U.S. Department of Energy (DOE) Bioenergy Technologies Office (BETO) 2019 Project Peer Review

Carbon Cycling, Environmental & Rural Economic Impacts from Collecting & Processing Specific Woody Feedstocks into Biofuels

March 5, 2019
Analysis and Sustainability

Steve Kelley, NCSU
Rick Gustafson, U of WA
Elaine Oneil – CORRIM
Maureen Puettmann – WoodLife

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Overall Goal

Goal: The goal of this project is to understand the carbon flows for woody biomass allocated for bioenergy products relative to no bioenergy, including the role of wood products, and an evaluation the implications for different forest management systems.

Context: Biofuels production results in an immediate release of forest carbon, while durable wood products (DWP) can sequester carbon for 20-70 years in buildings. The absence of bioenergy results in the slow emission of carbon from harvest residues over an extended period of time.

Counterfactuals for forest managements, uncertainty and timing all need to be included and carefully considered.

Goal Statement

Specifically, we will

- Conduct regionally specific (PNW, SE and NE) LCI for biomass residues and DWP coming from current, commercial softwood manufacturing systems
- Conduct regionally specific (PNW, SE and NE) LCI for SRWC that are well suited for bioenergy production
- Use DOE process models to measure the LCI for using these woody feedstocks in BC and TC processes
- Evaluate the impacts of variations woody biomass production systems and properties, e.g., ash, MC, chemical composition, on GWP emissions
- Evaluate the trade-offs for the use of woody biomass for DWP and biofuels

- Provide all the information to the ANL GREET team to allow them to review, and standardize the LCI data to create the final LCA

Quad Chart Overview

Timeline

- Initial start - Sept, 2010
- Restart - Sept, 2015
- Complete - March, 2019
- 90% of work completed

Budget

	Prior Years	FY 18 Costs	Total Planned Funding (FY 19-Project End Date)
DOE Funded	1.18 mil	0.26 mil	1.43 mil
Project Cost Share	0.34 mil	0.03 mi	0.37 mil

* data are totals across the entire project.

Barriers

- **St-A;** Scientific Consensus
- **St-C;** Science-Based Message
- **St-D;** Improved Indicators and Methodology

Partners

- See attached list
- ANL GREET Team (M. Wang)

- NREL, PNNL, INL, USFS
- DOE LEAF

Project Management Overview

- Initially funded with more of a focus on DWP
- After 1 yr. funding suspended in 2012 due to DOE-BETO “cash flow” limitations
- Reinitiated at the end of 2015 with a narrowed scope and focus on providing information for GREET

Specific goals for refocused project include

- the impacts of using mill and forest residues from current commercial operations (cost, quality and transportation issues)
- additional emphasis on SRWC as a biomass resource for biofuels and as an alternative/supplement to commercial softwoods
- understanding the impact of DWP as a “co-product”, including lifetimes, and end of life
- added decay emissions for no biofuel case

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Approach (Management)

- The members of this CORRIM team have been working together for more than 20 years on dozens of projects, and have a track record of delivering quality LCA products for government and industry funders (CORRIM data is the basis of published EPDs)

- Data quality, consistency and sources are all key for GREET. ANL GREET team has helped layout boundary conditions/supply chain protocols to match current GREET feedstock/process combinations
- The CORRIM team has reviewed and provided detailed comments on GREET reports
- NCSU, U of WA, and ANL GREET team have had calls, and personnel exchange to discuss the process models, and forest modeling for counterfactuals

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Partners (co- PIs)

Co-PI	Institution	Task
Steve Kelley	NCSU	SE – SFWD, SRWC LCI
Richard Gustafson	Univ. of Washington	PNW – SRWC LCI
Elaine Oneil	Univ. of Washington	PNW – SFWD, Forest Modeling
Tim Volk	SUNY	NE – SRWC LCI
Aaron Weiskittel	Univ. of Maine	NE- SFWD, Forest Modeling
Maureen Puettmann	WoodLife Consulting	Wood Products LCI
Richard Venditti	NCSU	P&P LCI
Sunkyu Park	NCSU	Improved TC model
Larry Mason	Alternate Dimensions	Carbon Storage Modeling
Bruce Lippke	Lippke and Assoc.	Carbon Storage Modeling
Leonard Johnson	Johnson and Assoc.	Forest Operations

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Tasks

- ✓ **Task 1 – LCI of the current, regionally specific commercial systems.**
- ✓ **Task 2 – LCI of regionally-specific, dedicated SRWC for production biofuels**
- ✓ Task 3 – LCA of the impacts of using woody biomass as a feedstock for different biochemical and thermochemical biofuels production processes
- ✓ Task 4 – an analysis of the impacts of natural variations in wood composition and production scenarios on the LCA of wood based biofuels

Task 5 – an analysis of the carbon storage implications of using woody feedstocks for the production of both biofuels and the current commercial suite of short-lived and DWP, and decay from residues

No-Harvest, counterfactuals.

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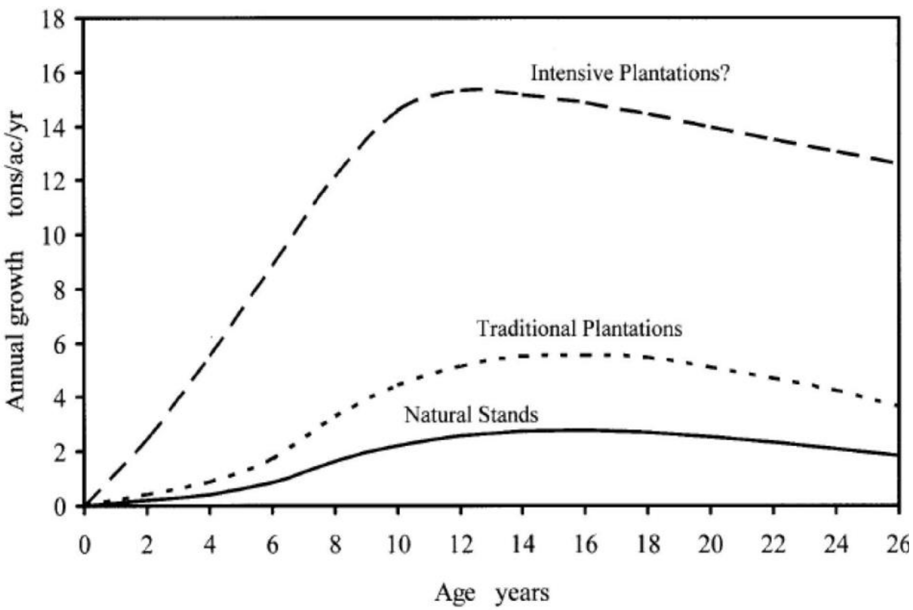
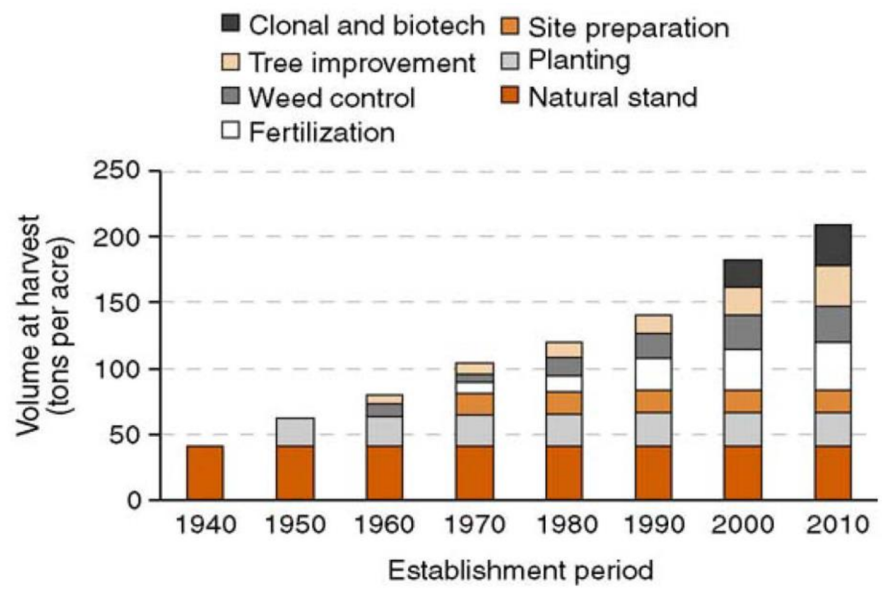
Approach (Technical)



*Source: Allen, Fox, and Campbell. 2005. S.



*Source: T. R. Fox, Silviculture and Management of Southern Pine Plantations. Forestencyclopedia.net.

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Approach (Technical)

Forests, with their relatively long growth cycles and harvesting every 25-75 years can accumulate considerable amounts of carbon, since a single location is only harvested periodically.

- Unlike an annual or perennial crop where the same acreage can be harvest every year (or even twice a year). Forests have to take the carbon on 25-75 parcels to get a complete picture.
- This work is focused on plantations that are commercially managed, with the expectation of a financial return
- Key management variables include spacing, seedling type, and fertilization and herbicides

Approach (Technical)

For commercial softwoods there are five ‘pools’ to be tracked, e.g., wood products, paper, biorefinery, forest growth and decay

SRWC are purpose grown for bioenergy so only one ‘pool’

- For the pools need regionally specific data on mass flows, timing, and end of life (landfill vs decay in the woods).
- Initial analysis focused on a single case that represents current practices
- Use sensitivity analysis to look for key points of leverage

- Stochastic tools (Monte Carlo) would be ideal, but beyond the scope of the information needed for GREET

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Approach (Technical)

- Use existing data sources,
  - Forest growth (USFS FIA datasets), and regional growth and yield models
  - CORRIM datasets to assign regional allocations to dimension lumber, other products, and mill energy systems
  - CORRIM data sets for DWP burdens, and end of life
  - NCASI pulp and paper models for paper production, recycle and end of life

- DOE TC process model modified with laboratory data to predict gas/diesel based on biomass composition (% total C, % ash, MC)
- Include all establishment burdens, e.g., site prep, fertilization, herbicide, harvesting and transportation (mass allocation)
- Include avoided emissions from decay of wood not collected
- Three SFWD are current ‘commercial management’ to ‘commercial management’ so assume no soil carbon change

Approach (Technical)

Challenges

- Forest are COMPLEX! Soils, slope, water, landowner objectives

- Temporal aspects of paper and DWP (2-70 yrs.) and thinning and harvest cycles for commercial forests in SE vs. Maine (25 vs. 80yrs)
- Great deal of variation in practices, regionally specific focus will reduce, but not eliminate these affects
- Forestry counterfactual,
  - No bioenergy, only lumber and paper, with current processes for process heat from residues
  - ‘natural’ regeneration,
    - only approach in NE
    - uncommon but can occur in SE
    - Not allowed in the PAC NW
- Forest growth and yield models less accurate at longer times (+60 yrs)

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Technical Approach

Softwoods

SRWC

LCI burdens

- Chemicals
- Fuels
- Planting stock

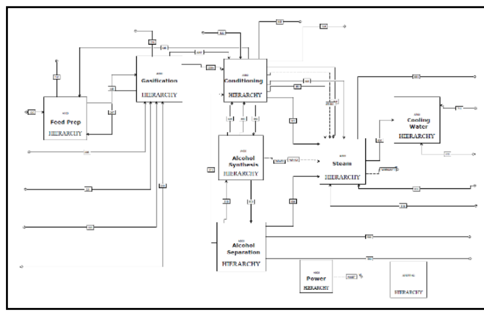
Allocation!

Technical Approach

Key chemical attributes

TC Process
- *MC*
- *Carbon*
- *Ash*

DOE Process models



LCA Attributes

GWP to GREET

Other TRACI attributes

The LCA attributes from DWP and P&P are critical when looking at the counterfactuals

Technical Accomplishments/ Progress/Results

- Complete … systems
- Identified … ough consister
- Updated … ss composit … E project team)
- Complete … ns from a log, also on m
- Assisted … ne report
- Defined c

ANL/ESD-18/10

Carbon Dynamics for Biofuels Produced From Woody Feedstocks

by
Jeongwoo Han*, Christina E. Canter[1]**, Hao Cai[1], Michael Wang[1], Zhangcai Qin[1], and Jennifer B. Dunn[1]

and

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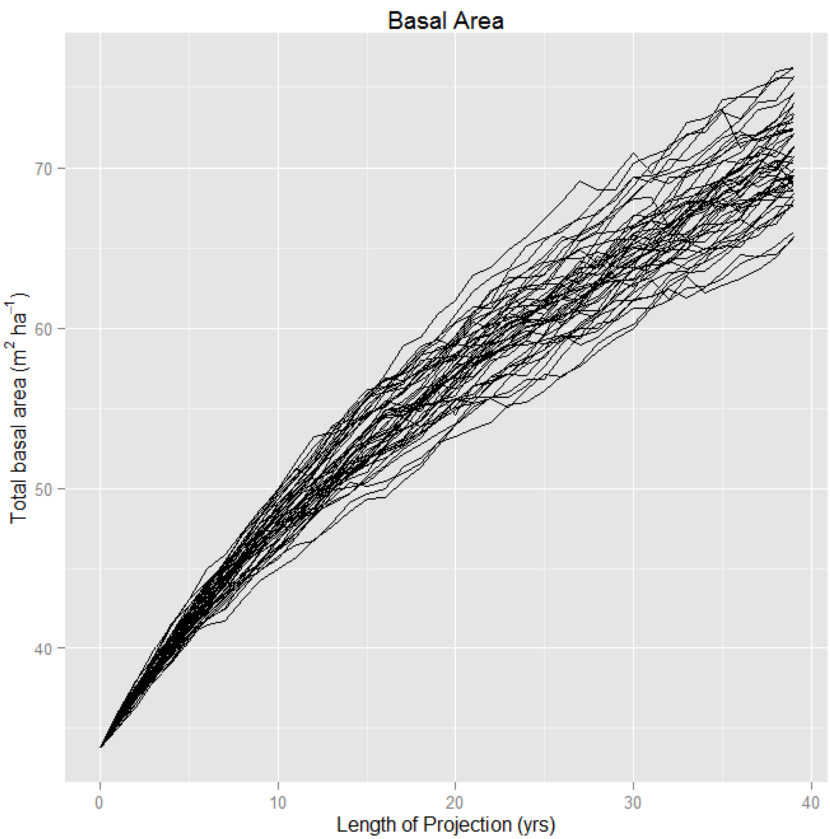
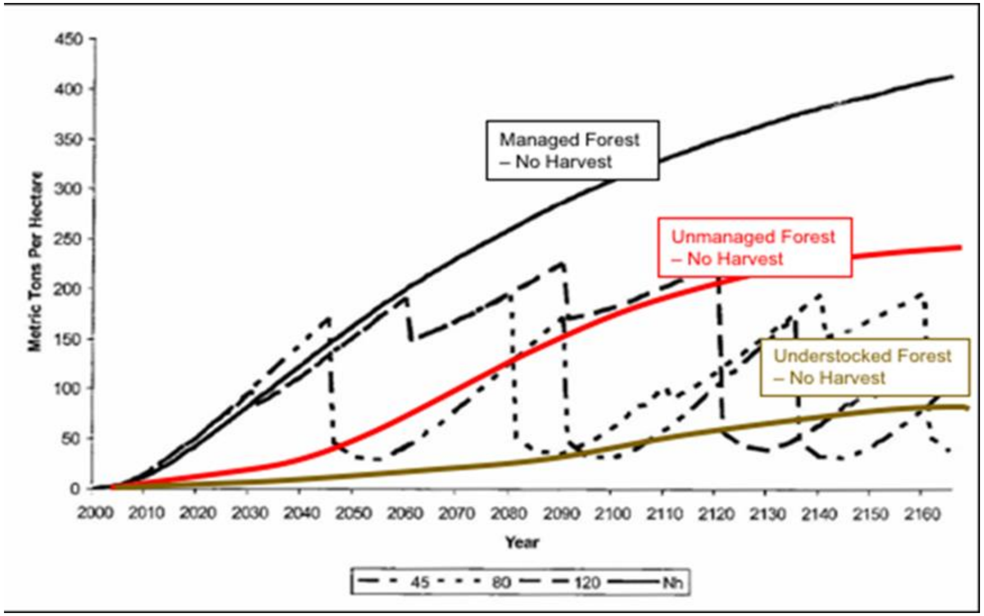
[2]University of Washington, Seattle, Washington
[3]North Carolina State University, Raleigh, North Carolina
[4]Consortium for Research on Renewable Industrial Materials (CORRIM), Corvallis, Oregon
[5]The State University of New York, Syracuse, New York
[6]University of Maine, Orono, Maine
*Now at Exxon Mobil Research, Clinton, New Jersey
**Now at LanzaTech, Skokie, Illinois

May 2018

Technical Accomplishments





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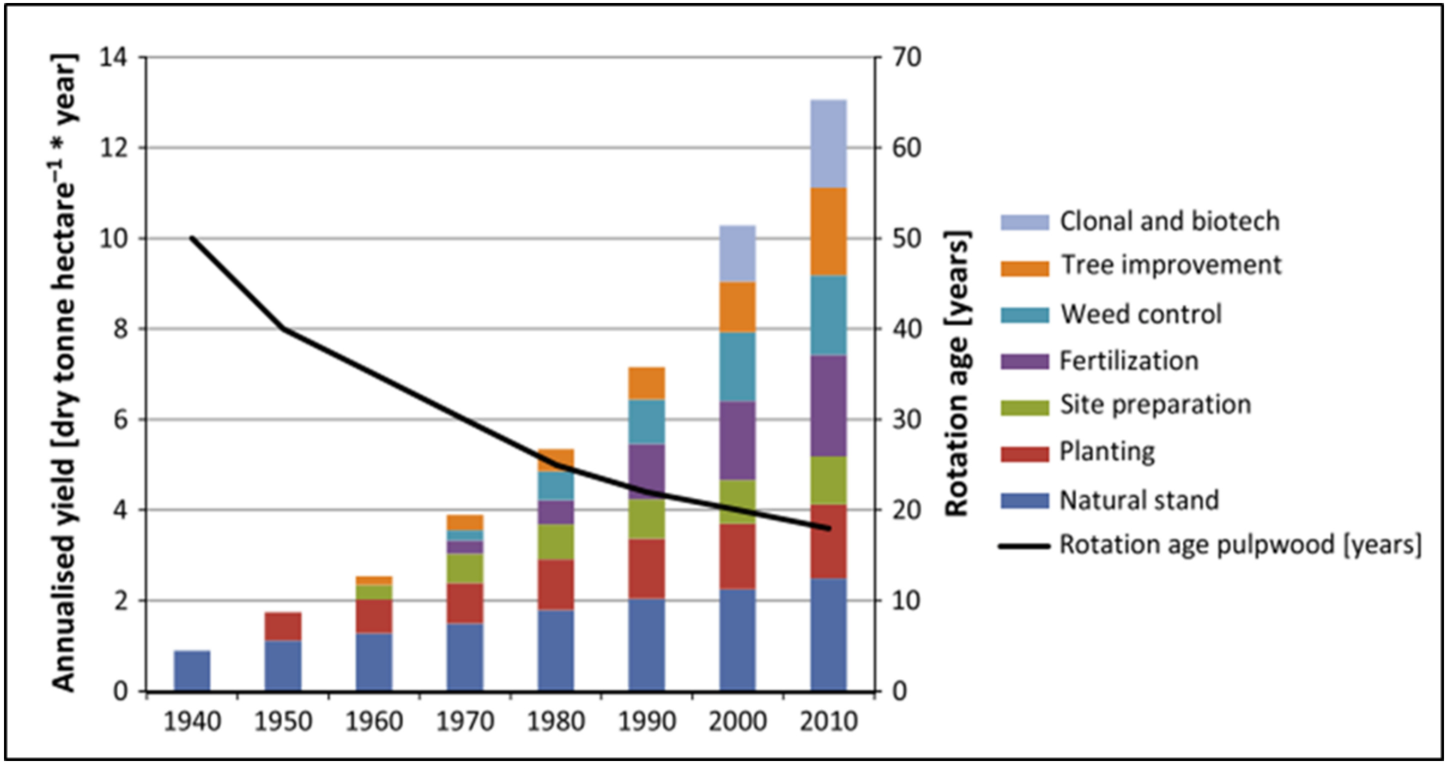
The counterfactual of ‘no harvest’ can only be (reasonably) made if you allow for natural regeneration

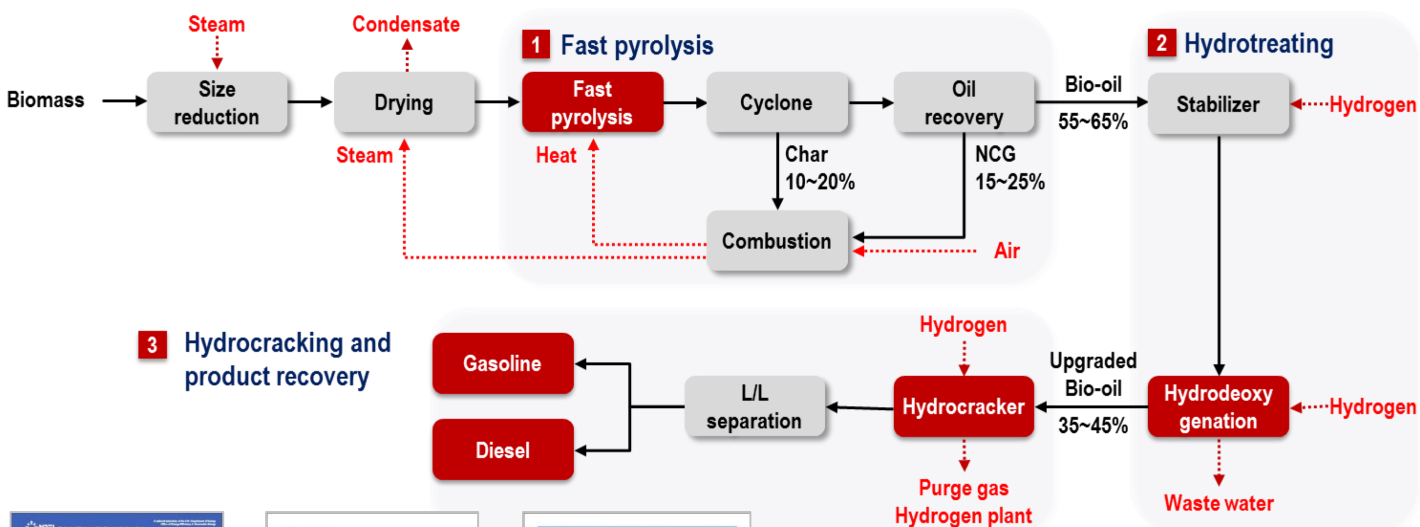
Technical Accomplishments/ Progress/Results

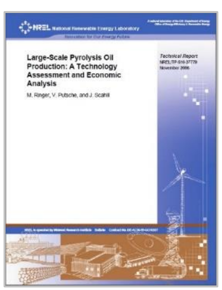


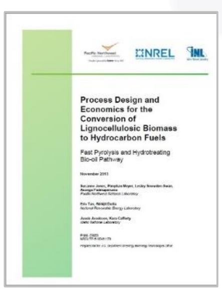
Just like other plant breeders, tree breeders have dramatically improved the productivity of planting stock, which is huge (3X) for a 25-40 year planting cycle

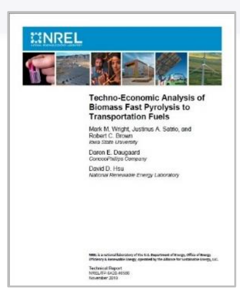
Technical Accomplishments/ Progress/Results

- Continued to updated the TC ASPEN models to track biogenic carbon
- Leverage work from *DOE Next Gen Logistics*









Technical Accomplishments/ Progress/Results

Carbon (%)	Ash (%)	Moisture (%)	Gasoline yield (MM liter/yr)	Diesel yield (MM liter/yr)	NG usage (kg/hr)	Net power (MW) *	TCI (MM$)	MFSP ($/L)
44	3	35	86.04	86.94	9603	10.0	595	1.08
46	3	35	84.22	87.92	9618	15.5	598	1.07
48	3	35	81.96	88.95	9779	21.3	601	1.06
50	3	35	79.91	89.96	9859	26.9	604	1.05
46	**1**	35	97.56	96.55	10978	10.4	620	1.00
46	**3**	35	84.22	87.92	9618	15.5	598	1.07
46	**5**	35	85.63	79.17	9122	17.1	588	1.09
46	**7**	35	88.98	72.82	8661	17.8	581	1.10
46	3	**15**	84.22	87.92	9618	24.6	598	1.04
46	3	**25**	84.21	87.92	9618	20.6	598	1.05
46	3	**35**	84.22	87.92	9618	15.5	598	1.07
46	3	**45**	84.22	87.91	9618	8.6	598	1.09

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Technical Accomplishments/ Progress/Results

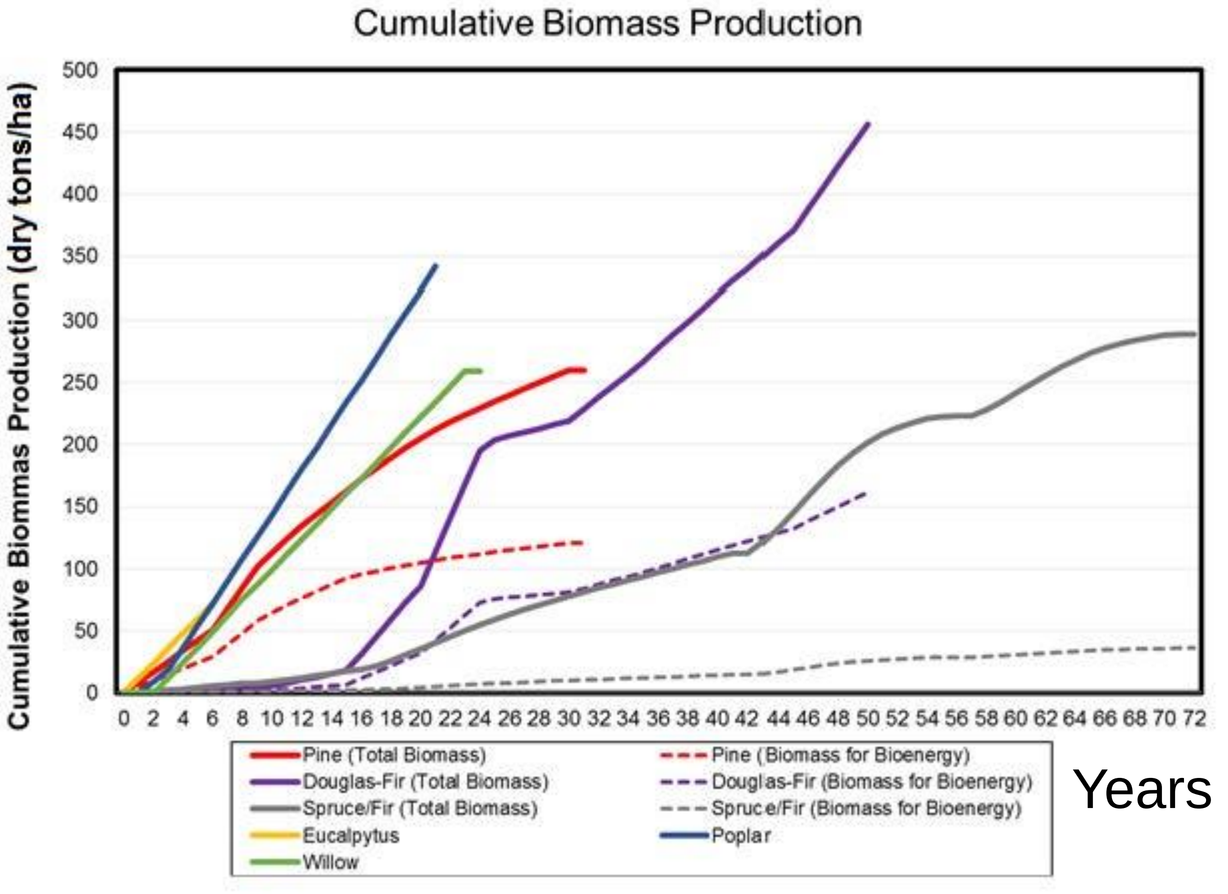

FIGURE 12 Cumulative biomass production of six species examined in this study

Technical Accomplishments/ Progress/Results

PNW rotations

- Douglas-fir even aged plantings with 50 yr. rotation, commercial thinning at 25 yrs.
  - Main product sawlogs, 500-700 M3/ha in 50 yrs
  - Limited residues depending on logging, essentially none with cable logging, some with skidders
- Douglas-fir even aged plantings with 50 yr. rotation, commercial thinning at 25 yrs.
  - Main product sawlogs, 500-700 M3/ha in 50 yrs
  - Allocate thinning to bioenergy, and also residues
- No planting, and allow for natural regeneration, red alder will dominate for years

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Technical Accomplishments/ Progress/Results

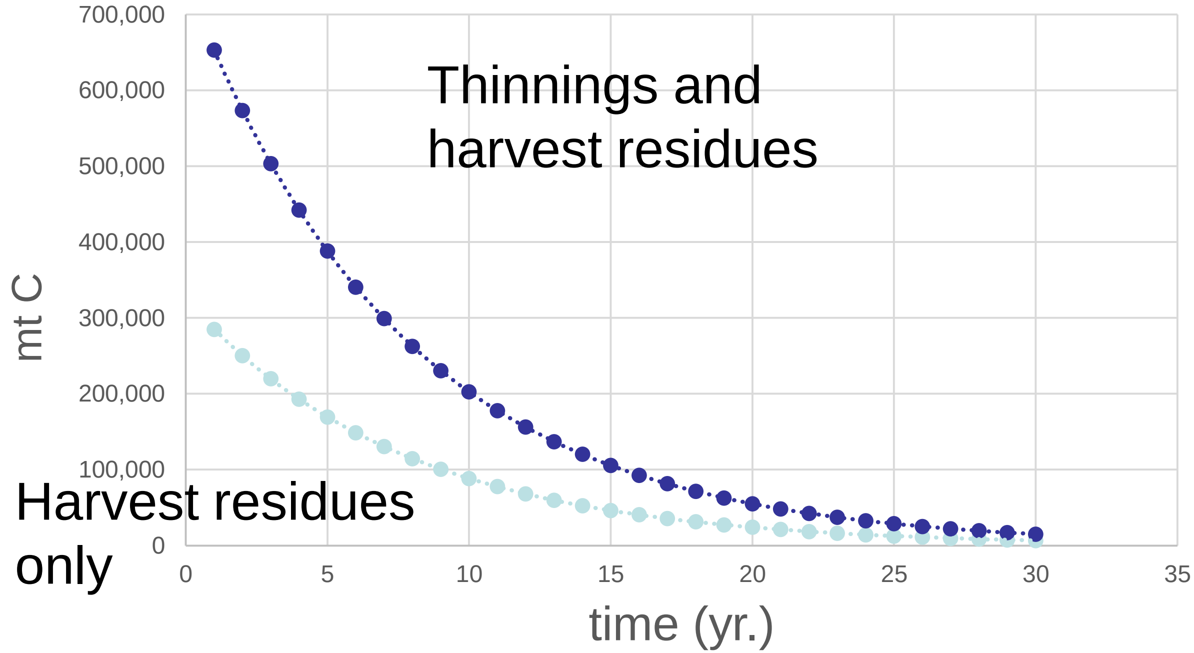
Age at Entry	Operation	DWP (m3/ha)	DWP (BDT/ha)	Residue (BDT/Ha)
25	Comm Thin	74	35	50
50	Clearcut	556	272	46
75	Comm Thin	74	35	50
100	Clearcut	556	272	46

Technical Accomplishments/ Progress/Results

Impact category	Unit	Residue Recovery	Pulp logs from thinning	Transport - pulp logs	Transport ground residues (from ground based locations)	Transport ground residues (from cable based locations)	Chipping pulp logs at facility	Total
Ozone depletion	kg CFC-11 eq	0.00	0.000	0.000	0.000	0.000	0.000	0.000
Global warming	kg CO2 eq	6.63	3.671	10.329	6.347	5.581	5.896	38.458
Smog	kg O3 eq	2.90	1.581	3.166	1.948	1.962	2.584	14.148
Acidification	kg SO2 eq	0.09	0.050	0.098	0.060	0.061	0.081	0.442
Eutrophication	kg N eq	0.01	0.003	0.006	0.004	0.004	0.005	0.026
Respiratory effects	kg PM2.5 eq	0.00	0.001	0.002	0.001	0.001	0.002	0.009
Ecotoxicity	CTUe	18.52	10.229	14.690	9.104	10.471	16.463	79.479
Fossil fuel depletion	MJ surplus	13.08	7.224	10.374	6.429	7.395	11.627	56.130

Technical Accomplishments/ Progress/Results

- Decay of course woody residue in southern and PNW forests, MRT_{95} SP = 25-42 yr., PNW 81-190 yrs



Technical Accomplishments/ Progress/Results

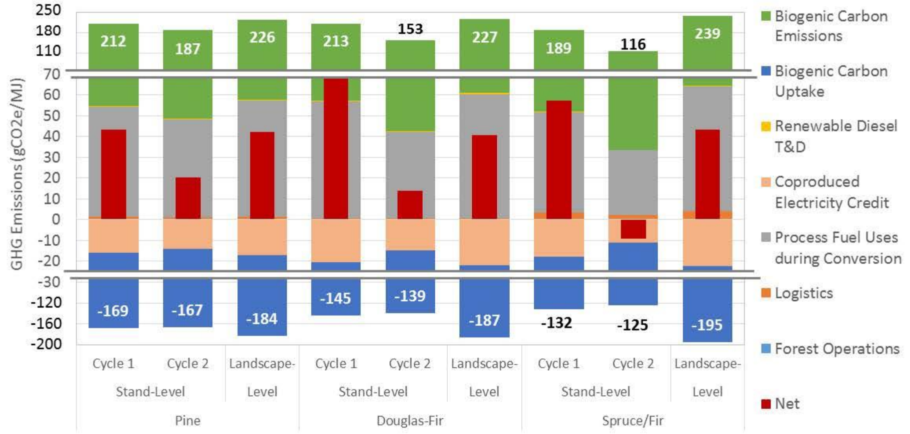


FIGURE B 2 GHG emissions of renewable diesel from softwoods in g CO_2e/MJ by landscape- and stand-level analyses

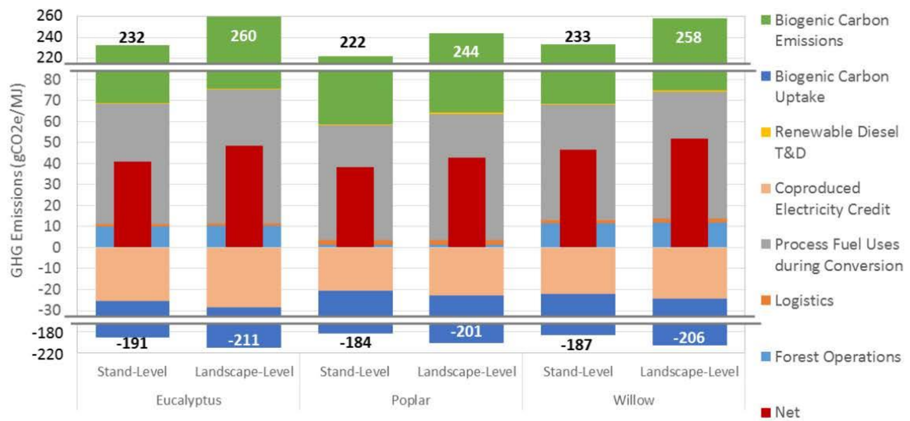
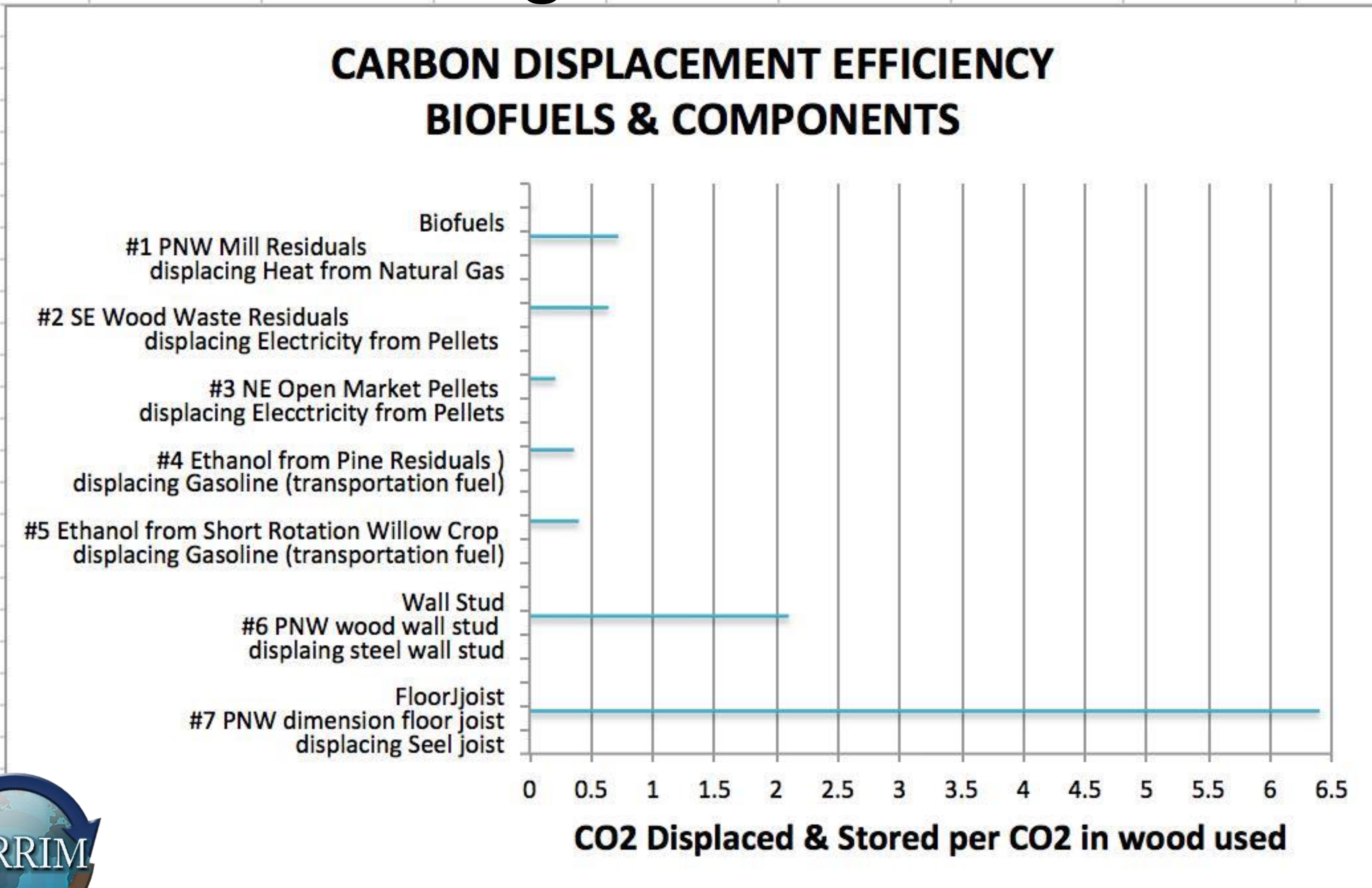
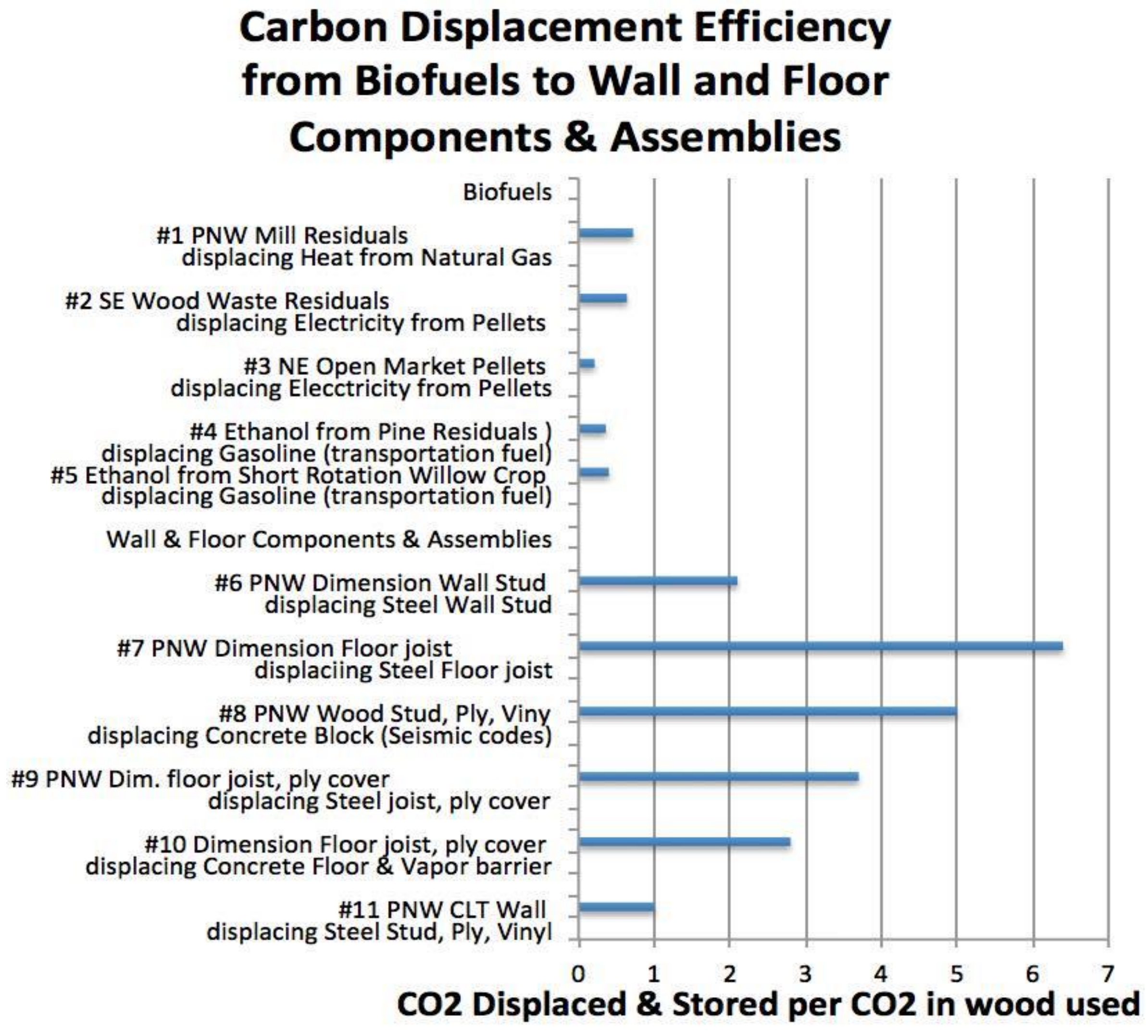


FIGURE B 3 GHG emissions of renewable diesel from SRWCs in g CO_2e/MJ by landscape- and stand-level analyses

Technical Accomplishments/ Progress/Results



Technical Accomplishments/ Progress/Results



Relevance (DOE)

- Understanding sustainability of woody biomass is a barrier for bioenergy systems.
  - **St-A; Scientific Consensus** - analysis of woody feedstocks for energy needs to be based on LCA tools and include allocation to DWP and P&P

- GREET is the internationally recognized tool for measuring the sustainability impacts of different biomass production scenarios.
  - **St-C; Science-Based Message** – adding the analysis of regionally specific feedstocks will help increase breadth and value of GREET

- Woody biomass systems are highly dependent on location and landowner management goals
  - **St-D; Improved Indicators and Methodology** – Regional data for LCI, WP and P&P are required, with regional counter factuals

Summary

Overview :

- Focused on tracking carbon from multiple forests management regimes into biofuels (gasoline and diesel) and DWP.
- Strong collaboration with ANL GREET.

Approach:

- Use forest growth and yield models, couples to ASPEN process models, and include tracking of DWP.
- Evaluate six regions supply chains, and the effects of variation.

Accomplishments:

- LCI for 6 feedstocks complete, and combined with ASPEN models
- Allocation of biomass to product ‘pools’ has been defined, data on variation is being developed
- Major sources of ‘variation’ are being addressed
  - Forestry growth
  - Forestry counterfactual

Relevance:

- Addressing DOE sustainability goals for a complex feedstock

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Backup

2017 Panel comments:

Positive

- Recognized the value of tracking all forest carbon pools, and the relevance to DOE BETO Sustainability Goals.
- Recognized the value of working closely with the GREET team.
- Agreed that we need to look at more plantation management regimes.

Advice

- Carefully look at forest counterfactuals that are significantly different, and focus on managed ecosystems.
- Need to include a more detailed analysis of the wood composition, e.g., MC, ash and carbon content.
- We recognize the value of merging this work with an economic evaluation, and landscape visualization tools, but these are both outside the scope of the current project.

Backup

2017-2019 Publications and Presentations

- Update on 22 years of CORRIM's life-cycle research: Opportunities to reduce carbon emissions. **Bruce Lippke (presenter)**. Society of American Forests annual meeting, Portland Oregon. October 5, 2018
- Forest Panel: *Update on Efficiency in Uses of Wood Products to store and displace fossil carbon emissions.* **Bruce Lippke (presenter).** Pacific NW Economic Region, Spokane WA. July 24, 2018
- *LCA for Environmental Assessment: The Case of Poplar to Ethanol*. **Morales Vera, R. *(presenter)*,** Gustafson, R., Shuren, R. 3° Coloquio de Investigación UCM Curicó-Los Niches 2018. Sustentabilidad desde la transdisciplinariedad: Propiciando diálogos colaborativos para el desarrollo sustentable. Sept 2018. Curicó. Region del Maule. Chile
- *Poplar to Ethanol Production Using Short Rotation Coppice Silviculture: Life Cycle Assessment*. **Morales Vera, R. *(presenter)***, Gustafson, R., Shuren, R. II Conferencia Chilena de Análisis de Ciclo de Vida. August 2018. Santiago. Chile
- *Greenhouse Gas and Energy Balance of Willow Biomass Crops are Impacted by Prior Land Use and Distance From End Users*. Volk, T.A., Yang, S., Fortier, M-O, and O. Therasme. 2018 Woody Crops International Conference, July 23-25, 2018, Rhinelander, WI.
- Frank, J., Brown, T. Volk, T.A. Heavey, P., Malmsheimer, R. 2018. A stochastic techno-economic analysis of shrub willow production using EcoWillow 3.0S. *Biofpr*. DOI: 10.1002/bbb.1897
- *Effects of Biomass Composition on the Economics and Life Cycle Impacts of Bio-oil Biorefinery.* Longwen Ou, Hoyong Kim, Maria Herrera, Yuan Yao, Sunkyu Park and **Stephen S. Kelley *(presenter)***. *Forest Products Society Annual Meeting, Madison WI June 11-14, 2018*

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Backup

2017-2019 Publications and Presentations

- *Production and Availability of Mill Residues for Use in a Biorefinery.* **Maureen Puettmann *(presenter*),** Bruce Lippke, and Steve Kelley. Forest Products Society Annual Meeting, Madison WI June 11-14, 2018
- *LCA of Poplar to Ethanol Production Using Short Rotation Coppice Silviculture.* **Rodrigo Morales *(presenter)*** and Rick Gustafson. Forest Products Society Annual Meeting, Madison WI June 11-14
- *Regional Variations in the lifecycle assessment of Softwood Residue Recovery for Biofuel Production for the Pacific Northwest and Northeast regions of the USA.* **Elaine Oneil (presenter)**, et al. Forest Products Society Annual Meeting, Madison WI June 11-14
- Yang, S. T. Volk, M-O. Fortier. 2016. Spatially explicit life cycle assessment of willow biomass production in northern New York. Short Rotation Woody Crops Operations Working Group meeting, St. Petersburg, FL, Oct. 11 – 13, 2016.