatives will be characterized as sensitivity scenarios to better inform the adoption of appropriate policies, marketing, and investment strategies to reach energy independence goals with reduced GHG emissions while effectively managing cellulosic resources.

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

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

Activities and Results

Soil Carbon Team

During the period August, 2011 - March, 2013 we have completed significant work on analysis of the sustainability of additional biomass removal from current production Douglas-fir plantations in the coastal region of the PNW relative to ecosystem nitrogen. Several presentations were made, including at NARA meetings, meetings of the Northwest Stand Management Cooperative, an industry cooperative of the primarily forest landowners and managers in the region, the Pacific Rim Meeting on Bioenergy and Bioproducts in Vancouver, Washington, and the Soil Science Society of America. Presentations will also be made at the upcoming Soil Science Society of America meeting. We have the draft of a journal article written by previous graduate student Austin Himes, who now works for GreenWood Resources, and Postdoctoral Research Associate Warren Devine, who has taken employment as a land manager for Joint Base Lewis-McChord in Washington State. The results show that industrial forest stands are likely resilient to high levels of additional biomass removal for bioenergy (Figure 1). Kim Littke finished her degree and is currently working for Port Blakeley Tree Farms as a research scientist. She continues to work on issues of sustaining and enhancing forest productivity.

We have made significant progress toward completion of a study of the role of deep soil in the functioning of forested ecosystems relative to their potential for sustained productivity with respect to additional biomass removals for biofuel production. We have sampled 26 sites within the primary Douglas-fir production plantation zone in coastal Washington and Oregon to depths of up to 4 meters, something that has never been done in the region. Results indicate deep soil is a substantial carbon and nutrient pool that is typically ignored, in some cases accounting for more than half of ecosystem carbon. The potential for changes in this pool have also been indicated in other studies, but we are not sure how to approach this potential in the NARA work. Graduate student Jason James is working on the draft of a manuscript.

MS graduate student Erika Knight is writing her MS thesis on this topic, and the literature review for Item 12 is part of her MS work. She is expected to complete her thesis work by June, 2013. Some initial results are compelling. For instance, Figure 2 shows that suppressing competing vegetation with herbicides enhances soil carbon, though only deep in the soil profile, probably because of the proliferation of tree roots without competing vegetation. PhD student Marcella Menegale, who started in Fall, 2012, has started working on this project and will continue the literature reviews.

MS graduate student Erika Knight and PhD student Marcella Menegale are continuing cooperative work with Weyerhaeuser, Oregon State University and the U.S. Forest Service, including processing and analyzing soil samples taken from the Fall River long-term soil productivity study for Item 13. The work was initiated by Paul Footen, now employed by the Washington Department of Natural Resources. Daramola Tolulope, a visiting fellow of the International Tropical Timber Organization will also be working on soil carbon field techniques in our NARA sites and studies with the goal of taking what he has learned back to his native country of Nigeria to improve management of tropical forests there in terms of soil carbon sequestration and utilization of forests for bioenergy.

We are adding two additional students that will work on NARA projects this summer/fall, Christiana Dietzgen, a graduate student who was awarded a full fellowship to study at the University of Washington, and Erin Burt, who will start working on her master's degree.

Community Impact Assessment Team

The goal of this research is to assess the economic impacts associated with the production of bio-jet fuel using forest-based materials in areas within the region encompassed by Idaho, Montana, Washington and Oregon at broad regional and smaller community levels. The study does so by reviewing, developing and using economic models that consider the industries and institutions that make up the economic and social infrastructure in the region. We have examined existing input/output models. We have constructed preliminary social accounting matrices (SAM) that contain the intra-industry relationships as well as the capital and labor flows needed to assess the impact from biojet fuel production. We have reviewed and adapted computable general equilibrium models that utilize the SAMs to analyze taxes, subsidies and programs that may promote or constrain activities related to bio-jet fuel production.

Input/Output Analysis: I/O analyses produce multipliers useful in impact analysis. The multipliers quantify how an external change in final demand will impact the various suppliers of production factors and producers of commodities in the economy. For example, an additional $50 million spent by wood manufacturers in Lakehead County, Montana would raise the value of output from other manufacturing industries by $12.4 million ($50 million x 0.2481) and the total county economy by $28.7 million ($78.7million - $50 million; where $78.7 million represents the sum of multiplier effects across all sectors of the additional spending by the wood manufacturers ($50 million x each multiplier in the highlighted column in Table 1, Wood Manufacturing labeled column). Common multipliers defined include total jobs multipliers, total employment multipliers, labor income multipliers and total output multipliers. Table 1 lists total output and employment multipliers. The employment multiplier can be interpreted to mean that for every new job added in the Wood Manufacturing sector, there would be an estimated 3.13 additional jobs (4.13 – 1.00) created throughout the county economy.

SAM Analysis: Several assumptions limit the applicability of I/O analysis results including the inability of these models to capture internal investment activities funded by tax dollars from government accounts for example. SAM analysis expands the intra-industry transaction tables to include all monetary flows from sources to recipients. A highly aggregated SAM for Lakehead County is presented in Table 2. The table contains data used directly by computable general equilibrium models, and it also allows us to describe the flow of transactions describing Lakehead County's economy. For instance, with the aggregation scheme used to collapse over 400 industrial activities into nine, the data suggests that the county's balance of trade with respect to wood manufacturing activities is negative, i.e., it imports $262.4 million from neighboring counties, states and internationally while it exports $49.4 million. The value of its wood products manufacturing is comparable to food manufacturing, wholesale and retail trade activity each, but it is only a small fraction of other manufacturing activities (see "Total" column values in Table 2 for each sector mentioned). The SAM analysis will allow us to describe the economic activity in those regions where a proposed bio-jet fuel facility may be constructed.

CGE Modeling: A general equilibrium modeling framework has been developed adapting models from Lofgren (2003) and McCullough et al., (2011). The Lofgren model consists of producers and consumers, who maximize profits and utility respectively, subject to production functions and budget constraints. A government sector is included as well as standard assumptions about factor mobility, unemployment and trade. The McCullough model is an adaptation of Lofgren that expands the CGE model to study biofuel related goals in the state of Washington. The policies studied include fuel blend mandates and tax/subsidy regimes. The McCullough study focused on the production of biodiesel using agricultural crops. A representation of the CGE developed for the assessment of bio-jet fuels is presented in Table A1 in the appendix of this report.

Data Collection: The construction of the I/O tables and social accounting matrices requires transaction data. For Washington State, these data are available from the Washington Office of Fiscal Management, and have recently been updated. For other states, these transaction data are available from IMPLAN, Inc. The University of Idaho has recently acquired IMPLAN data for the four states, and we are working collaboratively to produce the community impact assessment.

Life Cycle Assessment Team

During the first phase of the project (August, 2011 - March, 2013) a comprehensive literature review was undertaken and various LCA approaches were evaluated for the NARA bio jet fuel project. Upon thorough review of the proposed approaches and the compliance requirements it was established that the primary focus will be on attributional LCA. The research team further determined that though consequential LCAs are not required by the ISO standards, it is of prime importance to understand and analyze the long term environmental benefits of the proposed activities. Moreover, the results obtained from the consequential LCAs will play critical role in various advocacy and fundraising activities to economically sustain the program. Accordingly, primary consequential scenarios of the proposed activities are also reviewed and developed for the project. Two primary scenarios identified for Inland Empire are incorporation of (i) avoided environmental cost of slash pile burning and (ii) avoided environmental cost of catastrophic forest fires within the consequential LCA framework. On the pretreatment, final processing and delivery and distribution part of the bio-jet fuel the team will focus on the attributional LCA.

To be able to estimate the overall environmental footprint of the proposed bio-jet fuel, an integration of knowledge and research from the fields of forestry, logistics, energy economics and chemical engineering into energy industry research is crucial. Life cycle analysis (LCA) is a computational tool that transcends the disciplinary boundaries and can be used to evaluate the environmental sustainability of a bio-jet fuel industry. In this regard, we undertake the complete LCA starting from the seedling development up to the bio-jet fuel delivery to the pump. A broad overview of the process is depicted in Figure 3.

Overview of research findings/papers

Harvest and transportation scenarios: This paper presents the results of a series of LCA analyses comparing various harvesting and transportation scenarios associated with forest residuals collection in the Pacific Northwest region as a feedstock for bio-jet fuel. Emissions generated and total energy use was calculated for various harvesting and feedstock transportation scenarios to evaluate the optimal solutions and minimize environmental burdens, measured in terms of global warming and acidification potentials. In these scenario-based comparisons, emissions associated with traditional tree skidding are compared with the alternate harvesting scenarios of cable-yarding and helicopter-yarding. For the transportation scenarios, hauling forest residuals directly to a biomass processing facility is compared with two alternate transportation scenarios: 1) hauling forest residuals to a central landing for chipping and 2) transporting chips to a biomass processing facility. The results reveal that the forest road transportation of loose residue is the primary contributor to global warming potential for woody biomass. Options that reduce the carbon footprint associated with loose residue collection may be critical in reducing the overall environmental burdens of the process. The results further reveal that strategic forest road development may reduce the global warming potential of feedstock collection over the long run. Results are presented in Figures 4 and 5.

Avoided environmental burdens of slash pile burning: The results of a comparative LCA analysis of the avoided environmental costs and impacts of using woody biomass residuals for bio-jet fuel instead of slash pile burning are noteworthy. Forest residuals in the Inland West region are typically left in the forest after harvest, but have to be burned to avoid fuel accumulation on the forest floor. Compared to the alternative of burning the left-over slash piles from harvesting, the environmental impacts of extracting and hauling these residuals to market can be measured by the amount of carbon (CO_2) emitted into the atmosphere. Emissions generated for both scenarios were calculated to provide additional credence for the utilization of left over residuals instead of burning the piles and polluting the environment with unfiltered smoke and ash. Environmental burdens were measured in terms of global warming, acidification, smog, and ozone depleting potentials. The results reveal that the avoided GHG emissions from slash pile burning balances out the overall GHG emissions from woody feedstock collection and transportation under the assumed scenario. Moreover, there is a net reduction in the environmental impact resulting from extraction of residuals for the bio-jet fuel project by avoiding slash pile burning for the following indicators: Smog formation, Acidification, and Respiratory Effects. The results are summarized in Table 3.

Pretreatment and GEVO process: A factory gate-to-IPK storage life cycle impact assessment using TRACI was prepared for the forest residuals-to-IPK process. To facilitate this analysis, it was assumed that the DOE/NREL corn stover to ethanol process model could be adapted and used to convert forestry residues to fermentable sugars. The Gevo GIFT and Alcohol to Jet (ATJ) processes was used to convert the sugar stream to iso-paraffinic kerosene (IPK). A prototype LCA was undertaken to estimate the life cycle environmental performance of the integrated process of producing IPK from forest residuals.

The life cycle assessment has been carried out for a prospective process of producing IPK from forest residuals (primarily slash and trim materials) using a biochemical conversion process developed by Department of Energy and the National Renewable Energy Laboratory (NREL) to produce a fermentable sugar stream from lignocellulosic biomass. Fermentable sugars are converted to isobutanol (iBuOH) using the Gevo GIFT process. Isobutanol is processed through dehydration of the molecule and oligomerization of isobutene to produce IPK, the main product.

For the purposes of this assessment, the NREL process model mass and energy balance has been modified to accommodate a different feedstock (forest residuals). To this end, high-level process area inputs and outputs were extracted from the model and applied to the integrated NREL/Gevo process. Process cooling, steam and electrical power loads for the two Gevo process areas were then incorporated so that the total biorefinery (and supporting auxiliary systems) loads would reflect both a different feedstock and different products of fermentation and back end chemistry. Modifications were made to the processes areas as needed to account for differences in polysaccharide and lignin content between the two feedstocks. In Table 4 we can observe that after accounting for the avoided emissions from burning the feedstock, the net CO2 emissions for the feedstock process is negligible. Notably, the feedstock process has net beneficial impacts on the four highlighted impact categories: acidification potential, eutrophication potential, smog potential and respiratory effects. The overall environmental impact associated with the bio-jet fuel can be better understood when compared against the emissions associated with fossil based aviation fuel. The following section discusses the LCA emissions associated with transporting 1 metric ton of freight for one kilometer in an intercontinental flight using fossil fuel (kerosene) as compared biofuel (Iso-Paraffinic Kerosene -- IPK).

Comparative Analysis: Environmental Implications of NARA Bio-Jet Fuel vs Fossil Based Bio-Jet Fuel

Comparable aircraft utilizing biofuels or fossil fuel emit similar levels of carbon dioxide (CO2), which is the primary source of greenhouse gas emissions. However, the primary distinction between biofuels and fossil fuels is the source of carbon stored in the fuel. The environmental footprint associated with burning aviation fuels comes from two primary sources. First, the carbon stored in the aviation fuels is released during combustion. Second, there is a large amount of emissions associated with the extraction, transportation and processing of crude oil into jet fuel. The use of fossil aviation fuels releases geologic carbon that has been stored for millions of years, and those emissions represent a net addition of CO2 to the atmosphere. The NARA bio-jet fuel uses wood residue derived from timber harvest operations as the raw material to produce iso-paraffinic kerosene (IPK) jet fuel. Trees use atmospheric carbon dioxide to grow and burning biofuels simply releases this sequestered carbon dioxide back into the environment. With a sustainable resource harvest system, where the biomass extracted from the forest is less than the biomass growth during a specified time frame, the net addition of CO2 into the atmosphere is negative. However, the conversion of forest woody residue to bio-jet fuel requires various inputs from nature (the atmosphere) and industry (the technosphere). Hence, the overall environmental footprint associated with bio-jet fuel includes all the resources used, emissions and waste generated during the process of biomass growth, collection and conversion into biofuel.

In essence, this project will produce IPK jet fuel as a “drop-in” substitute for fossil-based jet fuel by producing the same molecule synthetically from the bioderived iso-butanol molecule. The major difference between the bio and fossil jet fuel is that the bio-jet fuel consists of a higher ratio of pure C10 and C12 molecules. The comprehensive Life Cycle Assessment (LCA) based ‘cradle to grave’ estimation approach used to calculate the overall environmental footprint of these two types of aviation fuels is generally considered to be the most credible. Moreover, the LCA results will be critical in demonstrating that bio-jet fuel produced from forest residuals meets the greenhouse gas (GHG) reduction target specified in the US Energy Independence Act of 2007. The US Energy Information Administration (EIA) requires that the overall GHG emissions of cellulosic biofuel produce 60% lower carbon emissions (H.R.6: http://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf; Argyropoulos 2010: http://www.eia.gov/conference/2010/session2/paul.pdf), relative to fossil fuel-based jet fuel, in order to qualify for public procurement.

The NARA project LCA team, comprising of researchers from the University of Washington, Gevo, WSP Environment and Energy, TSI and the University of Minnesota, has completed a preliminary analyses of the “forest to wake” greenhouse gas emissions of the NARA bio-jet fuel process. The preliminary results obtained from the “forest to pump” LCA analysis are carried forward to combustion in a jet engine during an intercontinental passenger flight to provide a “forest-to-wake” analysis. These results are compared to the same results obtained from combustion of fossil fuel-based jet fuel. The preliminary results of this LCA comparison suggest that the overall global warming potential of the NARA bio-jet fuel, measured in kilograms of CO2 emissions, is just 38.4% that of fossil fuel-based jet fuel (Table 5). In addition, the ozone depletion potential of the NARA bio-jet fuel is approximately 12% that of fossil fuel-based jet fuel while the fossil fuel depletion potential is 39.1% of fossil-based jet fuel. In other words, our preliminary analysis suggests that there is a 61.6% reduction in the global warming potential, an 88.1% reduction in the ozone depletion potential and a 60.7% reduction in fossil fuel depletion by substituting bio-jet fuel for fossil fuel-based jet fuel. This preliminary result is significant in that it exceeds the mandated 60% emission reduction criterion specified in the US Energy Independence Act guidelines.

The LCA team assessed the LCIA data to get an initial determination of what individual processes were contributing to the reduced environmental impacts associated with using the bio-jet fuel as a substitute for the fossil-based jet fuel. Following our preliminary evaluation, it appears that the superior environmental performance of the bio-based jet fuel was due in part to the following factors:

1. A minimal amount of fossil fuel is used during the conversion process, because waste biomass (in the form of lignin), can be substituted for coal and/or natural gas to provide the heat and power needed for the IPK process.
2. The avoided environmental burdens associated with not having to burn the slash piles in the forest reduced the overall environmental footprint of the process.

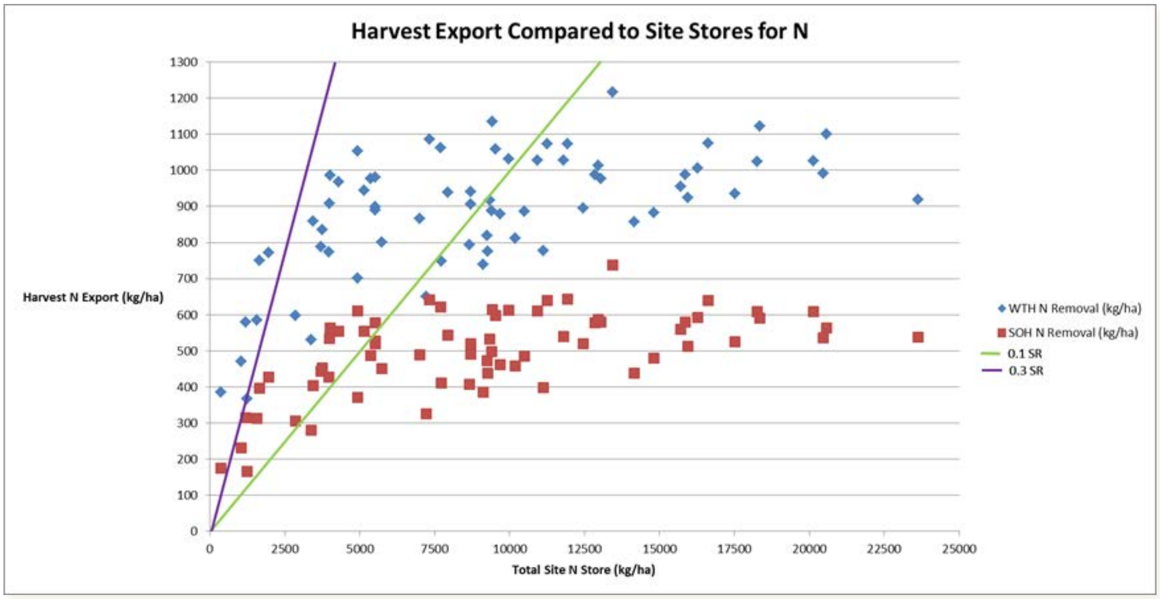

Figure 1. Evaluation of nitrogen removal from 73 forest ecosystems at predicted harvest age for bole-only and whole-tree harvests vs. ecosystem pools of total N to 1 m soil depth.

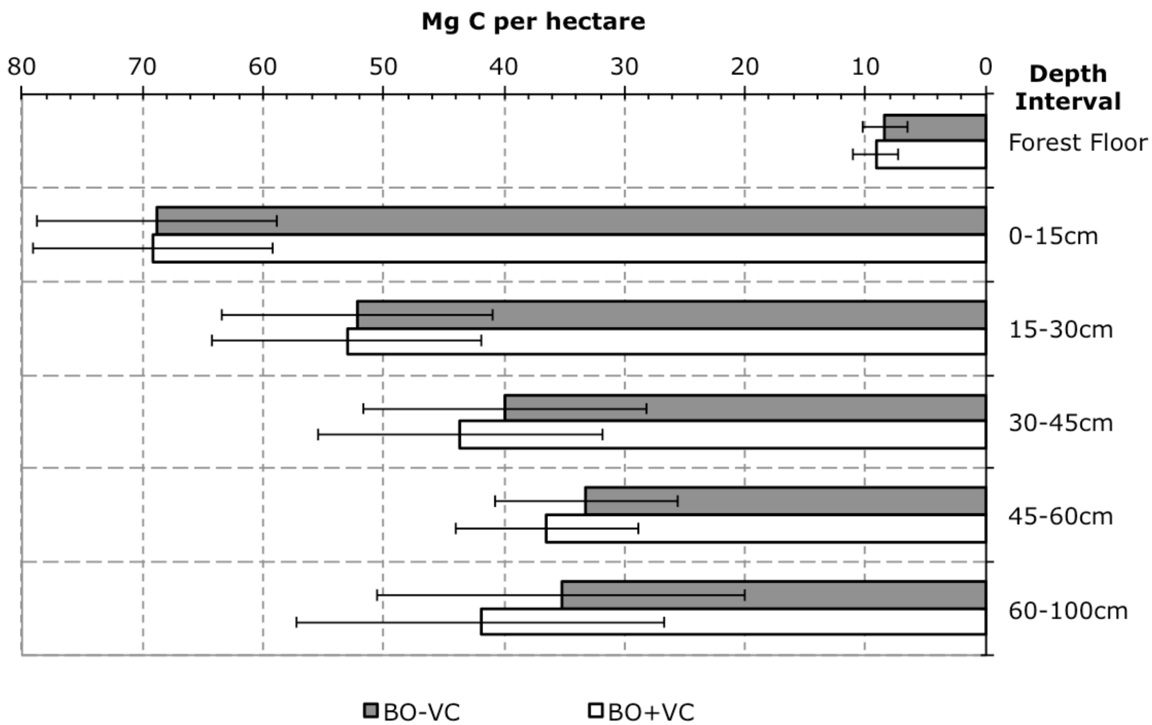

Figure 2. Carbon contents by depth at Fall River LTSP. BO-VC = Bole-only harvest without completing vegetation control, BO+VC = Bole-only harvest with completing vegetation control.

Table 1. Multipliers (Total Dollars of Input Per Dollar of Output) for Lakehead County, Montana

	Agriculture	Natural Resources	Utilities	Wholesale/Retail Trade	Food Processing
Agriculture	1.0815	0.0176	0.0128	0.0141	0.0995
Natural Resources	0.0615	1.0980	0.1516	0.0290	0.0228
Utilities	0.0329	0.0709	1.0397	0.0644	0.0131
Wholesale/Retail Trade	0.0241	0.0376	0.0454	1.0823	0.0101
Food Processing	0.0382	0.0577	0.0695	0.0852	1.0384
Wood Manufacturing	0.1218	0.0868	0.0888	0.0770	0.0244
Manufacturing	0.6777	1.0471	1.0872	1.3017	0.3160
Other Services	0.0779	0.1255	0.1531	0.1880	0.0318
Transportation	0.0852	0.1306	0.1581	0.1640	0.0304
Value Added	0.5057	0.7804	0.9460	0.9750	0.1815
Employment*	1.81	2.69	12.06	1.82	6.10
	Wood Manufacturing	**Manufacturing**	**Other Services**	**Transportation**	**Personal Consumption**
Agriculture	0.0021	0.0103	0.0181	0.0148	0.0224
Natural Resources	0.0117	0.0296	0.0293	0.0254	0.0321
Utilities	0.0225	0.0362	0.0520	0.0477	0.0617
Wholesale/Retail Trade	0.0084	0.0411	0.0603	0.0533	0.0809
Food Processing	0.0120	0.0561	0.1126	0.0905	0.1325
Wood Manufacturing	1.0691	0.0668	0.0784	0.0738	0.0923
Other Manufacturing	0.2481	2.0222	1.3432	1.3535	1.6268
Other Services	0.0265	0.1288	1.1920	0.1779	0.2603
Transportation	0.0249	0.1252	0.2045	1.1826	0.3046
Value Added	0.1485	0.7481	1.2166	1.0865	1.8241
Employment*	4.13	2.73	1.96	2.49	

* This multiplier can be interpreted to mean that for every new job in Wood Manufacturing (for example 4.13 under Wood Manufacturing column heading in row labeled Employment) there are an estimated 3.13 (4.13 – 1.00) additional jobs expected throughout the economy.

Table 2. Highly Aggregated SAM(Transaction Table) for Lakehead Co. Montana (Million Dollars)

	AGRI-C	NATRES-C	UTIL-C	TRADE-C	FOOD-C	WOODMAN-C	MAN-C	OTHSER-C	TRANS-C
AGRI-C	$ 5.35	$ 1.90	$ 0.00	$ 0.11	$ 26.92		$ 3.69	$ 0.63	$ 0.01
NATRES-C	$ 3.17	$ 19.79	$ 24.56	$ 0.74	$ 3.49	$ 1.58	$ 66.57	$ 3.28	$ 0.18
UTIL-C	$ 0.77	$ 10.89	$ 0.01	$ 8.67	$ 1.14	$ 5.00	$ 45.89	$ 9.10	$ 4.95
TRADE-C	$ 0.01	$ 0.21	$ 0.34	$ 11.63	$ 0.31	$ 0.31	$ 36.26	$ 5.11	$ 1.78
FOOD-C	$ 0.07	$ 0.08		$ 4.02	$ 7.41	$ 0.30	$ 5.16	$ 25.67	$ 7.02
WOODMAN-C	$ 6.04	$ 9.50	$ 5.84	$ 5.05	$ 0.85	$ 17.96	$ 126.85	$ 10.91	$ 6.36
MAN-C	$ 10.49	$ 65.73	$ 28.72	$ 96.97	$ 27.96	$ 24.70	$ 1,660.42	$ 202.41	$ 186.11
OTHSER-C	$ 0.08	$ 2.02	$ 2.57	$ 13.04	$ 0.87	$ 0.93	$ 102.80	$ 15.13	$ 10.84
TRANS-C	$ 0.05	$ 0.04	$ 0.01	$ 0.32	$ 0.00	$ 0.01	$ 1.22	$ 1.41	$ 0.68
LAB	$ 3.13	$ 33.04	$ 16.99	$ 74.08	$ 5.26	$ 9.12	$ 847.53	$ 509.05	$ 248.12
CAP	$ 10.12	$ 45.95	$ 62.78	$ 42.87	$ 2.60	$ 1.74	$ 1,026.13	$ 132.67	$ 64.47
INDT	$ (0.37)	$ 4.59	$ 20.77	$ 19.17	$ 0.82	$ 0.40	$ 183.47	$ 22.73	$ 6.89
HH								$ 24.14	
GOV	$ 0.21	$ 4.29		$ 3.73			$ 4.17	$ 2.70	$ 42.30
INV	$ 0.00	$ 0.00			$ 0.48	$ 0.06	$ 13.35	$ 47.03	
Imports	$ 39.87	$ 96.86	$ 28.84	$ 57.95	$ 227.58	$ 262.36	$ 2,440.52	$ 135.25	$ 101.82
TOTAL	$ 77.09	$ 287.17	$ 201.37	$ 332.05	$ 305.64	$ 326.21	$ 6,601.51	$ 1,121.70	$ 673.83

SAM for Lakehead Co, Montana (con't)

	LAB	CAP	INDT	HH	GOV	INV	Exports	TOTAL
AGRI-C				$ 13.60	$ 0.27	$ 0.26	$ 24.36	$ 77.09
NATRES-C				$ 3.46	$ 0.32	$ 27.37	$ 132.65	$ 287.17
UTIL-C				$ 69.71	$ 4.22		$ 41.03	$ 201.37
TRADE-C				$ 114.83	$ 6.08		$ 155.19	$ 332.05
FOOD-C				$ 202.48	$ 3.92	$ 0.06	$ 49.44	$ 305.64
WOODMAN-C				$ 76.31	$ 10.66	$ 0.48	$ 49.40	$ 326.21
MAN-C				$ 1,761.25	$ 188.84	$ 812.57	$ 1,535.34	$ 6,601.51
OTHSER-C				$ 381.19	$ 393.75		$ 198.47	$ 1,121.70
TRANS-C				$ 521.91	$ 3.29		$ 144.88	$ 673.83
LAB								$ 1,746.31
CAP								$ 1,389.34
INDT								$ 258.48
HH	$ 1,506.18	$ 733.18		$ 59.60	$ 800.12	$ 694.07	$ 31.13	$ 3,848.41
GOV	$ 240.13	$ 26.78	$ 258.48	$ 350.29	$ 451.82	$ 493.04	$ 0.00	$ 1,877.92
INV		$ 760.85		$ 293.79	$ 14.63	$ 38.70	$ 897.67	$ 2,066.56
Imports		$ (131.47)		$ 0.00	$ (0.00)	$ 0.00		$ 3,259.56
TOTAL	$ 1,746.31	$ 1,389.34	$ 258.48	$ 3,848.41	$ 1,877.92	$ 2,066.56	$ 3,259.56	$ 30,766.25

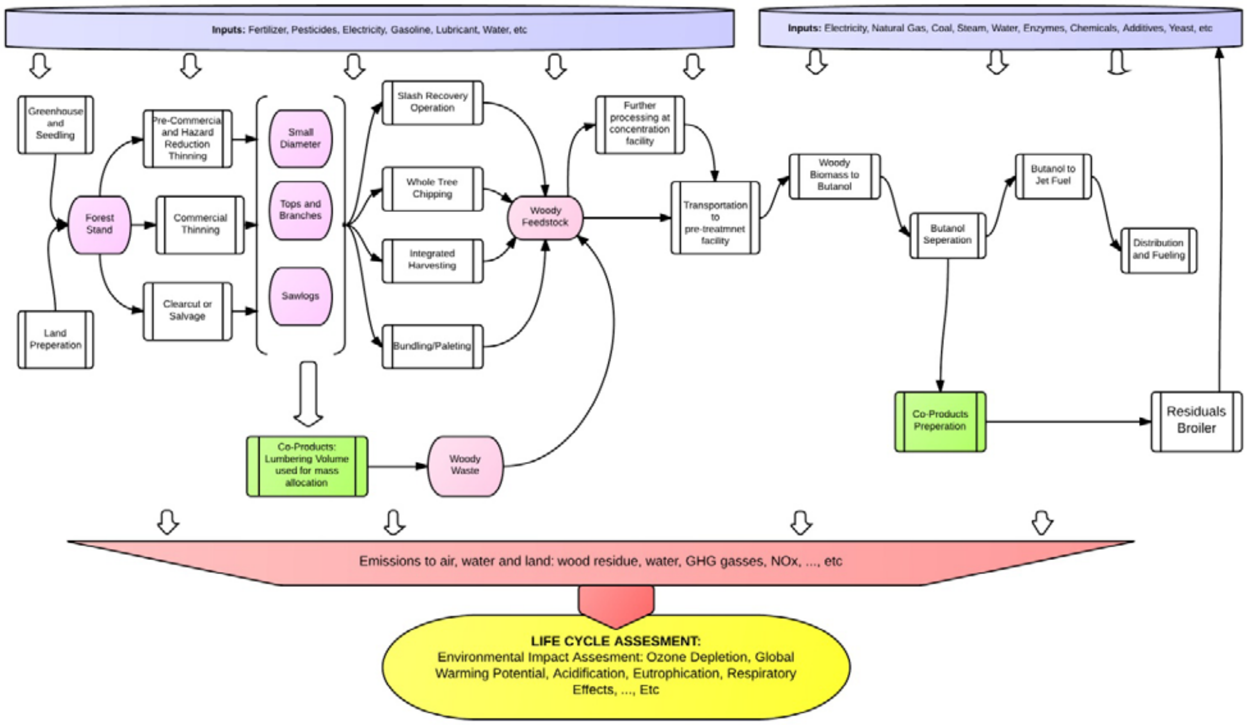

Figure 3: Overall Scope for LCA of woody biomass to bio-jet fuel

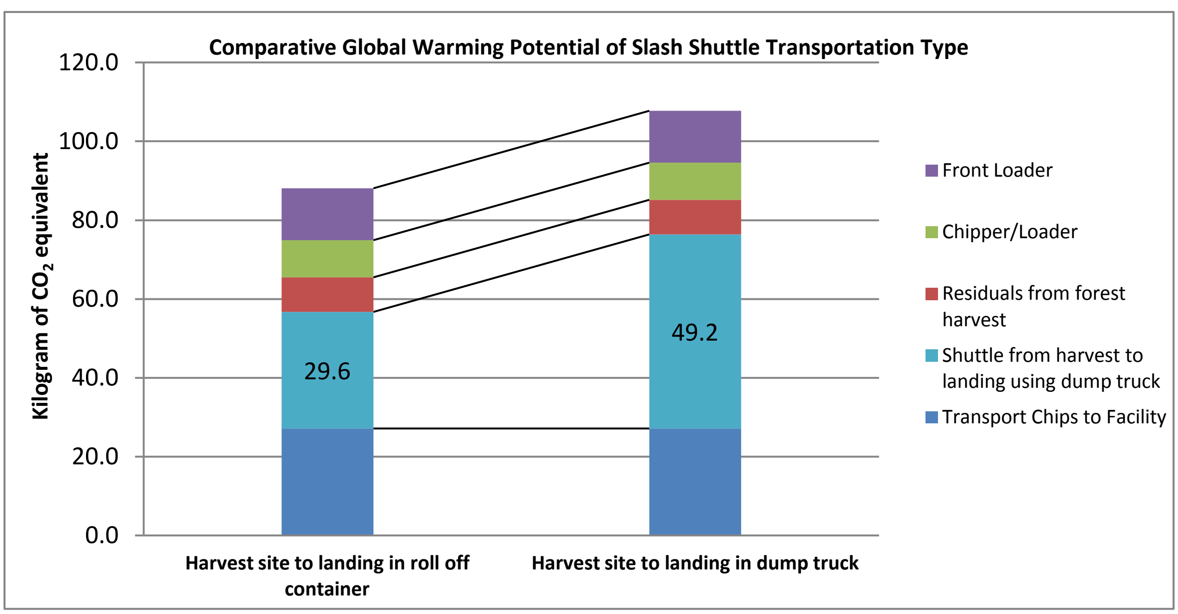

Figure 4: Comparative Global Warming Potential of Shuttle Transportation Type

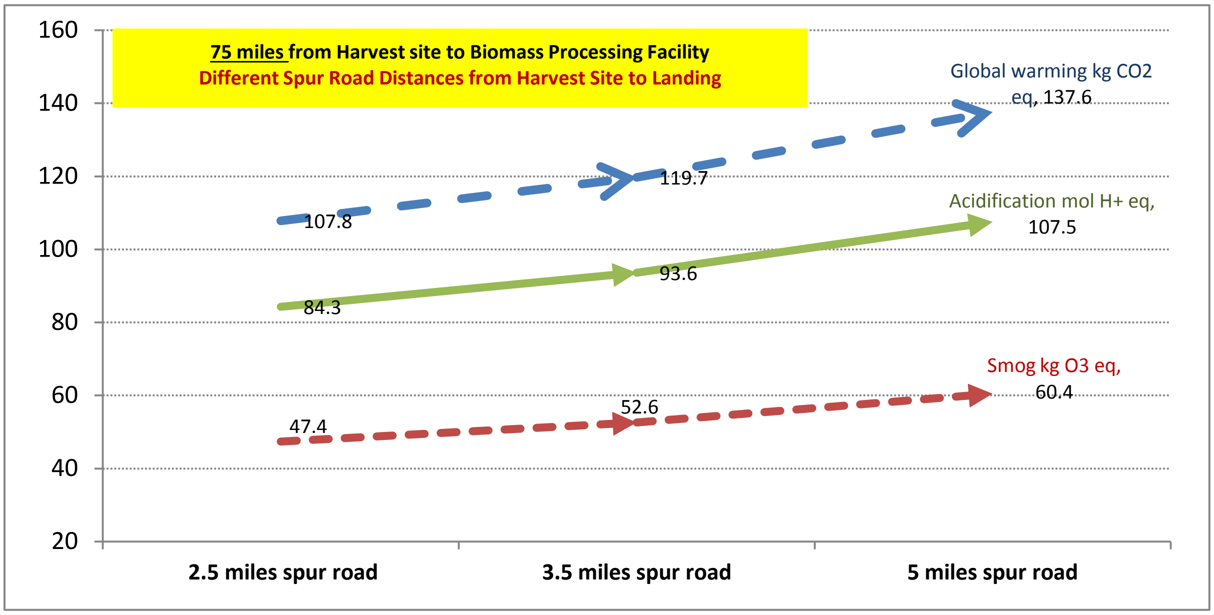

Figure 5: Environmental impact assessments of various forest road distances for hauling slash

Table 3: Environmental Impacts of Residual Extraction and Avoided Impacts of Slash Pile Burning

		System Impact	Avoided Impact	Total Impact
Global Warming	kg CO2 eq	65.71	-65.7	0.006
Smog	kg O3 eq	28.8	-89.5	-60.7
Acidification Air	mol H+ eq	52	-176	-124
Ozone Depletion	kg CFC-11 eq	2.71E-09	-3.26E-10	2.38E-09
Respiratory Effects	kg PM10 eq	0	-11.1	-11.1

Table 4: Complete Forest to IPK Process: Environmental Performance of 1 kg of IPK

Impact Category	Unit	Total	Contribution from Feedstock process	Contribution from Pretreatment and GEVO process
Global warming potential (GWP)	kg CO2 eq.	1.304708	4.38848E-05	1.304664
Acidification Potential	H+ moles eq.	-0.83518	-0.85198225	0.016798
Eutrophication Potential	kg N eq.	0.004714	-0.000699414	0.005413
Ozone depletion Potential	kg CFC-11 eq.	6E-08	1.63197E-11	6.00E-08
Smog Potential	kg O3 eq.	-0.27772	-0.4162199	0.138496
Respiratory Effects	kg PM10 eq.	-0.07464	-0.075427	0.00079

Table 5: ***Preliminary*** analysis of the emissions associated with aircraft transportation of one person for 1 kilometer on an intercontinental flight.

Impact category	**Unit**	**Transport, aircraft, passenger, intercontinental**	
		Bio-Jet Fuel (IPK)	**Fossil Fuel (Kerosene)**
Ozone depletion	kg CFC-11 eq	1.69E-06	1.42E-05
Global warming	kg CO2 eq	32.32	84.22
Fossil fuel depletion	MJ surplus	65.17	165.79

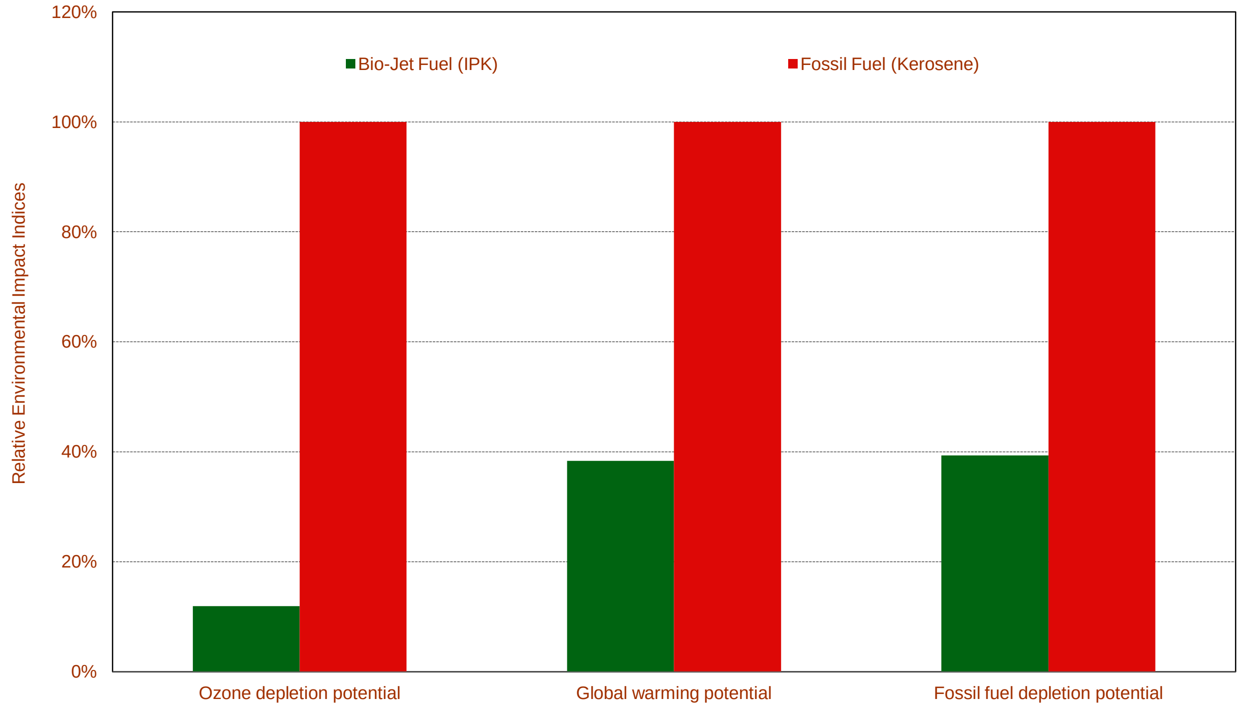

Figure 6. ***Preliminary*** analyses of the emissions reduction associated with bio-jet fuel used as a substitute for fossil-based jet fuel in an intercontinental flight.

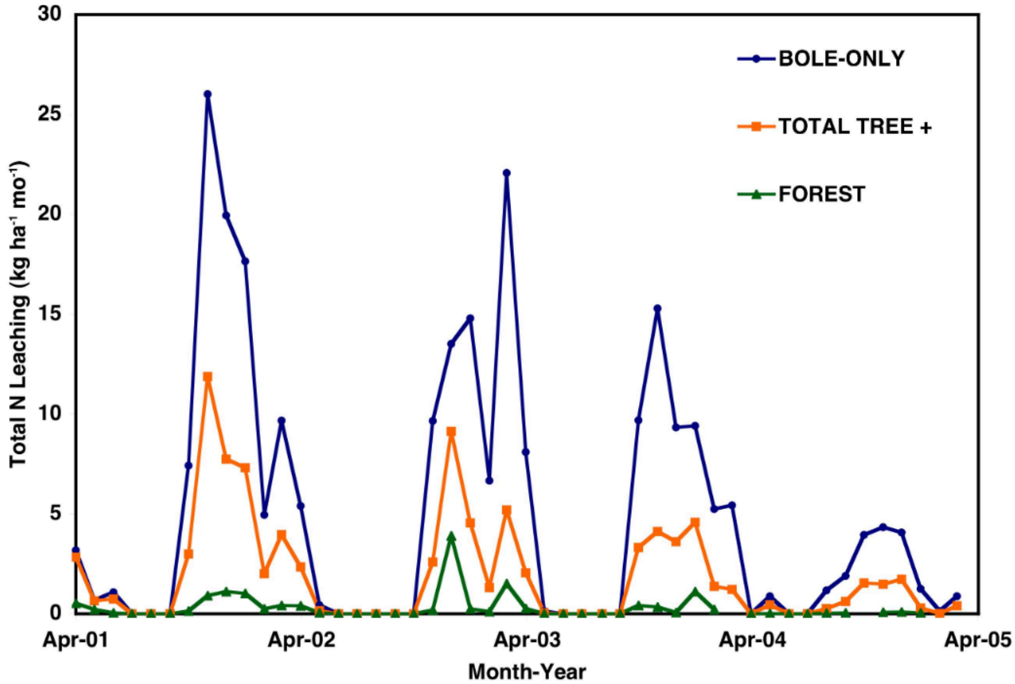

Figure 7. Temporary increase in nitrogen leaching and capture by new plantation growth at 1 m depth at the Fall River LTSP according to biomass removal levels. Note that the total loss is relatively modest compared to the 14,000 kg N/ha soil nitrogen pool.

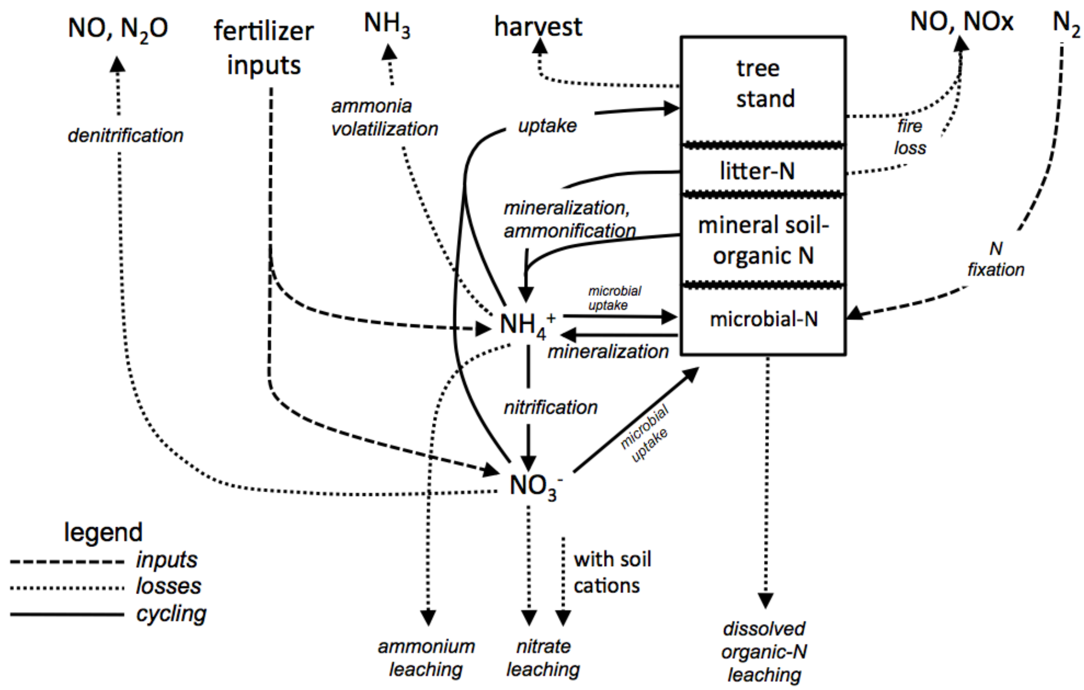

Figure 8. Sum of potential nitrogen pools and fluxes within a forest ecosystem, plantation or otherwise, relevant to sustained productivity.

Recommendations/Conclusions

Soil Carbon Team: We have completed a substantial amount of research relative to the potential for sustained productivity of conventional levels of biomass and increased levels of biomass from Pacific Northwest managed forests. The initial conclusions indicate that these ecosystems are currently highly productive, relatively rich in nutrients, and likely resilient to additional levels of nutrient removal through higher levels of organic matter removals. The assessments of nutrient levels and productivity correlates well with growth studies at the Fall River, Matlock and Molalla long-term soil productivity studies. The assessment of the 73 sites in the coastal Douglas-fir region from North Vancouver Island to Southern Oregon also indicates that most forests have good nitrogen stocks, at least, though some will have to be managed carefully or removals potentially ameliorated through fertilization. We will continue expanding and monitoring current studies, and participate in the new Willamette long-term soil productivity study. We plan to install a full suite of soil lysimeters and soil moisture and temperature monitoring equipment at the new Willamette LTSP in early May, 2013. This will be monitored for a duration sufficient to see the rise in soil nitrogen leaching characteristic of a disturbed ecosystem, as was done at Fall River (Figure 7). In the case of the Fall River LTSP, despite our ability to track the changes in mineralization, and movement of nitrogen into and out of the ecosystem, we found that there were no growth losses, as < 2% of total ecosystem nitrogen was lost at the most extreme treatment level. This and previous work at the new Willamette LTSP will help us to establish where the nitrogen is found in this ecosystem, and any potential adverse impacts that additional removal of biomass might cause, but in the static (pools of nitrogen in the ecosystem), and in the dynamic nitrogen cycle (fluxes into, within and out of the ecosystem) (Figure 8).

Community Impact Assessment Team: We have begun to populate our models with data from IMPLAN and will continue to do so in cooperation with the University of Idaho. Over the next two quarters we expect to have completed an impact assessment from the use of forest residuals on western Montana communities which will show us the economic contribution that the increased utilization of forest-based materials (forest residuals and thinnings) could have on communities in western Montana. The impact assessment will also allow us to assess community impacts through additional job creation and economic activity in those rural communities. Similar work is planned for NARA community #2 in western Washington/Oregon as well as the broader impacts to the four state region.

LCA Team: Preliminary framework LCA using secondary data is completed for the Inland Empire region and the report will be available by the end of June 2013. Most of the secondary data is sourced from the data generated by the CORRIM group headed by the University of Washington. Moreover, attempts are being made to have access to the Potlatch in-woods biomass program results. Multiple residual transportation and harvesting scenario-based analyses have been conducted and will be expanded over time. A preliminary LCA report structure following the ISO 14044 using simulated data will be available by end of April 2013. The LCA results will be enhanced when the simulated data is replaced with the primary data collected by the research team. Moreover, additional LCA scenarios will be developed based on the interview results increasing the regional specificity of the results. Accordingly, the target groups specific to the NARA Inland Empire project region are identified for the study and the sample frame developed. Four separate surveys developed, one for each of the identified target groups, are currently being pre-tested. The survey for Inland Empire region will be implemented between April-May, 2013. The Preliminary 'Feedstock LCA' report incorporating primary data for Inland Empire will be available by mid June 2013.

Proposed activities in the immediate short term include: (i) coordinating with Tim Smith to integrate the co-product LCA development task into the LCA group, (ii) meetings with the pre-treatment group and Gevo planned for end of April 2013, and (iii) completion of basic forest-to-pump LCA framework by mid June 2013 – *(Contingent on selection of pre-treatment process)*. Given the enhanced role of the LCA team, a new research fellow from Italy with chemical engineering and LCA background has been recruited and will be joining the LCA team in August 2013.

Research Papers: In the attributional LCA section, future research papers will include an enhanced list of harvest and transportation scenarios. In the consequential LCA section, the next phase of research papers will include studies that will account for fire abatement scenarios that involve crew travel, machine travel, additional piling, travel, and fuel use.

Physical and Intellectual Outputs

Physical Outputs

Soil Carbon Team

- Assessment of nitrogen pools and potential for depletion at 73 Pacific Northwest plantation sites
- Results on production of new forests after different levels of biomass and nutrient removals
- Assessment of soil carbon in new forests with and without competing biomass control
- Installation of nitrogen leaching in new Willamette LTSP

Community Impact Assessment Team

- Tables of economic output multipliers by county, state and region
- Tables of employment multipliers by county, state and region
- Social accounting matrix by county, state and region

LCA Team

- Updated database on biomass harvest techniques in Interior Empire Region
- Assessment of avoided environmental burdens due to reduction in slash pile burning
- Assessment of relative environmental burdens of various aspects of biomass harvest and transportation.
- Educational and training material on importance of Life Cycle Assessment of Bio-Jet fuel
- Development of training material on LCA calculations for graduate IDeX courses at Washington State University.

Refereed Publications (accepted or completed)

Devine, WD, P.A. Footen, B.D Strahm, R.B. Harrison, T.A. Terry and T.B. Harrington. 2012. Nitrogen leaching following whole-tree and bole-only harvests on two contrasting Pacific Northwest sites. For. Ecol. Mgt. 267:7-17.
Available at: http://soilslab.cfr.washington.edu/publications/Devine-etal-2012.pdf

Devine, WD, P.A. Footen, R.B. Harrison, T.A. Terry C.A. Harrington, S. M. Holub and P. J. Gould. 2013. Estimating Tree Biomass, Carbon, and Nitrogen in Two Vegetation Control Treatments in an 11-Year Old Douglas-Fir Plantation On a Highly Productive Site. USFS Research Paper PNW-RP-591, March 2013. Available at: http://soilslab.cfr.washington.edu/publications/Devine-etal-2013.pdf

Harrison, R. et al. 2012. Estimating tree biomass, carbon, and nitrogen in an 11-year-old Douglas-fir plantation on a highly productive site. In-preparation.

Austin J. Himes, Rob Harrison, Darlene Zabowski, Eric Turnblom, David Briggs, Warren Devine, Kimberly Hanft. Predicting risk of long-term N depletion due to whole-tree harvesting in the coastal Pacific Northwest. *under review by Soil Science Society of America Journal*

Jason James, Warren Devine, Rob Harrison Eric Turnblom The Importance of Deep Soil Carbon and Nitrogen in Ecosystem Analysis in Rocky Forest Soils of the Pacific Northwest. *In preparation:*

Research Presentations

Bowers, C. T., Ganguly, I., & Eastin, I. (2013). Avoided Impacts by Utilizing Woody Biomass Residuals for Bio-Jet Fuel: A Comparative LCA Investigating an Alternative to Slash Pile Burning. Poster session presented at the Wood Composites Symposium. April, 2013, Seattle, WA.

Bowers, C. T., Ganguly, I., & Eastin, I. (2013). Avoided Impacts by Utilizing Woody Biomass Residuals for Bio-Jet Fuel: A Comparative LCA Investigating an Alternative to Slash Pile Burning. Poster session presented at the Small Logs Conference. March, 2013, Coeur d'Alene, Idaho.

Bowers, C. T., Ganguly, I., & Eastin, I. (2012). *Scenario based LCA analysis: minimizing environmental burdens associated with collection of woody biomass for bio-jet fuel*. Poster session presented at the Future Forestry Leaders Symposium. December 7th, 2012, Vancouver, B.C., Canada.

Bowers, C. T., Ganguly, I., & Eastin, I. (2012). *Scenario based LCA analysis: minimizing environmental burdens associated with collection of woody biomass for bio-jet fuel*. Poster session presented at the Northwest Bioenergy Research Symposium. November 13th, 2012, Seattle, WA.

Bowers, T., I. Eastin and I. Ganguly. 2012. Pacific Northwest Residual Processing Life Cycle Impact Assessment. Poster presented at the International Wood Composites Symposium, Seattle, WA, April 11-13.

Ganguly, I., Bowers, C. T., Eastin, I., & Oneil, E. (2012). *LCA analysis of transportation scenarios in the woody feedstock supply chain of bio-jet fuel.* Presentation given at the Future Forestry Leaders Symposium. December 7th, 2012, Vancouver, B.C., Canada.

Ganguly, I., Bowers C. T, Eastin I. L., & Oneil, E. (2012). LCA of Feedstock Supply Chain Forest conditions: Inland West, The Northwest Bioenergy Research Symposium, Seattle. November 13, 2012.

Ganguly, I., Bowers C. T, Eastin I. L., & Oneil, E. (2012). LCA of Feedstock Supply Chain, NARA meeting 2012, Missoula, MT.

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Appendix 1.

Community Impact Assessment

Table A1: BioJet Fuel Computable Equilibrium Model Statement

Import Price:	$PM_c = (1 + tm_c) \times EXR \times pwm_c$	$c \in CM$
Export Price:	$PE_c = (1 + te_c) \times EXR \times pwe_c$	$c \in CE$
Absorption:	$PQ_c + QQ_c = [PD_c \times PD_c + (PM_c \times PM_c)_{\mid c \in CM}] \times (1 + tq_c)$	$c \in C$
Domestic Output Value:	$PX_c + QX_c = [PD_c \times QD_c + (PE_c \times QE_c)_{\mid c \in CE}$	$c \in C$
Activity Price:	$PA_a = \sum_{c \in C} PX_c \times \theta_{ac}$	$a \in A$
Value-added Price:	$PVA_a = PA_a - \sum_{c \in C} PQ_c \times ica_{ca}$	$a \in A$
Activity Production Function:	$QA_a = ad_a \times \prod_{f \in F} QF_{fa}^{\alpha}$	$a \in A$
Factor Demand:	$WF_f \times WFDIST_{fa} = \frac{a_{fa} \times PVA_a \times QA_a}{QF_{fa}}$	$f \in F, a \in A$
Intermediate Demand:	$QINT_{ca} = ica_{ca} \times QA_a$	$c \in C, a \in A$
Output Function:	$QX_c = \sum_{a \in A} \theta_{ac} \times QA_a$	$c \in C$
Composite Supply Function:	$QQ_c = aq_c \times \left(\delta_c^q \times QM_c^{-\rho_c^q} + \left(1 - \delta_c^q\right) \times QD_c^{-\rho_c^q}\right) \rho_c^{\frac{-1}{q}}$	$c \in CM$

Import-Domestic Demand Ratio:

$$\frac{QM_c}{QD_c} = \left(\frac{PD_c}{PM_c} \times \frac{\delta_c^q}{1 - \delta_c^q}\right)^{\frac{1}{1+\rho_c^q}} \qquad c \in CM$$

Composite Supply for Non-imported Commodities:

$$QQ_c = QD_c \qquad c \in CNM$$

Output Transformation (CET) Function:

$$QX_c = at_c \times (\delta_c^t \times QE_c^{\rho_c^t} + (1 - \delta_c^t) \times QD_c^{\rho_c^t})^{\frac{1}{\rho_c^t}} \qquad c \in CE$$

Export-Domestic Supply Ratio:

$$\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PD_c} \times \frac{1 - \delta_c^t}{\delta_c^t}\right)^{\frac{1}{\rho_c^t - 1}} \qquad c \in CE$$

Output Transformation for Non-exported Commodities:

$$QX_c = QD_c \qquad c \in CNE$$

Factor Income: $YF_{hf} = shry_{hf} \times \sum_{a \in A} WF_f \times WFDIST_{fa} \times QF_{fa} \qquad h \in H, f \in F$

Household Income: $YH_h = \sum_{f \in F} YF_{hf} + tr_{h,gov} + EXR \times tr_{h,row} \qquad h \in H$

Household Consumption Demand:

$$QH_{ch} = \frac{\beta_{ch} \times (1 - mps_h) \times (1 - ty_h) \times YH_h}{PQ_c} \qquad c \in C, h \in H$$

Investment Demand: $QINV_c = qinv_c \times IADJ \qquad c \in C$

Government Revenue:

$$YG = \sum_{h \in H} ty_h \times YH_h + EXR \times tr_{gov,row} + \sum_{c \in C} tq_c \times (PD_c \times QD_c + (PM_c \times QM_c)_{c \in CM}) + \sum_{c \in CM} tm_c \times EXR \times pwm_c \times QM_c + \sum_{c \in CE} te_c \times EXR \times pwe_c \times QE_c$$

Government Expenditures: $EQ = \sum_{h \in H} tr_{h,gov} + \sum_{c \in C} PQ_c \, qg_c \qquad c \in C$

Factor Markets: $\sum_{a \in A} QF_{fa} = QFS_f \qquad f \in F$

Composite Commodity Markets:

$$QQ_c = \sum_{a \in A} QINT_{ca} + \sum_{h \in H} QH_{ch} + qg_c + QINV_c \qquad c \in C$$

Current Account Balance for ROW (in Foreign Currency):

$$\sum_{c \in C} pwe_c \times QE_c + \sum_{i \in I} tr_{i,row} + FSAV = \sum_{c \in CM} pwm_c \times QM_c$$

Savings-Investment Balance:

$$\sum_{h \in H} mps_h \times (1 - ty_h) \times YH_h + (YG - EG) + EXR \times FSAV = \sum_{c \in C} PQ_c \times QINV_c + WALRUS$$

Price Normalization: $\sum_{c \in C} PQ_c \times cwts_c = cpi$

SETS

$a \in A$ activities

{FOR-A forestry activity, AGR-A agricultural activity, NAGR-A nonagricultural activity}

$c \in C$ commodities

{FOR-C forest commodity, AGR-C agricultural commodity, NAGR-C nonagricultural commodity}

$c \in CM\ (C)$ imported commodities

{NAGR-C nonagricultural commodity}

$c \in CNM\ (C)$ nonimported commodities

{FOR-C, forest commodity, AGR-C agricultural commodity}

$c \in CE\ (C)$ exported commodities

{AGR-C agricultural commodity}

$c \in CNE\ (C)$ nonexported commodities

{FOR-C, forest commodity, NAGR-C nonagricultural commodity}

$f \in F$ factors

{LND, land, LAB labor, CAP capital}

$i \in I$ institutions

{F-HHD forest household, U-HHD urban household, R-HHD rural household, GOV government, ROW rest of world}

$h \in H$ ($<I$) households

{F-HHD forest household, U-HHD urban household, R-HHD rural household}

PARAMETERS

ad_a	*efficiency parameter in the production function for activity a*
aq_c	*shift parameter for composite supply (Armington) function*
at_c	*shift parameter for output transformation (CET) function*
cpi	*consumer price index (CPI)*

$cwts_c$	*weight of commodity c in the CPI*
ica_{ca}	*qnty of c as intermed. input per unit of output in activity a*
mps_h	*marginal (and average) propensity to save for household h*
pwe_c	*export price (foreign currency)*
pwm_c	*import price (foreign currency)*
qg_c	*government commodity demand*
$qinvc$	*base-year qnty of investment demand for commodity c*
$shry_{hf}$	*share for household h in the income of factor f*
te_c	*export tax rate*
tm_c	*import tariff rate*
tq_c	*sales tax rate*
$tr_{ii'}$	*transfer from institution i' to institution i*
ty_h	*rate of household income tax*
α_{fa}	*share of value-added for factor f in activity a*
β_{ch}	*share in household h consumption spending of commodity c*
δ_c^q	*share parameter for composite supply (Armington) function*
δ_c^t	*share parameter for output transformation (CET) function*
θ_{ac}	*yield of output c per unit of activity a*
ρ_c^q	*exponent* ($-1 < \rho_c^q < \infty$) *for composite supply (Armington) function*
ρ_c^t	*exponent* ($1 < \rho_c^t < \infty$) *for output transformation (CET) function*
σ_c^q	*elasticity of substitution for composite supply (Armington) function*
σ_c^t	*elasticity of transformation for output transformation (CET) function*

VARIABLES

EG	government expenditure
EXR	foreign exchange rate (domestic currency per unit of foreign currency)
FSAV	foreign savings
IADJ	investment adjustment factor

P_c	market price of commodity *c*
PA_a	price of activity *a*
PD_c	domestic price of domestic output
PE_c	export price (domestic currency)
PM	import price (domestic currency)
PQ_c	composite commodity price
$PVAa$	value-added (or net) price of activity *a*
PX_c	producer price (excluding sales tax) of commodity c
QA_a	level of activity *a*
QD_c	quantity of domestic output sold domestically
QE_c	quantity of exports
QF_{fa}	demand for factor *f* from activity *a*
QFS_f	supply of factor *f*
QH_{ch}	consumption of commodity *c* by household *h*
$QINT_{ca}$	qnty of commodity *c* as intermediate input in activity *a*
$QINV_c$	quantity of investment demand for commodity *c*
QM_c	quantity of imports
QQ_c	quantity supplied to domestic commodity demanders (composite supply)
QX_c	quantity of domestic output
$WALRAS$	dummy variable (zero at equilibrium)
WF_f	price of factor *f*
$WFDIST_{fa}$	wage distortion factor for factor *f* in activity *a*
YF_{hf}	income of household *h* from factor *f*
YG	government revenue
YH_h	income of household *h*

Sustainable Production Team

SM-SP-1: Sustainable Feedstock Production Systems

Key Personnel	Affiliation
Scott Holub	Weyerhaeuser
Greg Johnson	Weyerhaeuser

Task Description

The importance of ensuring environmental sustainability and carbon benefits of biofuel production cannot be overstated. 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 be detrimental to 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 (Figure 1).

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 we also plan to study biomass removal and compaction effects on wildlife and water quality to round out the environmental sustainability picture for biomass harvesting.

Activities and Results

Task SM-SP-1.1. Pre-treatment site selection and assessment

All pre-harvest data have been collected. Extra plots have been dropped. Statistical blocks have been determined (using total soil nitrogen with spatial consideration) and treatments randomly assigned across each block. (Figure 2.) Over 150 physical, chemical, and biological parameters have been recorded for below-ground plot information. Average soil carbon to 1 m depth across the plots is 224 Mg ha^{-1}. Soil Nitrogen is 11,250 kg ha^{-1}. Rock volume is 1.5%. Clay in the surface 15cm is 30% and 47% to 1-m depth. Above-ground over 40 parameters have been recorded on the plots. Highlights include 156 Douglas-fir stems and 4 other species' stems per ha; quadradic mean diameter of the Douglas-fir was 16.5 inches; tree volume in Douglas-fir was 104 cunits ac^{-1}; and tree biomass was 332 Mg ha^{-1}.

Task SM-SP-1.2. Implement Treatments

Harvesting and treatment-implementation began on February 26, 2013. Cutting of trees outside of the plot areas has been completed. 5 plots (of 28 total) have been cut and harvested. Further cutting, logging, and treatments is ongoing.

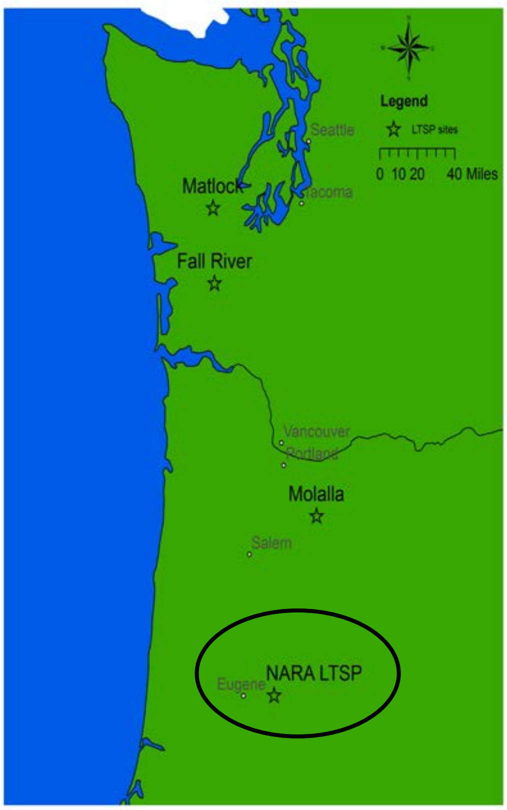

Figure 1. Map of the coastal Douglas-fir LTSP study sites in Oregon and Washington.

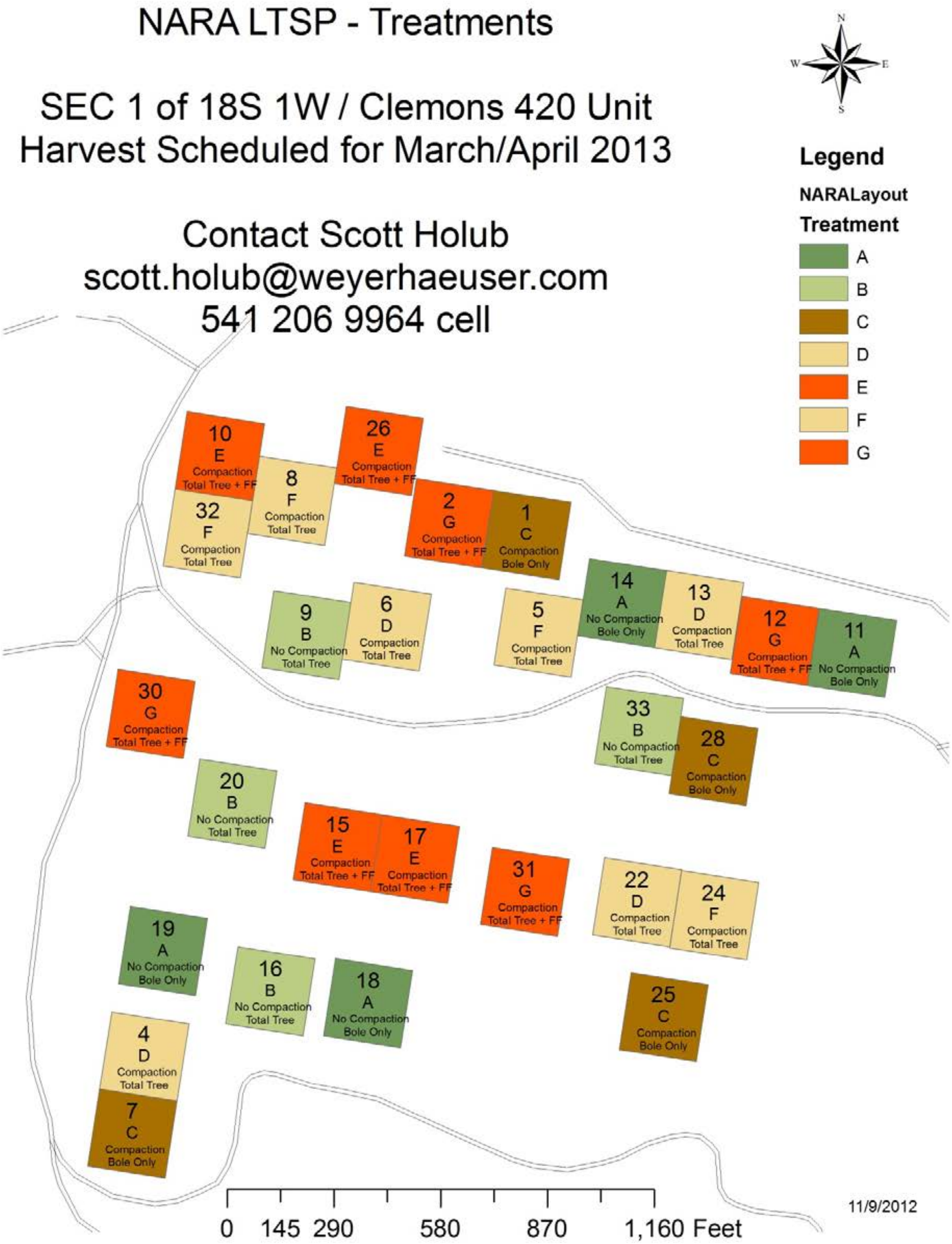

Figure 2. NARA LTSP Treatment map.

Recommendations/Conclusions

Year 3 funding will be critical for this aspect of the NARA study. In years 1 and 2 we began the lengthy process of installing a new study site to address sustainability issues. In year 3, funding will provide the resources needed to complete the required treatments, instrument the site with temperature and moisture probes, and construct a fence to prevent big game browse of seedlings. In year-3 funding will also support the planting, care, and measurement of over 10,000 Douglas-fir seedlings, which are the major bio-indicator of site productivity.

Physical and Intellectual Outputs

Refereed Publications (accepted or completed)

Holub, S.M., T.A. Terry, C.A. Harrington, R.B. Harrison, R. Meade. 2013. Tree growth ten years after residual biomass removal, soil compaction, tillage, and competing vegetation control in a highly-productive Douglas-fir plantation. Forest Ecology and Management – Under Revision. March 14, 2013.

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

Conference Proceedings and Abstracts from Professional Meetings

Holub, S., N. Meehan, B. Carrier, R. Meade, G. Johnson, R. Harrison, M. Betts, M. Barber. 2012. NARA Long-term Soil Productivity (LTSP) Project. Poster presentation at IUFRO meeting "Nutrient Dynamics of Planted Forests." Vancouver, WA, November 27-28, 2012.

Research Presentations

Holub, S., N. Meehan, B. Carrier, R. Meade, G. Johnson, R. Harrison, M. Betts, M. Barber. 2012. NARA Long-term Soil Productivity (LTSP) Project. Poster Presentation at NARA annual meeting. Missoula, MT, September 13, 2012.

Other Publications

Templeton, A. 2013. Leaving behind logging debris could help fight invasive weeds. Scott M. Holub was interviewed on Oregon Public Radio about the role of slash retention on seedling growth. (http://www.nwpr.org/post/leaving-behind-logging-debris-could-help-fight-invasive-weeds) March 15, 2013.

Awards & Recognition

Scott M. Holub was a winner of the Corporate EcoForum Sustainability Leadership Contest. April 7, 2013. http://corporateecoforum.com/ecoinnovator/?p=7783

Task SM-SP-2: Sustainable Biomass Supply from Forest Health and Fire Hazard Reduction Treatments

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

Task Description

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

Activities and Results

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

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

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

Task SM-SP-2.2 is ongoing. We have collaborated regularly with Darius Adams and the economic modeling team in order to gain a greater understanding of cross-disciplinary goals and needs. A sensitivity analysis of model assumptions are currently being completed, including: management entry requirements, characteristics of a successful treatment, re-entry requirements and prescription formulation. This analysis is being performed using the ArcFuels tool bar within ArcGIS. A workshop on the functionality of this toolbar and the assumptions of the software was completed at the 5th International

Fire Ecology and Management Congress in Portland Oregon. Preliminary forest growth model runs have been completed as well as quality control of those results. In addition, baseline fire hazard modeling has been completed across Oregon in order to measure effectiveness of thinning regimes and ability of the utilization of biomass material to alter landscape level fire hazard. Prototype model runs will be available for review soon and conducted in conjunction with Task SM-SP-2.3.

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

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

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

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

Recommendations/Conclusions

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

Physical and Intellectual Outputs

Conference Proceedings and Abstracts from Professional Meetings

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

Vogler, K. "Developed silvicultural prescriptions and overall model framework." Poster presentation at the 5th International Fire Ecology and Management Congress, Portland, OR, December 4, 2012.

Bailey, J.D. "Scaling up our understanding of fire risk and fuels management." Presentation at the 5th International Fire Ecology and Management Congress, Portland, OR, December 5, 2012.

Bailey, J.D. "Stocked Stands to Standing Stocks: Sustainable Forest Management and Bioenergy. Presentation at Northwest Bioenergy Research Symposium, Seattle, WA, November 13, 2012.

Research Presentations

Vogler, K. "Regional Biomass Assessment of the Deschutes National Forest." Oral presentation to colleagues in Forest Biometrics course at OSU. Corvallis, OR, March 15, 2012.

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

Task SM-SP-3: Biomass Modeling and Assessment

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

Task Description

The goals of this task are to : 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 Idaho and Montana 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 Oregon and Washington 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: biomass processing plant locations and capacities, as well as biomass supply volumes under alternative biomass prices.

Activities and Results

This project has three major parts: (i) develop an efficient and flexible means to use the Forest Vegetation Simulator (FVS) model to project biomass available tributary to timber harvesting and to simulate large numbers of alternative silvicultural regimes (designed in some cases to increase biomass production); (ii) modify existing regional timber market models to recognize sale of biomass from harvests (including costs of collection, chipping and transportation to hypothetical refinery locations); and (iii) development of biomass supply curves at hypothetical locations under a broad range of scenarios on potential collection technology, constraints on types and sources of biomass, and other conditions affecting the cost of delivered biomass. As a first step we assembled all the Forest Inventory and Analysis (FIA) plot data for the NARA study region, devised methods for estimating key site quality (plant association) measures not collected (or erroneously collected) in FIA sampling, and constructed methods to screen extraneous portions of the FIA database and detect errors in critical parts of the tree and condition class data. We assembled key data on production, output prices, input use and input prices for lumber and plywood mills in the NARA region and began estimation of profit functions by industry and region to provide critical log demand elasticity parameters for the market models. Demand elasticities have been estimated for Oregon and Washington.

In a major step, we successfully converted all the FVS variants in the NARA study region to a composite model based on simplified C++ code. This allows rapid generation of 100-year projections of timber volumes and biomass under user-specified silvicultural regimes. As a quality assurance step we compared yields from the C++ code with results derived directly from FVS across the roughly 4000 condition classes of timberlands sampled in western Oregon and found only modest differences. Yield computations have been augmented to provide estimates of three components of harvest: sawlog/veneer logs, pulpwood, and residual biomass. The latter category comprises estimates of weight by tops, branches and broken portions of logs, as would be encountered in residual slash piles.

The timber market model has been revised to include biomass collection from harvested sites and sales at user-specified locations together with extraction and sale of roundwood pulpwood volumes. The model determines flows to pulpwood and biomass destinations endogenously based on costs and prices. Pulpwood can be downgraded to biomass if price/cost conditions warrant. A western Oregon example market projection has been run with the model using timber yield inputs from the C++ code and assumptions about biomass extraction and haul costs. The model has been used to examine both single and multiple hypothetical biomass destination scenarios and an example biomass supply curve has been generated for a single site case.

Recommendations/Conclusions

Over the next few months we will refine our work by elaborating details in the model's treatment of biomass harvesting (using more complex cost structures to represent alternative extraction and hauling methods), developing better estimates of biomass delivery cost components (in conjunction with other projects in NARA), and adding a milling residues component (to have a more complete materials balance picture, though these residues are unlikely to find their way into biofuels use). We plan to demonstrate the overall modeling system's capabilities on two areas: western Oregon, which has high timber volumes per unit area, rapid timber growth, and a relatively dense network of milling facilities with expanding capacity and the "western Montana corridor" with lower timber densities, slower growth and a relatively sparse milling network with contracting capacity. We will construct example delivered biomass supply curves for these regions under various background assumptions on facility location(s).

In conjunction with the NARA sub-project developing silvicultural regimes, we will simulate the impact of these regimes on near and long-term timber and biomass supply. We will also begin coordination with elements of the overall NARA project dealing with the environmental and ecosystem services impacts of wide-scale biomass harvesting.

Physical and Intellectual Outputs

Thesis and Dissertations

Guerrero, Isabel. 2012. An econometric analysis of output supply and input demand in the Oregon softwood lumber and plywood industries. Paper submitted for MS (without thesis) in Applied Economics, Oregon State University.

Task SM-SP-4: Long Term Productivity Studies

Key personnel	Affiliation
Doug Maguire	Oregon State University

Task Description

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

Activities and Results

Two seasons of field sampling have been completed, including sampling of numerous tree components from 199 trees ranging in breast height age from ~9 to ~90 years, in diameter at breast height (dbh) from 10-85 cm, and in height from 5-58 meters. Processing the biomass components of these trees in the lab is ~80% complete, and chemical analysis of component tissue has been completed on about 60% of the samples. In addition, understory vegetation sampling has been completed across a chronosequence of sites ranging in age from 0-20 years. Biomass equations have been fit to data collected during the first sampling season, and are currently being incorporated into a Master's thesis.

Recommendations/Conclusions

Progress has been steady and is on schedule. When all of the data are available from the two seasons of field sampling, final equations will be fit, enabling their use for simulations.

Physical and Intellectual Outputs

Research Presentations

Coons, K., D. Maguire, and D. Mainwaring. 2012. The nutrient harvest limits of biofuel production from Douglas-fir biomass in coastal Pacific Northwest forests. Poster presented at 2012 Oregon Society of American Foresters Meeting, Seaside, OR. April 25-26, 2012.

Coons, K., D. Maguire, and D. Mainwaring. 2012. Sustainable biofuel production from forest biomass. Poster presented at NARA 2012 Annual Meeting, Missoula, MT. September 12-13, 2012.

Other Publications

Coons, K., Mainwaring, D., Bluhm, A., Maguire, D., Harrison, R., and Turnblom, E. 2012. Response of allometric relationships to stand density regime and nitrogen fertilization. Pp. 39-42 in D.A. Maguire and D.B. Mainwaring (eds). 2011 CIPS Annual Report, Center for Intensive Planted-forest Silviculture, College of Forestry, Oregon State University, Corvallis, OR, USA.

Task SM-SP-5: Environmental Impact Analysis to Support NARA Biofuel Development in the Pacific Northwest

Key Personnel	Affiliation
Michael Barber	Washington State University
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 and water quality. There is a need to investigate both air and water quality, as well as water quantity. The work will determine impacts that biofuel harvesting may have on short- and long- term changes in air pollution, sediment and nutrient loadings, and hydrologic dynamics within the project watersheds at scales ranging from field scale to regional scale. The *specific objectives* of this project are to: (1) 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) collect and examine macroinvertebrate communities at the test plots; (3) develop predictive water quantity and quality models that can be used to evaluate watershed-scale regional impacts; and (4) develop an air quality model of the region.

Activities and Results

Water Quality and Resources

We have been examining erosion and runoff modeling to evaluate the impacts of additional biomass removal from logged areas and evaluated several model options before selecting the WEPP model. Processes in WEPP erosion include rill and interrill erosion, sediment transport, and deposition, infiltration, soil consolidation, residue and canopy effects on soil detachment and infiltration, surface sealing, rill hydraulics, surface runoff, plant growth, residue decomposition, percolation, evaporation, transpiration, snow melt, frozen soil effects on infiltration and erodibility, climate, and effect of soil random roughness. The basic equation for sediment erosion:

$$\frac{dq_s}{dx} = D_r + D_i \qquad (1)$$

where q_s is the sediment load (kg/s-m), x is the longitudinal downslope distance (x), D_r is the rill erosion rate (kg/s-m^2), and D_i is the interrill erosion rate (kg/s-m^2). Equations for the rill and interrill erosion can be expressed as:

$$D_r = K_{rb}\left(\tau_f - \tau_{cb}\right)\left(1 - \frac{q_s}{T_c}\right) \qquad (2)$$

and

$$D_i = K_{i\,adj}\ I_e\ \sigma_{ir}\ SDR_{rr}\ F_{nozzle}\ {R_s}/{W_e} \quad (3)$$

where $K_{r\,adj}$ is the adjusted baseline erodibility (s/m), τ_f is the shear stress of the flow (Pa), τ_{cb} is the baseline critical shear stress (Pa), T_c is the transport capacity (kg/s-m), $K_{i\,adj}$ is the adjusted baseline interrill erodibility, I_e is the equivalent rainfall intensity (m/s), σ_{ir} is the interrill runoff rate (m/s), SDR_{rr} is the interrill sediment delivery ratio, F_{nozzle} is the sprinkler nozzle energy factor, R_s is rill spacing (m), and W_e is the equilibrium rill width (m).

The interrill erodibility equation in (3) can be adjusted for local conditions including ground cover (Ki_{gc}) as follows:

$$K_{i\,adj} = K_{ib}K_{ican}K_{igc}K_{idr}K_{ilr}K_{isc}K_{isl}K_{ift} \quad (4)$$

The ground cover coefficient is given by

$$K_{igc} = e^{(-2.5 * Fgc)} \quad (5)$$

This study considers existing logging operations as the baseline for comparison and focuses on the changes directly related to the removal of slash materials. Other researchers have concluded that ground cover would impact erosion more than runoff although both parameters would respond in similar ways. Figure 1 shows the exponential decrease predicted by Equation 5.
We are in the process of designing field experiments that will begin later this summer to improve Equation 5 by developing an improved method linked to biomass removal.

Air Quality Assessment

The focus is on developing air pollution emission inventories related to potential biojet supply chains in the Northwest so that regional air quality modeling simulations can be conducted to assess the impacts of biojet production on local air quality. We have followed two tracks in this assessment: compilation of emission inventory information and laboratory studies of biomass pre-treatment emissions. In this first case, the starting place is our regional air quality forecast system, AIRPACT, which operates daily to produce detailed, hourly concentration maps for the region with a focus on ozone (a summertime issue) and particulate matter (PM2.5) (http://lar.wsu.edu/airpact/gmap/ap4.html). AIRPACT emissions are taken from compilations by the state agencies and the Environmental Protection Agency (EPA) and account for virtually all anthropogenic and natural sources, including detailed emissions for various segments of the wood product industry. As a first step, we have compiled the emissions from the wood product industry with the intent of using these emissions as a first step in understanding how changes to the wood product industry due to new biofuel processing might affect air quality. A graphic of these emissions is shown in Figure 2.

In the second track, we have initiated laboratory studies of what gas phase pollutants are produced as a result of pre-treatment of wood chips using a digestion process similar to that envisioned for the biofuel process. This process is shown in Figure 3. Results from the laboratory tests, based on measurements of the headspace of the digestion chamber after a treatment process, are shown in Figure 4. These measurements were collected using a Proton Transfer Reaction Mass Spectrometer. The results show the wide range of organic compounds produced by the process. Further work will be focused on identification of the key species.

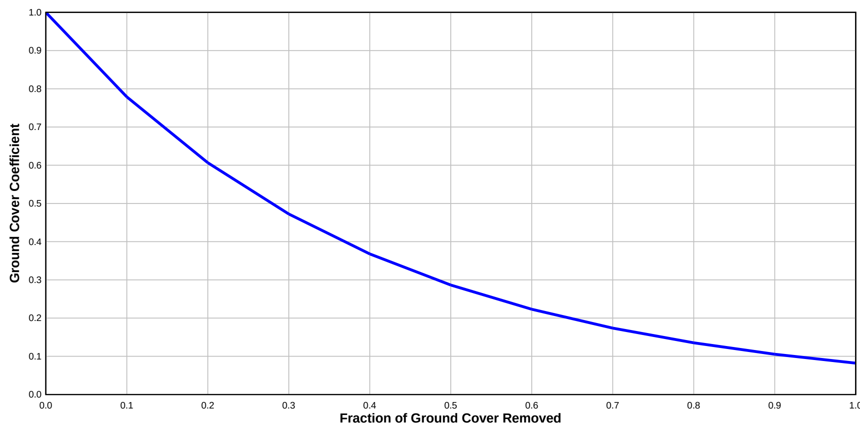

Figure 1. Impact of ground cover on interrill erosion.

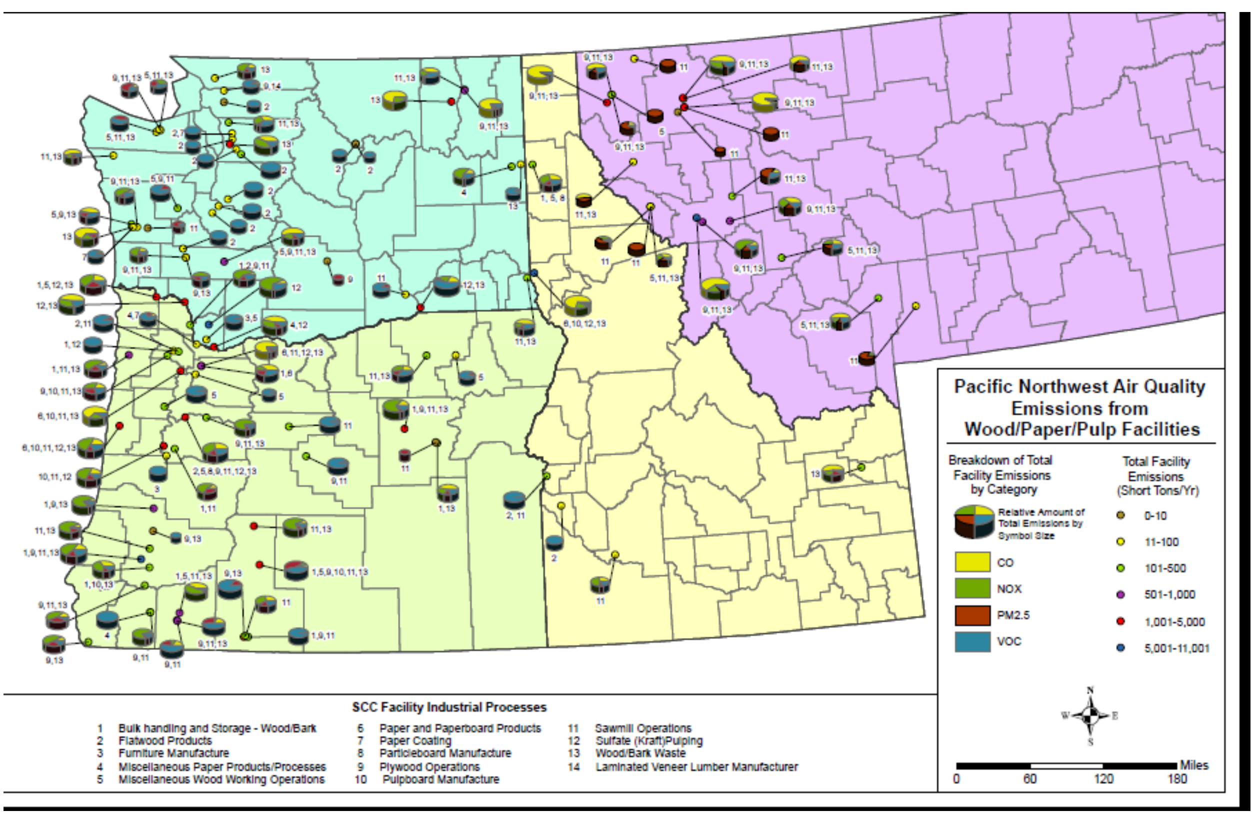

Figure 2. Compilation of air pollution emissions from wood product facilities.

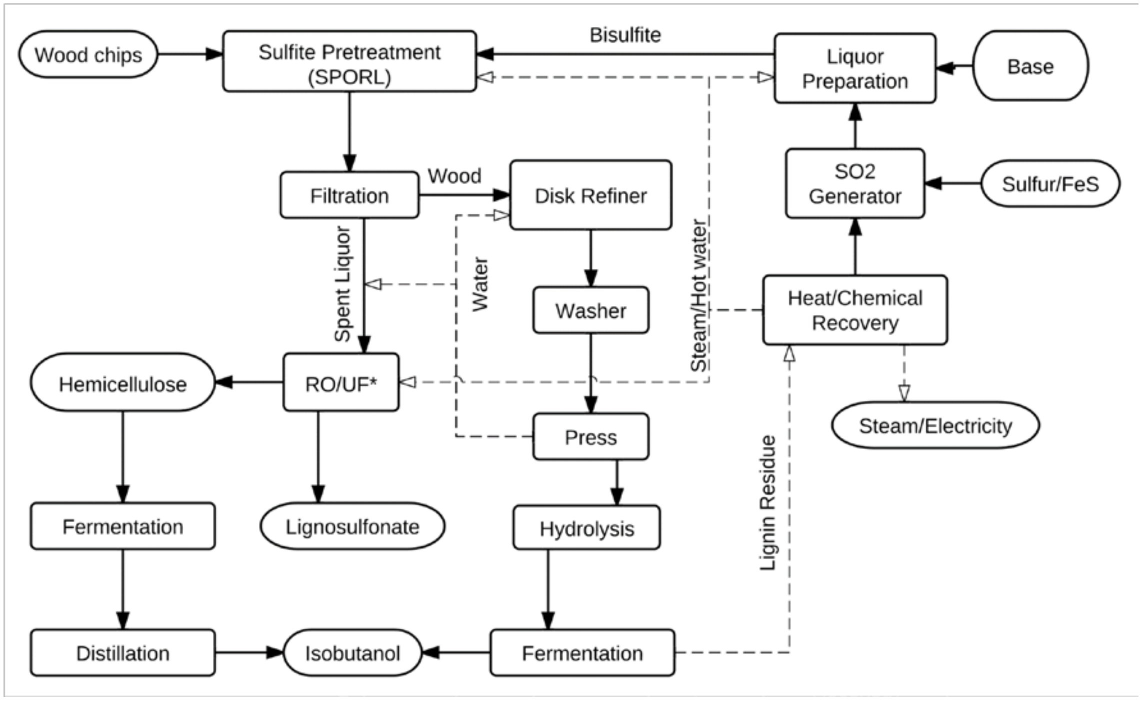

Figure 3. Flow diagram of the biofuel treatment process, including the SPORL pre-treatment step.

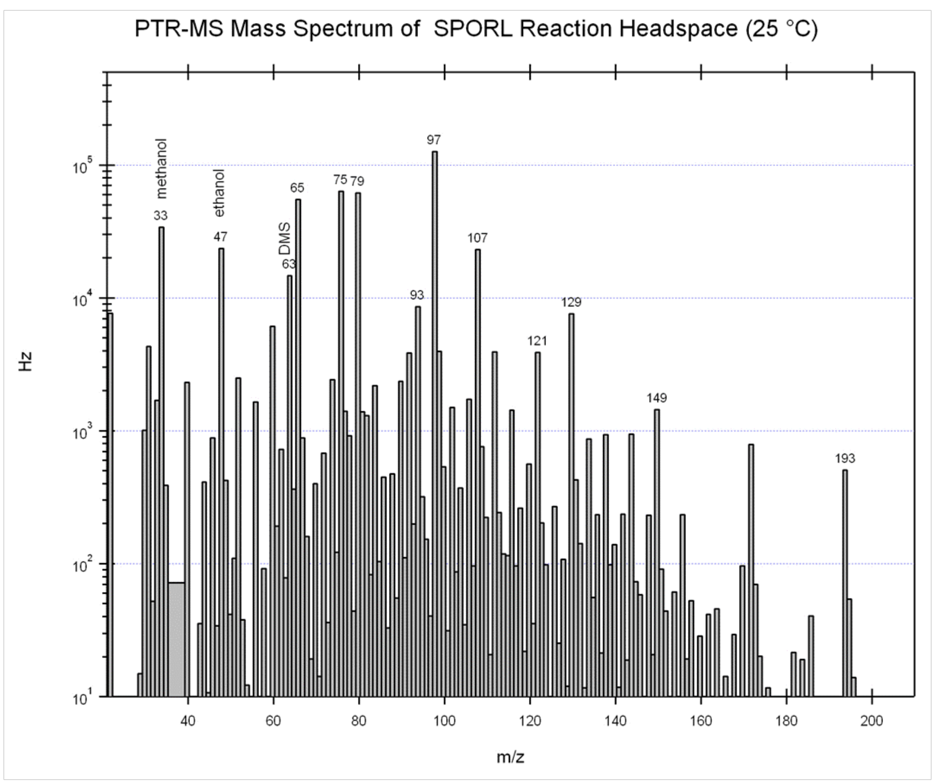

Figure 4. PTR-MS spectra of organic compounds in the off-gas of the SPORL treatment process

Recommendations/Conclusions

While Figure 1 was developed for agricultural ground, if the data from forested lands follows a similar trend then the difference between traditional logging and biojet fuel processing will result in small changes that would likely impact only the steepest and most erodible soils. This result would mean that only small sections of harvested areas would be excluded from biomass.

Physical and Intellectual Outputs

Research Presentations

Fuchs, M., M. Wolcott, T. Jobson, B. Lamb, N. Martinkus, J. Jiang, and P. Gray. 2012. NARA Biofuels Production Emissions. Northwest Advanced Renewables Alliance Summer Undergraduate Research Experience (NARA SURE). Poster presentation, August 3.

Fuchs, M., M. Wolcott, T. Jobson, B. Lamb, N. Martinkus, J. Jiang, and P. Gray. 2012. NARA Biofuels Production Emissions. Poster presentation at NARA 2012 Annual Meeting, Missoula, MT, Sept 13-14, 2012.

Barber, M. and M. Mettler. 2012. Evaluating ecosystem responses to harvesting small diameter biomass. Poster presentation at NARA 2012 Annual Meeting, Missoula, MT, Sept 13-14, 2012.

Task SM-SP-6: Local and Regional Wildlife Impacts of Biomass Removals

Key Personnel	Affiliation
Matthew Betts	Oregon State University

Task Description

Silvicultural regimes proposed will be reviewed to reduce fire hazard and improve forest health. Existing data from the Pacific Northwest (PNW) on the relationship between species and stand structures (e.g., downed woody material, snags) will be used to estimate the potential impact of regimes on vertebrate abundance. Also, using existing published research, we will conduct a meta-analysis that tests the influence of species life-history traits on sensitivity to proposed silvicultural regimes. Landscape patterns resulting from regional models of biomass collection and removal will be reviewed. 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

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

Currently, we are reviewing the literature to understand which habitat characteristics are the most likely to be affected by biofuel harvesting, in particular loss of woody debris and soil disturbance and compaction. Through our literature review, we are determining which woody debris characteristics, such as exposure, decay class, and size, are important habitat features. We are reviewing wildlife and botany literature to identify species most likely to be affected by these practices both in relation to their habitat needs and life-history patterns.

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

Recommendations/Conclusions

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

Physical and Intellectual Outputs

Refereed Publications (accepted or completed)

Betts, M.G., Verschuyl, J., Stokely, T., Giovannini, J. and Kroll, A.J. In Review. Initial effects of herbicide on bird abundance in plantation forests. Forest Ecology and Management.

Research Presentations

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

Task SM-SP-7: Supply Chain Analysis

Key personnel	Affiliation
Todd Morgan	University of Montana

Task Description

Land managers and bioenergy specialists lack definitive knowledge of woody biomass inventories and availability in the Pacific Northwest. This information is key to understanding the social, economic, and environmental impacts and sustainability of producing new wood-based energy products. To answer these needs, The University of Montana's Bureau of Business and Economic Research's Forest Industry Research Program will characterize the composition, quantities, and spatial distribution of varied sources of woody biomass across the NARA four-state area. The *specific objectives* of the Feedstock Supply Chain Analysis Phase are to identify and provide primary data necessary to assess the woody biomass inventory with particular emphasis on mill and logging residue in the 4-state region and standing forest inventory in Montana and Idaho.

Activities and Results

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

The University of Montana's Bureau of Business and Economic Research (BBER) Forest Industry Research Group has provided fellow NARA researchers with forest industry and timber products output (TPO) data for modeling and 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. 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 Timber Product Output (TPO) data for Idaho (2006), Oregon (2008), Montana (2009), Washington (2010), with updated Idaho (2011) data scheduled for delivery in the fall of 2013.

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.

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 1,300 felled trees measured at 56 sits across the region (Table 1).

We can provide logging residue estimates for the NARA regionat 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.

Table 1: Logging utilization field work progress through March 31, 2013

State	Sites	Percent complete
Idaho	14	40
Montana	14	40
Oregon	14	40
Washington	14	40
Total	56	40

Recommendations/Conclusions

Conclusions

Mill Residues: BBER's recent TPO research (Gale et al. 2012; McIver et al. 2012; Brandt et al. 2012) confirms preliminary observations: virtually all mill residues currently produced in the region are used for either internal energy purposes or sold for a variety of industrial uses (primarily pulp and reconstituted board production). Bioenergy firms (such as NARA biomass 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 increases in domestic new home construction.

Logging Residues: BBER's recent summary of Idaho logging utilization research (Simmons et al. 2013) clearly shows that logging residues as a fraction of mill delivered volume have continued to decline through time as land managers have progressively utilized more woody biomass on commercial logging units. Improved technology, such as mechanized processing, helps ensure that more of each felled tree is utilized. BBER analysts have found that more than half of the variation in the logging residue fraction is related to 1. method of harvest- by hand or mechanical, 2. Presence/absence of pulp removal, and 3. broad geographic differences in site quality (Berg et al. 2012). Landing residue "slash" piles offer an important source of woody material for potential conversion to bio-jet and ancillary products.

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

Recommendations

Data management: We should organize NARA data so that it can be readily accessed and understood by both NARA researchers and the public.

Cooperation: We should improve collaboration and communication among NARA scientists. We have much to offer each other! The recent change in NARA's team structure has fostered better communications among team members; we need to continue seeking innovative ways that our colleagues can use BBER's TPO, logging utilization, timber harvest, forest industry, delivered log prices, and timber harvesting and hauling cost information in their work.

Logging utilization studies: We should 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 four years of data collection would substantially reduce the total number of sample sites per state and would jeopardize the utility of the data. BBER intends to focus Year-3 logging utilization sampling efforts on coastal Washington and Oregon and western Montana. We have now sampled 33 sites in Idaho (14 funded by NARA, 19 by Interior West FIA); we plan on returning to Idaho in years 4 & 5 of the project to "freshen our database" and gain information on 5 to 8 additional Idaho logging sites.

The Future

In Year 3, the BBER team will conduct logging utilization fieldwork, analyze and report logging utilization and other forest industry data, and share information with NARA Teams and stakeholders.

In order to provide NARA Teams with current information on the production and potential availability of woody biomass from the residues of commercial timber activities, BBER's Year-3 efforts will include:

- Measuring logging utilization at active logging sites across the four-state NARA region;
- Processing, summarizing, and sharing those logging utilization data and results with other members of NARA, regional stakeholders, and others;
- Collecting, analyzing, reporting, and otherwise sharing a variety of forest industry information in the region, including timber harvest levels by county and ownership, timber use, production of primary wood products, and production & disposition of mill residue.

Given proposed budget changes (i.e., direct expenses reduced to accommodate increased indirect costs) BBER is reducing the number of active logging sites to be measured in the third year from 5-7 sites per state to 3-6 sites per state. Measurement efforts will be prioritized in Oregon and Washington to ensure adequate samples per state. We anticipate being able to complete 5-6 more sites (each) in Washington and Oregon. Neither state has had a comprehensive logging utilization study conducted in 20 years, and more up-to-date information is critically needed in both states. Measuring 3-5 sites in Montana is the second priority, and we do not expect to measure more than three sites in Idaho during the third year.

Physical and Intellectual Outputs

Refereed Publications (accepted or completed)

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

Research Presentations

Berg, E., E. Simmons, S. Zarnoch, S. Hayes, T. Morgan, and C. Gale. 2012. Logging Residues: preliminary predictive models. Poster presented at the NARA Annual Meeting, Missoula, MT, September 12-14, 2012.

Berg, E., E. Simmons, T. Morgan, C. Gale, S. Zarnoch and S. Hayes. 2012. Estimating logging residues in the State of Idaho: preliminary predictive models. Presentation to the Society of American Foresters 2012 national convention, October.

Hayes, S. 2012. Presentation to US Forest Service Region One Timber Management Staff. Logging cost analysis. March 29, 2012. (not funded by NARA).

Morgan, T., E. Simmons, E. Berg, C. Gale, S. Hayes, C. Sorenson. 2012. Characterizing logging residues as potential feedstock for the manufacture of biojet. Presentation at the Western Forest Economists Meeting in Newport, OR, June.

Morgan, T., E. Simmons, E. Berg, C. Gale, S. Hayes. 2012. Forestry is rocket science: quantifying logging residues as feedstock for bio-jet and other uses. Poster presented at the International Wood Composites Symposium, Seattle, WA. April 11-13, 2012.

Morgan, T. 2012. Presentation to Montana Department of Natural Resources. Biomass utilization potential: presentation included the role of NARA-funded logging utilization data in predicting biomass. Feb. 6, 2012.

Morgan, T. 2012. Presentation to Oregon Forest Industry Council. Dynamics of the Oregon forest products industry; included prediction of logging residue. Jan. 5, 2012. (not funded by NARA).

Morgan, T. 2012. Presentation to US Forest Service Region One Timber Management Staff. The status of the inland northwest forest industry; presentation included predicting forest residues through logging utilization studies. March 28, 2012. (not funded by NARA).

Simmons, E., J. Meek, E. Berg, T. Morgan, S. Hayes, and C. Gale. 2012. Idaho Logging Utilization, 2008/2011. Poster presented at 2012. International Wood Composites Symposium, Seattle, WA. April 11-13, 2012.

Simmons, E., J. Meek, E. Berg, T. Morgan, S. Hayes, and C. Gale. 2012. Idaho Logging Utilization, 2008/2011. Poster presented at the NARA Annual Meeting, September 12-14, 2012. Missoula, MT.

Simmons, E., E. Berg, T. Morgan, C. Gale, and S. Hayes. October 2012. Logging Utilization in the State of Idaho 2008/2011. Presentation at the 2012 Society of American Foresters national convention.

Simmons, E., J. Meek, E. Berg, T. Morgan, C. Gale, S. Hayes. 2012. Logging Utilization in the State of Idaho 2008/2011. Poster presented at the USDA Forest Service Forest Inventory and Analysis Science Symposium held December 2012.

Sorenson, C. and C. McIver. *Mill Residue Production and Use in Montana, 2009*. Poster presented at the NARA Annual Meeting, September 12-14, 2012. Missoula, MT.

Other Publications

Brandt, J., T. Morgan, C. Keegan, J. Songster, T. Spoelma, L. DeBlander. 2011. Idaho's forest products industry and timber harvest, 2006. USDA Forest Service Rocky Mountain Research Station Resource Bulletin RMRS-RB-12. (not funded by NARA).

Gale, C., C. Keegan III, E. Berg, J. Daniels, C. Sorenson, T. Morgan, P. Polzin, and G. Christensen. 2012. Oregon's forest products industry and timber harvest, 2008. Industry trends and impacts of the Great Recession though 2010. USDA Forest Service PNW Station PNW-GTR-868. (not funded by NARA).

McIver, C., C. Sorenson, T. Morgan, Montana's Forest Products Industry and Timber Harvest, 2009. Draft tables posted at: http://www.bber.umt.edu/forest/regionalreports.asp). (not funded by NARA).

Meek, J. 2012. Bureau of Business and Economic Research Chip Sample Study. Forestry 435/436 Term Paper. College of Forestry and Conservation. University of Montana. Missoula, MT.

Techno-Economics Team

Task SM-TEA-1: Techno-Economics Analysis

Key Personnel	Affiliation
Gevan Marrs	Weyerhaeuser
Tom Spink	TSI

Task Description

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

- Feedstock cost estimates at various facility scales
- Key process blocks
- Mass and energy balances for each block, tracking
  - Wood polysaccharides to bio-jet
  - Wood lignin residuals to co-products
  - Other wood components (volatiles, ash: waste) where appropriate
- Operating costs for each block (materials, energy)
- Capital cost for each process block
- Total Capex vs. scale, optimization against feedstock costs at scale, selection of base case facility scale.
- Other financial incentives (RINS for 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

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

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

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

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

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

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

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

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

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

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

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

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

Activities and Results

In order to rapidly have a fully constructed techno-economic analysis (TEA) model framework and to take advantage of the significant prior work on structure and assumptions, the NREL 2011 Corn Stover to Ethanol TEA model was obtained and used as a starting model template and a logic check for our work. Feedstock sourcing curves for a hypothetical optimum sourcing location (lowest cost) for either western Oregon or Washington softwood forest harvest residuals were generated. The rising average feedstock delivered cost with scale tonnage was compared against capital efficiency of increasing conversion facility scale to yield a target facility scale of 770,000 bone dried ton (BDT) feedstocks per year. A full chain of process yield by stage for softwood to biojet blendstock (iso-paraffinic kerosene, IPK) was built for the base case using demonstrated results from each area expert participant in the project conversion chain, giving a final base case yield of 45.6 gallons IPK per BDT feedstock and 35 million gallons per year. The overall process flow was mapped and material mass balances calculated for the entire conversion process. Capital, operating and fixed costs estimates were made for each process step by the project experts for each process area. These were assembled into an entire process mass balance and operating costs and with capital incorporated into the TEA model.

Total capital investment for the conversion facility to produce just IPK (biojet), burning the lignin residue for power, was $881 million, and with operating and fixed costs, the total manufacturing costs were calculated to be $8.91/gal IPK. Cellulosic RINs were estimated for the IPK product, and were valued at $2.25/gal, resulting in a net total manufacturing cost of $6.66/gal IPK. This is considerably higher than the current wholesale jet fuel price trend price of $3.09/gal. The full key results for this case are shown in Figure 1.

Estimates were made for all identifiable improvements that were believed to be 50% probable within three years of development work. The cumulative effect of all of these together only improved the manufacturing costs to $4.97/gal (Figure 2). Accordingly, to be commercially viable, additional sales of high-value lignin co-products was deemed necessary. A model based upon reserving all lignin residue for co-products preparation, instead of burning for power, was calculated. Overall manufacturing cost for IPK(after C-RINs) was increased to $7.21/gal IPK, but now there is a considerable annual mass of lignin residue from which we can potentially generate a high-value co-product.

An initial potential lignin-based co-product has been identified at the speculative level. This is production of a high-value activated carbon (AC) from the lignin fraction of the residue left from fermentation and distillation. A rough estimate of the case where the lignin residue was not burned for power, but reserved and sent to an AC lignin co-products facility, is estimated to possibly generate revenue in considerable excess of the AC manufacturing costs. This case, based upon these very early indications, would appear sufficient to bring the overall conversion facility into positive returns, and therefore warrant considerable further investigation of production feasibility, cost, yield, market size and selling price.

This information is potentially proprietary and has been omitted. Please contact members of the NARA Executive Committee for further information.

Figure 1. Overall Summary Techno-Economics of Bio-Jet production from softwood.

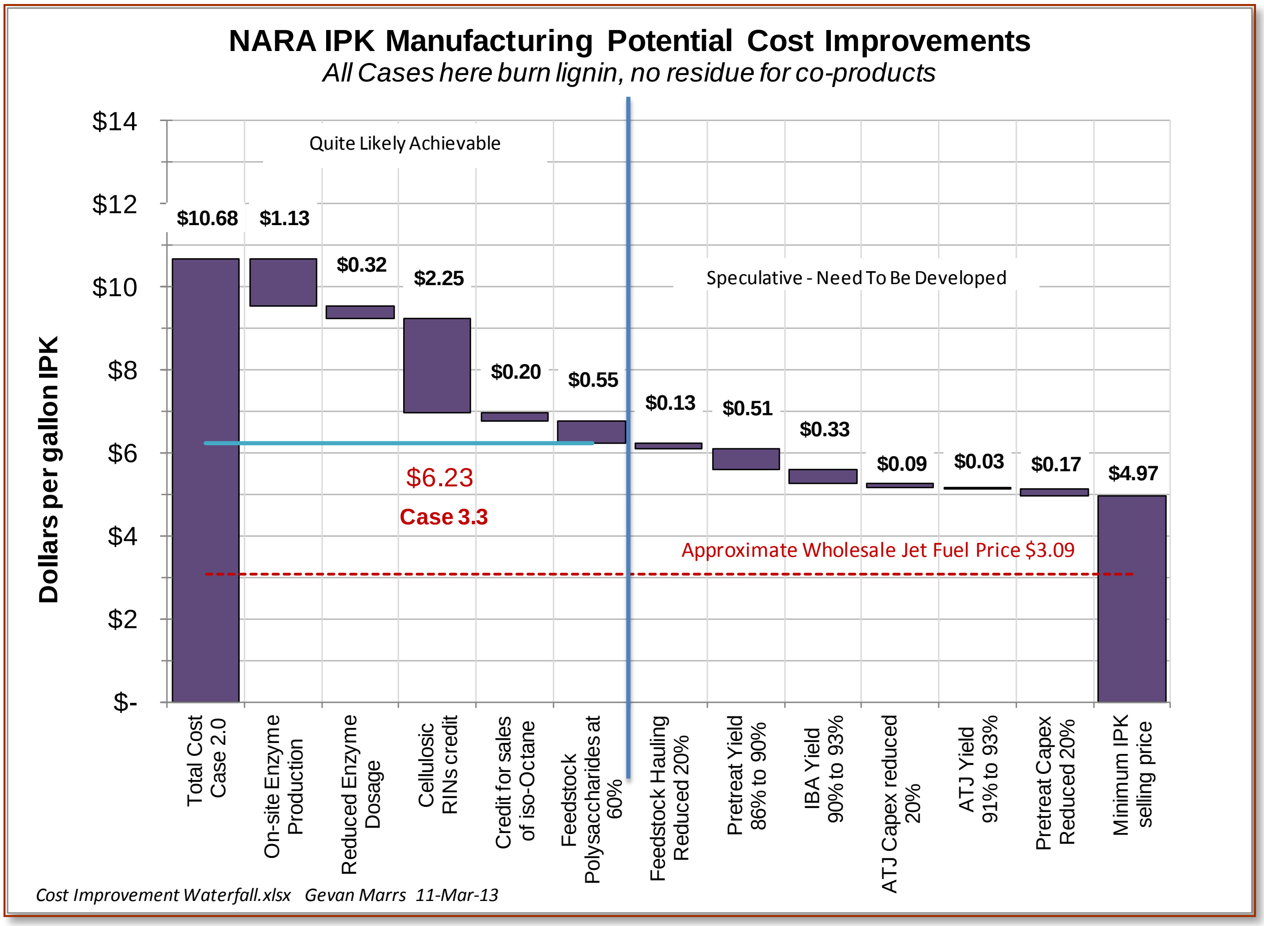

Figure 2. Potential impact of plausible improvement options for IPK-only manufacturing.

Recommendations/Conclusions

1. Given the feedstock supply of softwood forest harvest residuals, locating a facility in an optimum feedstock location in western Washington or Oregon, delivered feedstock costs at optimized facility scale (777,000 BDT/year) are estimated to be $68 per BDT. We do not find major opportunities to reduce this to a dramatic degree.
2. The net yield of IPK is estimated to be 45.6 gallons per BDT feedstock to conversion mouth, yielding 35.1 million gallons IPK production per year. Compared to many other published cellulosic ethanol or hydrocarbon product yields (70 to 90 gal/BDT) this imposes a significant cost hurdle on IPK (biojet).
3. Total capital investment for a facility producing only IPK as a primary product (no lignin co-products – burn the lignin residue for power) is estimated to be $881 million dollars. This puts the Total Invested Capital at $25/annual gal IPK production capacity, which is roughly double published production cost figures for cellulosic biofuels. This mostly reflects a difficult feedstock (recalcitrant softwood) and a relatively low final product yield, all for a fairly low-priced commodity product (jet fuel).

4. Under the “IPK-only” case, with all manufacturing costs, amortized capital costs, including recovery of capital, plus fixed costs, the per gallon manufacturing costs for IPK are $8.91—considerably above a likely wholesale jet fuel price of about $3.09/gal.
5. Cellulosic RINS for IPK (assuming qualifying renewable feedstocks and adequate greenhouse gas (GHG) reductions are very significant—estimated to be about $2.25/gal IPK. This would bring net manufacturing costs down to $6.66/gal IPK—still considerably above what jet fuel users have stated as their willingness to pay, about $3.09/gal (that is, there is no buyer premium paid for renewable fuel standard (RFS) biojet).
6. With all identified “plausibly achievable” improvements on the “IPK-only” case, we have identified improvements that if achieved in total would bring manufacturing costs down to about $4.97/gal IPK—still considerably above the $3.09 target. Accordingly, we conclude that we MUST utilize some fraction of the biomass flow not going to IPK (“lignin residue”) to generate additional profit if the currently envisioned venture is to be commercially viable.
7. Generating revenue from co-products in addition to IPK is most likely to derive from lignin fractions, hence a preliminary speculative case for *not* burning the lignin residue and reserving it for manufacturing of co-products was generated. One potential high-value co-product has been speculatively identified—a specialized activated carbon (AC) used for mercury amelioration applications. This market for AC appears to be in a significant growth phase as the result of a significant new use for AC, prompting market prices for AC to be in the range of $2.50/lb. Initial laboratory work indicates that an AC from NARA lignin is compatible with this new market. Preliminary financial estimates for AC from NARA lignin suggest it may be produced at a cost that could bring the entire IPK & AC facility to a positive return.
8. Overall, it would seem that evolutionary improvements in even multiple areas of the process cost or yield are *not* going to be sufficient to bring the bio-jet production facility into commercially viable range if only IPK is produced. We need to review these TEA results with all team area-experts for “revolutionary” improvement options not yet considered. Included among these might be:
    a. High-value co-products, as described tentatively above.
    b. Significant shift in value-chain construct, such as distributed production of intermediate products at lower scale (perhaps sugars or indole-3-butyric acid (IBA)) such that there are multiple potential customers and products, beyond just biojet fuel.
    c. Examination of the scale efficiency impact of the current pre-treatment options that scale like pulp mills, leading to very large capital costs and feedstock demands to a central site, adding to average feedstock costs.
    d. Identification of dramatic cost-reduction elements such as brown-field site utilization and state and/or local incentives.

Physical and Intellectual Outputs

Physical

- A facility scale optimization spreadsheet that takes estimated feedstock costs with scale from the Feedstock Sourcing task and combines with facility capital scale efficiency estimates to target base case facility optimum scale.
- A documented and reconciled process yield chain spreadsheet for a key metric—gallons of IPK per BDT feedstock—(including all intermediate stage yields as well).

- A full set of process hand-drawn and calculated flow diagrams, mass and energy balances for all 10 unit operations in the process, including material costs.

- Produced multiple techno-economic spreadsheet models for production of:
    - Biojet fuel as the only product, burning the residual lignin fraction for power.
    - Biojet fuel and reserving the lignin residue for high-value co-products production.
    - Iso-butanol intermediate as our product, rather than IPK.

- Each model contains as key ouput:
    - Summary sheet for all key metrics (unit production costs, total capital, Opex by dept., etc.)
    - Two-way cost breakdown table and charts by process area and cost type (Capex, Opex, Fixed).
    - Capital costs bar charts by process area to identify big-hitters.
    - Case history and data sources all documented internally to each spreadsheet.

- For each key case, a summarized presentation with background, approach, key results, conclusions and recommendations.

- An “improvement opportunities” analysis spreadsheet (waterfall chart) that shows estimated potential gains with 3-year improvement ideas at a 50% probability level.

Intellectual

- An understanding of the basic (challenging) economic feasibility of producing biojet from softwood, the criticality of qualifying for the C-RINs, and the need for breakthrough improvements like high-value co-products or very significant feedstock and capital cost reductions.

SystemsMetrics_EPP

NARA

#	Task Name	% Complete
1	SYSTEMS METRICS - ENVIRONMENTALLY PREFERRED PRODUCTS TEAM	
2	SM-EPP-1. Environmentally Preferred Products	41%
3	Task SM-EPP-1.1. "Public" stakeholders (SHs): demographic, psychographic, and market-specific assets through dataset analysis (Leigh Stowell, Rupasingha, and Roper-Putnam)	80%
4	Analysis – literature review to predict public bioenergy behaviors	100%
5	Preliminary Report	100%
6	Refine "public" SH perceptions	65%
7	Final Report	0%
8	Task SM-EPP-1.2. Review Sustainability Approaches: standards, eldes, product claims, LCA/EIO data sources & models	50%
9	Research environmental claims, labels and standards associated with product categories in N. America, including detailed criteria (focus on products qualifying under USDA's BioPreferred program)	100%
10	Preliminary Report	100%
11	Develop in a common format comprehensive assessment of criteria across life cycle phases of up to 4 representative bioproducts categories, and where possible, production process stages. Analyzing for common attributes	15%
12	Final Report	80%
13	Task SM-EPP-1.3. Review Regional Bioenergy Stakeholder Perceptions: issues, influencial groups, etc.: NARA site personal/focus group interviews and analysis	80%
14	Examine criteria for initial NARA Community (NC) screening from NARA project experts	100%
15	Analyze Outreach team input	100%
16	Report	100%
17	Analyze physical asset criteria	85%
18	Preliminary Report	100%
19	Final Report	0%
20	Preliminary NC site selection	85%
21	Preliminary report (for NC site selection)	100%
22	Final report (for NC site selection)	0%
23	Preliminary protocols, constructs, and interviews	85%
24	Preliminary report Preliminary protocols, constructs, and interviews	100%
25	Final report. Preliminary protocols, constructs, and interviews	0%
26	Task SM-EPP-1.4. "Informed" stakeholder interaction/operationalization (pop's, sampling, constructs, protocols)	35%
27	Western Montana Corridor (WMC)	35%
28	Preliminary Report	0%
29	Final Report	0%

	Task Name	% Complete
30	West Side (WS)	35%
31	Preliminary Report	0%
32	Final Report	0%
33	Task SM-EPP-1.5. Refine Operationalization – sop's, sampling, constructs, protocols – select additional NARA community sites	0%
34	Nara community SH Interviews	0%
35	Report	0%
36	Task SM-EPP-1.6. Techno-Market Assessment: Jet Fuels	65%
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	0%
40	Jet fuel products - data collection preliminary report	0%
41	Jet fuel products - data analysis report	0%
42	Task SM-EPP-1.7. Economic, Environmental & Social Assessment: Jet Fuels	40%
43	Collaborate w/ LCA and SH NARA teams to develop social hotspot analyses	75%
44	Life cycle inventory (LCI) development for preprocessing and processing stages for biojet; Baseline biojet fuel module for EPP decision-making using GaBi	60%
45	Define select "ideal" aviation fuels and bio-based polymer co-products & substitutes; Eval env/social criteria against hot-spot analysis; dev value props for fuels	0%
46	Parameterized model for Biojet developed (assessed for GHG, water and abiotic depletion)	0%
47	Task SM-EPP-1.8. Techno-Market Assessment: BioProduct Polymers (1-2 product categories)	18%
48	Examine & define market opportunities for select co-products	20%
49	Collect co-products supply chain SH data; Assess procurement needs of key product sectors via primary data collection	20%
50	Identify key channels, buyers & specifiers for select bio-based polymer co-products in PNW	0%
51	Bio-based polymer co-products - data collection preliminary report	0%
52	Bio-based polymer co-products - data analysis report	0%
53	Task SM-EPP-1.9. Economic, Environmental & Social Assessment: BioProduct Polymers	0%
54	Collaborate w/ LCA & SH NARA teams to develop env & social hotspot analyses	0%
55	Define select "ideal" bio-based polymer co-products & substitutes in terms of properties, prices & other attributes; Evaluate env/social criteria; Dev value props	0%
56	Incorporation of co-product modules into parameterized biojet model	0%
57	Task SM-EPP-1.10. Prototype Integrated EPP Protocol	0%
58	Develop a prototype integrated protocol for expanding methodologies developed in Tasks 6 & 8 across product categories by designing a process consistent with EPP best practices	0%

	Task Name	2011 Q1	2011 Q2	2011 Q3	2011 Q4	2012 Q1	2012 Q2	2012 Q3	2012 Q4	2013 Q1	2013 Q2	2013 Q3	2013 Q4	2014 Q1	2014 Q2	2014 Q3	2014 Q4	2015 Q1	2015 Q2	2015 Q3	2015 Q4	2016 Q1	2016 Q2	2016 Q3	2016 Q4
59	Develop an EPP marketing and procurement decision support tool to integrate economic, environmental and social impacts of NARA biojet and co-products																								
60	Final EPP Report																							0%	

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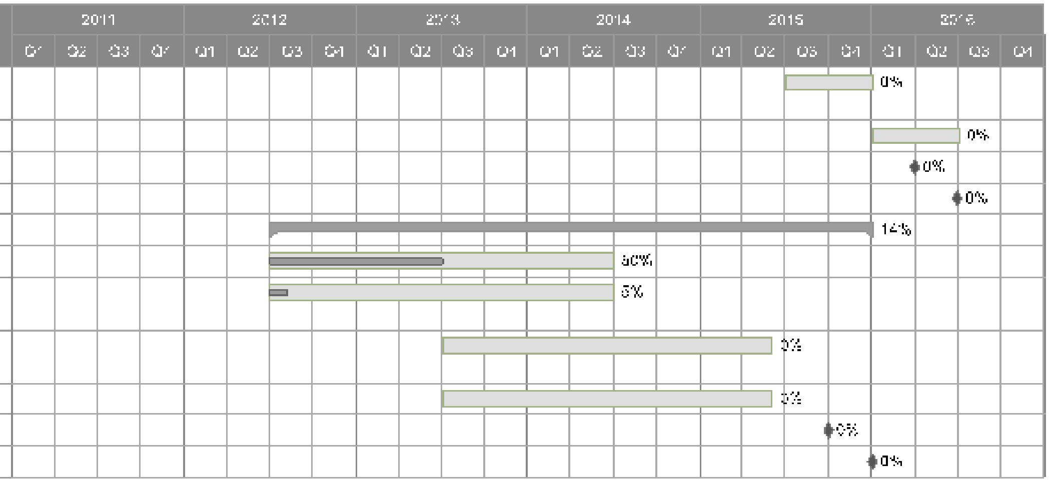
SystemsMetrics_LCA

NARA

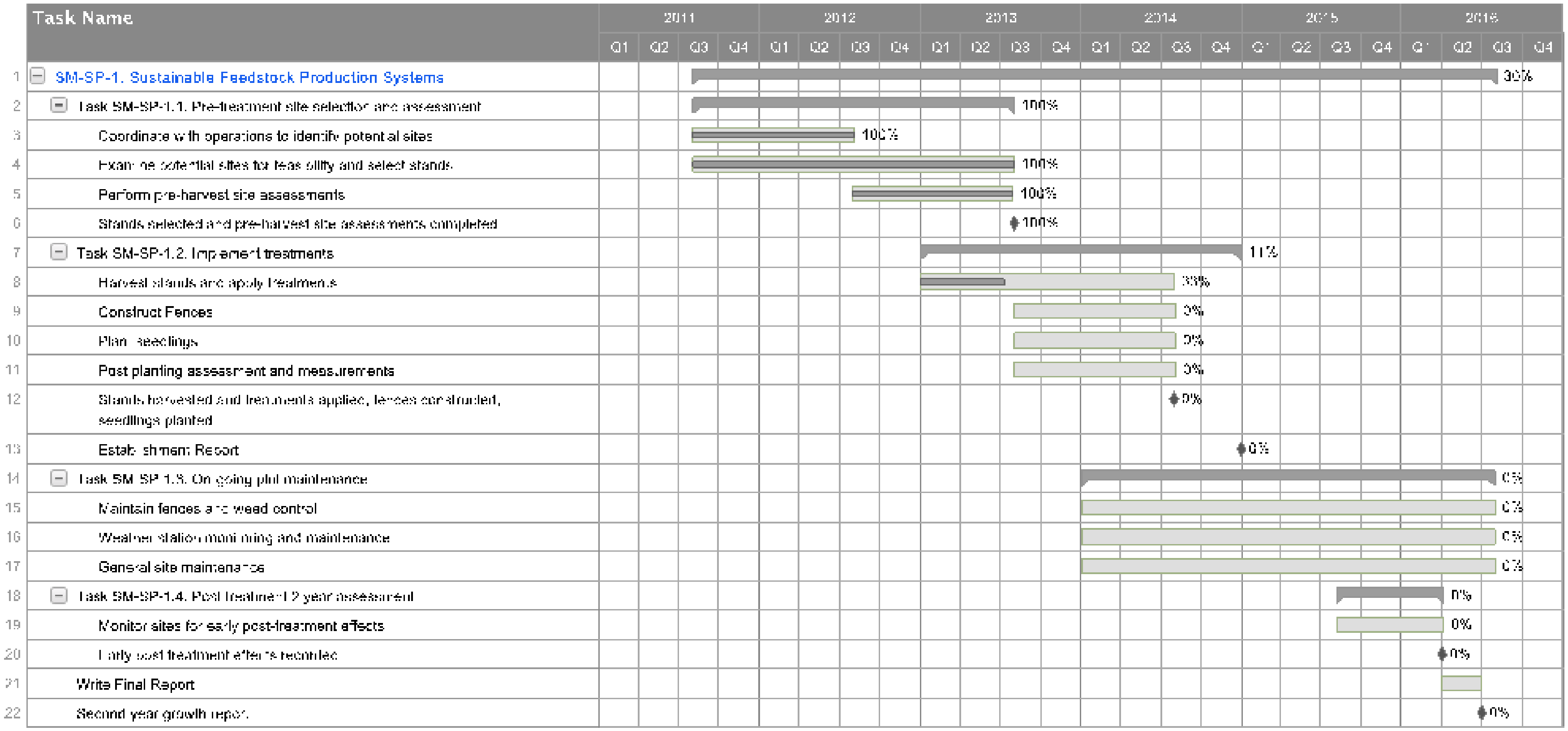
	Task Name	% Complete
1	SYSTEMS METRICS - LCA & COMMUNITY IMPACT TEAM	
2	SM LCA 1. LCA Assessment of Using Forest Biomass as a Feedstock for Biofuels	25%
3	Task SM LCA 1.1. Soil Carbon Analysis	30%
4	Review literature on carbon impacts of forest thinning and residual collection	50%
5	Review literature of carbon implications of alternate systems for harvest collection and transport of forest thinnings and residuals	60%
6	Review literature of impacts of collecting forest thinnings and residuals on soil carbon and stand productivity including the soil impact of avoided wildfires	25%
7	Review impact of forest residual removal on soil carbon and stand productivity	20%
8	Collect soil carbon data	20%
9	Preliminary report	0%
10	Final report	0%
11	Task SM-LCA-1.2. LCA Analysis	27%
12	Review literature on LCA of forest residuals and their use in producing biofuel	100%
13	Collect LCA data for conifers forest and plantation feedstock (in conjunction w/WaySC)	25%
14	Develop framework LCA analysis for forest residuals (Inland Empire)	75%
15	Conduct framework LCA analysis for pretreatment (in conjunction with Gevo and Catchlight)	10%
16	Integrate framework forest residual and pretreatment LCA with biofuel LCA (with Gevo)	0%
17	Collect LCA data for Inland Empire (in conjunction with EPP Tasks 6 and 7)	33%
18	Preliminary LCA report for feedstock (Inland Empire)	0%
19	Integrate LCA data into framework LCA (Inland Empire)	5%
20	Preliminary LCA framework with report for complete process (Inland Empire) (in conjunction with Gevo and Catchlight)	0%
21	Develop framework LCA analysis for forest residuals (NARA Community #2)	0%
22	Collect LCA data for NARA Community #2 (in conjunction with EPP Tasks 6 and 7)	0%
23	Preliminary LCA report for feedstock (NARA Community #2)	0%
24	Preliminary LCA framework with report for complete process (NARA community #2) in conjunction with Gevo and Catchlight	0%
25	Integrate LCA data into framework LCA (NARA Community #2)	0%
26	Complete LCA analyses for both locations	0%
27	Conduct peer review of LCA data and revise	0%
28	Upload LCI data to national databases	0%
29	Preliminary LCA report	0%
30	Final LCA Report	0%

	Task Name	
31	Collect and assess information for eco-labels and environmental product declaration (EPD) for jet biofuel (in conjunction with EPP Task 9)	0%
32	Develop EPD for bio-jetfuel (in conjunction with EPP team)	0%
33	Draft EPD complete	0%
34	Final EPD	0%
35	Task SM-LCA-1.5: Community Economic Impact Assessment	14%
36	Review literature on rural economic impact and infrastructure requirements	50%
37	Characterize rural economic impacts and infrastructure limitations and needs for both locations (in conjunction with EPP Task 6)	5%
38	Cost/benefit analysis of integrating biofuel production with existing forest products infrastructure for both locations (in conjunction with EPP Task 6)	0%
39	Model community economic impacts of biofuel production for both locations	0%
40	Preliminary Economic Impact Report	0%
41	Final Economic Impact report	0%



SustainableProduction_Holub

NARA



SustainableProduction_Bailey_Boston

NARA

#	Task Name	% Complete
1	SM-SP-2. Sustainable Biomass Supply from Forest Health and Fire Hazard Reduction Treatments	28%
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	0%
6	Task SM-SP-2.2. Develop Models and Tools for Public Decision Makers to constantly assess potential for feedstock yields	13%
7	Review of prototype model runs by managers	25%
8	Compiled regional model runs	0%
9	Modeling Tools developed	0%
10	Task SM-SP-2.3. Establish Large Scale Adaptive Management Studies	24%
11	Draft framework	75%
12	Review by managers	0%
13	First installations	0%
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	0%
17	Draft framework	0%
18	Review by managers	0%
19	First installations	0%
20	Updated framework	0%
21	Large-scale experimental framework report	0%
22	Task SM-SP-2.5. Final Report	0%

Timeline: 2011–2016, by quarter (Q1–Q4).

SustainableProduction_Adams

NARA

#	Task Name	% Complete
1	SM-SP-3. Biomass Modeling and Assessment	41%
2	Task SM-SP-3.1. Develop Preliminary Biomass Model and Supply Curves for OR, WA, ID, MT	65%
3	Spatial model of biomass volumes/weights based on harvest projections	0%
4	Expanded model of fuel treatments on OR/WA rural communities that includes a wider range of biomass supply and the entire NARA region	0%
5	Biomass supply curves for alternative locations based on integrated spatial models of biomass and transportation	0%
6	Extend existing models to include biomass	75%
7	Spatial model of biomass volume/weights based on FIA inventory	0%
8	Market model of fixed-price revenue and price-flexible demand relations for alternative regions/plant locations	0%
9	Develop transportation model	30%
10	Spatial model of alternative avenues for biomass transport for the NARA region	0%
11	Integrate model with biomass projections	0%
12	Develop harvest projections	60%
13	Expand existing model of OR, WA timber markets to ID, MT	0%
14	Model of forest inventory for public lands in NARA region	0%
15	Coordinate with silviculture, soil productivity and logistics groups on model inputs	35%
16	Establish economics of biomass harvest, removal and transport and potential plant locations from logistics group for transportation model inputs	0%
17	Confirm biomass harvest projections with silvicultural group	0%
18	Task SM-SP-3.2. Second iteration regional biomass supply curves as improved estimates of biomass availability and costs become available.	0%
19	Revise and iterate the Task 1 models in response to information from other groups (including logistics and silviculture groups)	0%
20	Task SM-SP-3.3. Model alternative plant locations and capacities	0%
21	Generate projections of resource supplies and costs under alternative assumptions of biomass processing locations and biomass supply	0%
22	Task SM-SP-3.4. Final Report	0%
23	Summary of harvest projections, transportation model, alternative plant location/capacities, and biomass/supply curve mode	0%

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SustainableProduction_Maguire

NARA

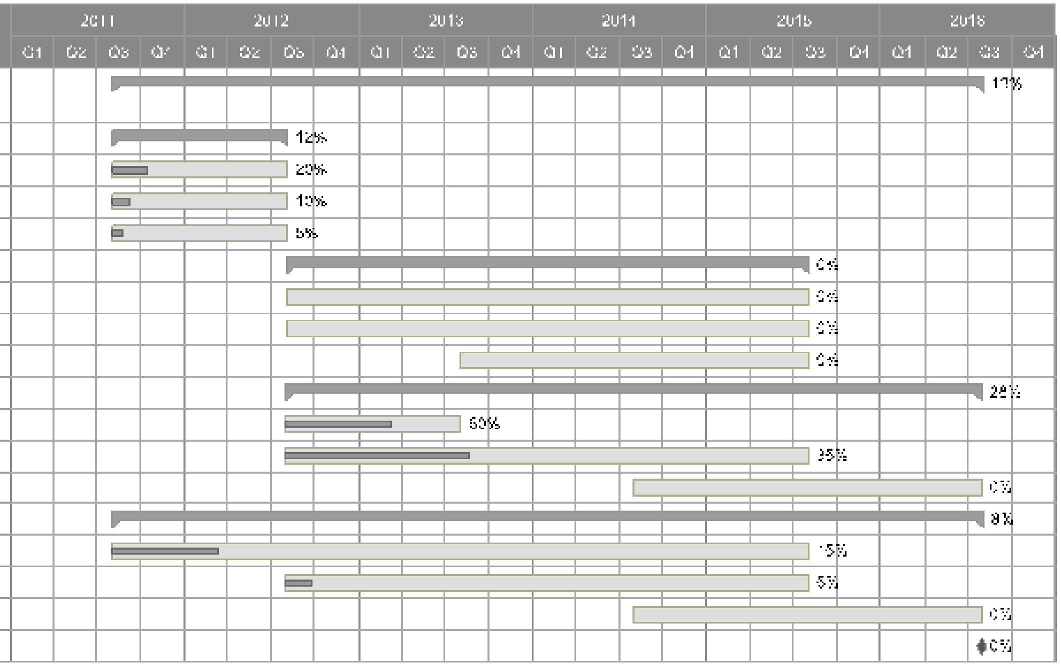
Timeline: 2011–2016, quarters Q1–Q4 for each year.

#	Task Name	% Complete
1	SM-SP-4. Long Term Productivity Studies	45%
2	Task SM-SP 4.1. Develop allometric equations for managed stands	95%
3	First season of biomass sampling	100%
4	Complete first field season of biomass sampling; construct and edit database for first field season of biomass sampling, including elements analysis of all plant tissues	100%
5	Second season of biomass sampling	75%
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	50%
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	0%
9	Task SM-SP-4.3. Determine sustainable levels of bioenergy feedstock under range of silvicultural intensities	0%
10	Sustainable levels of bioenergy feedstock production determined under a range of silvicultural intensities using forest simulation models	0%
11	Task SM-SP-4.4. Estimate changes in long term site productivity under different climate change scenarios	0%
12	Changes estimated in long-term site productivity under different rates of biomass removals and different climate change scenarios using forest simulation models	0%
13	Task SM-SP-4.5. Synthesis of Results & Final Report	0%
14	Report summarizing: 1) key tools dev. For simulating biofuel feedstock production as part of total system production in managed Doug-fir forests; 2) conclusions about sustainable levels of feedstock production on diff sites characterized by soil & climate	0%

SustainableProduction_Barber_Lamb

NARA

	Task Name	%
1	SM SP 5. Environmental Impact Analysis to Support NARA Biofuel Development in the Pacific Northwest	17%
2	Task SM-SP-5.1. Develop sampling plans and methodologies	12%
3	Investigate appropriate methods and write sampling/QA plan	20%
4	Conduct exploratory field evaluation of potential sites	10%
5	Revise sampling plan, order materials, and data equipment	5%
6	Task SM-SP-5.2. Conduct field sampling	0%
7	Monitor runoff quantity from field plots and weather stations	0%
8	Monitor sediment erosion from sites	0%
9	Sample and identify macroinvertebrates	0%
10	Task SM-SP-5.3. Create water resources models of study areas	29%
11	Evaluate water quality/quantity model input requirements	60%
12	Set-up, calibrate, evaluate multi-scale water resources models	35%
13	Run and appraise models using field data, evaluate future impacts	0%
14	Task SM-SP-5.4. Create atmospheric model of study sites	8%
15	Develop scenarios for evaluation of air quality	15%
16	Set-up, evaluate multi-scale air models	5%
17	Run and appraise model, evaluate future impacts	0%
18	Final report	0%



SustainableProduction_Betts

NARA

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

SustainableProduction_Morgan

NARA

#	Task Name	% Complete
1	SM-SP-7. Supply Chain Analysis	36%
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	35%
3	Coordinate with "west-side" modeling team on data needs and standards for Idaho & Montana	35%
4	Task SM-SP-7.2. Enhance and update primary mill residue and capacity information for 4-state region	60%
5	Task SM-SP-7.2.1. Survey of primary mill facilities in Washington and Oregon	50%
6	Cooperate with Washington DNR on mill surveys to collect mill residue and capacity information	25%
7	Washington primary mill (residue, wood use, capacity, etc.) data available for modeling	0%
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	40%
13	Idaho primary mill (residue, wood use, capacity, etc.) data available for modeling	0%
14	Task SM-SP-7.3. Enhance and update logging and other forest residue for 4-state region	27%
15	Conduct forest industry studies in Idaho, Montana, Oregon and Washington	40%
16	Incorporate updated logging residue data into woody supply analysis	0%
17	Final report on forest/logging residue and primary and secondary mill residue	0%

SystemsMetrics_TEA

NARA

	Task Name	% Complete
1	SM-TEA-1. Techno-Economic Analysis	84%
2	Task SM-TEA-1.1. Build and populate first-cut NARA project TEA model framework	100%
3	Determine scope, detail, contents and obtain or build starting model template	100%
4	Task SM-TEA-1.2. Obtain and Assemble first-cut Capital Cost Estimates	100%
5	Determine facility scale optimum from preliminary total CAPEX and feedstock cost	100%
6	Obtain initial CAPEX estimates for each process block at scale	100%
7	Task SM-TEA-1.3. Obtain and Assemble first-cut Process Flow and Operating Cost Estimate	80%
8	Perform literature review relative to software to Jet via Gevo process	100%
9	Review flow with experts via meeting contacts and phone conferences	100%
10	Draft layout of individual units of process	100%
11	Collaboratively prepare and communicate "Yield Chain" base case	100%
12	Obtain market price for materials and energy	100%
13	Estimate material and energy requirements for each process step	100%
14	Prepare Admin and labor staffing and cost diagrams	100%
15	Estimate utility costs	100%
16	Estimate Co-product financial impact	20%
17	Identify and estimate all other non Co-product revenue	20%
18	Task SM-TEA-1.4. Construct first-cut pass at overall economics	100%
19	Incorporate Capex into base case model and document	100%
20	Incorporate Opex into base case model and document	100%
21	Investigate and quantify base case incentives value (RINs)	100%
22	Build preliminary estimate of Co-products breakeven need or value estimate	100%
23	Task SM-TEA-1.5. Summarize reporting elements and communicate with stakeholders	44%
24	Build overall Executive Summary report sheet	5%
25	Develop and report Cost components in order to understand key leverage points	100%
26	Develop and report Probability Adjusted Sensitivity Analysis for major leverage points	60%
27	Develop full Discounted Cash Flow - Net Present Value - Return on Investment sheet	10%
28	Document initial results and review with stakeholders, revise as needed	70%
29	Task SM-TEA-1.6. Evaluate the Pretreatment options on an equitable basis	0%
30	Obtain initial CAPEX estimates for each alternative pretreatment process	0%
31	Estimate Opex for each alternative pretreatment process	0%
32	Meld Capex and Opex into NARA TEA and report out	0%
33	Task SM-TEA-1.7. Solicit process improvements in key leverage areas and update economics	0%
34	Hold communications meetings with key NARA task elements and explain results	0%
35	Work with NARA staff to identify key improvement possibilities	0%

Timeline: 2012–2016 (Q1–Q4 each year)

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