U.S. Department of Energy (DOE) Bioenergy Technologies Office (BETO) 2017 Project Peer Review

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

March 7, 2017
Analysis and Sustainability

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Overall Goal

Goal: The goal of this project is to understand the carbon flows for woody biomass allocated to wood and paper products, and bioenergy products, and evaluate the implications for different forest management systems.

Context: Durable wood products (DWP) can sequester carbon for 20-70 years in buildings, for 2-5 years in paper, and for hundreds of years in *mature, undisturbed* forest. Or this carbon can be released immediately by bioenergy systems. But all of these bioproducts replace a fossil-based alternative.

Counterfactuals, discounting and uncertainty all need to be included and carefully considered.

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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

Goal Statement

FACTS on the ground

- Total forest lands and carbon stocks in the US are growing
- The forest products industry has the ability to sustainably deliver woody biomass with well-known cost structures, e.g., 500,000-1,000,000 ODT/yr.
- The current forest products industry can serve as a co-location site for early commercialization of bioenergy technology

- Currently forest products/pulp and paper industries does not welcome subsidized alternative markets for its raw materials
- The use of woody biomass is truly complicated, and attracts a high level of societal interest (not all of which is well-informed)

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Quad Chart Overview

Timeline

- Initial start - Sept, 2010
- Restart - Sept, 2015
- Complete - March, 2018
- 50% of work completed

Budget

	Total Costs FY 12*	FY 15 Costs	FY 16 Costs	Total Planned Funding (FY 17-Project End Date)
DOE Funded	399,802	0	217,673	813,060
Project Cost Share	123,003	0	83,385	167,765

* 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; C. Canter; J. Dunn)
- NREL, PNNL, INL, USFS
- DOE LEAF

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

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

Added pulp and paper as co-product, along with lumber

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1 - Project 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 paper as a co-product, along with recycle and end of life

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2 – Approach (Technical)

<u>For commercial softwoods there are four ‘pools’ to be tracked, e.g., wood products, paper, biorefinery, forest</u>

<u>SRWC are purpose grown for bioenergy so only one ‘pool’</u>

- For the four pools need regionally specific data on mass flows, timing, and end of life (landfill vs decay in the woods).
- First analysis will focus on a single case that represents current practices
- Will 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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2 – 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
- Discounting done by ANL GREET team (IPCC protocols)

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2 – 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)

2 – 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 will work closely with the GREET team. Have used monthly (or at crunch times) weekly calls, reviewed milestones for both teams, and insure constant feedback between ANL GREET and CORRIM teams
- NCSU hosted ANL GREET team to discuss the improved TC models, how to include P&P modeling, and forest modeling for counterfactuals

2 - Technical Approach

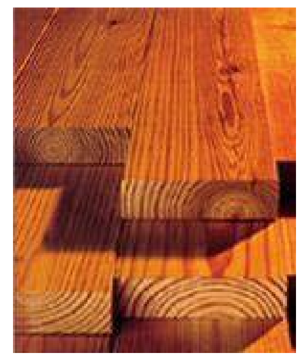
Softwoods

SRWC

LCI burdens

- Chemicals
- Fuels
- Planting stock

Allocation!

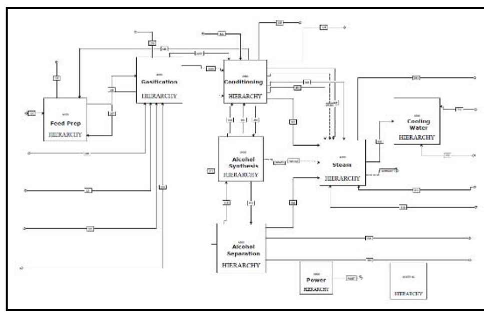


2 - Technical Approach

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

3 – Technical Accomplishments/ Progress/Results

- Completed collection of LCI for 6 biomass production systems
- Completed allocation to products pools for 2 of 3 systems
- Identified wood composition data sources (working through consistency issues)
- Updated NREL/PNNL process model to reflect biomass compositional differences (joint effort with another DOE project team)
- Completed update of mill surveys on product allocations from a log, also on mill energy boiler/dry kiln alternatives
- Worked with ANL GREET team to agree on discounting methods
- Assisted in editing and review of ANL GREET milestone report
- Defined one counterfactual, started LCI alternatives

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3 – Technical Accomplishments/ Progress/Results

<u>Completed collection of LCI for 6 biomass production systems</u>
<u>Completed allocation to products pools for 2 of 3 systems</u>

PAC NW – Douglas fir plantation, Poplar
SE – Loblolly plantation, Eucalyptus
NE – Spruce/Fir, Willow

- Establishment – chemicals, fuels
- Maintenance – chemicals, fuels
- Harvesting – fuels
- Transportation – fuels

- Allocation at 'mill' – Sawmill and biorefinery co-located, 2nd (or 3rd) sawmill ship residues, pulp mill outside collection radius

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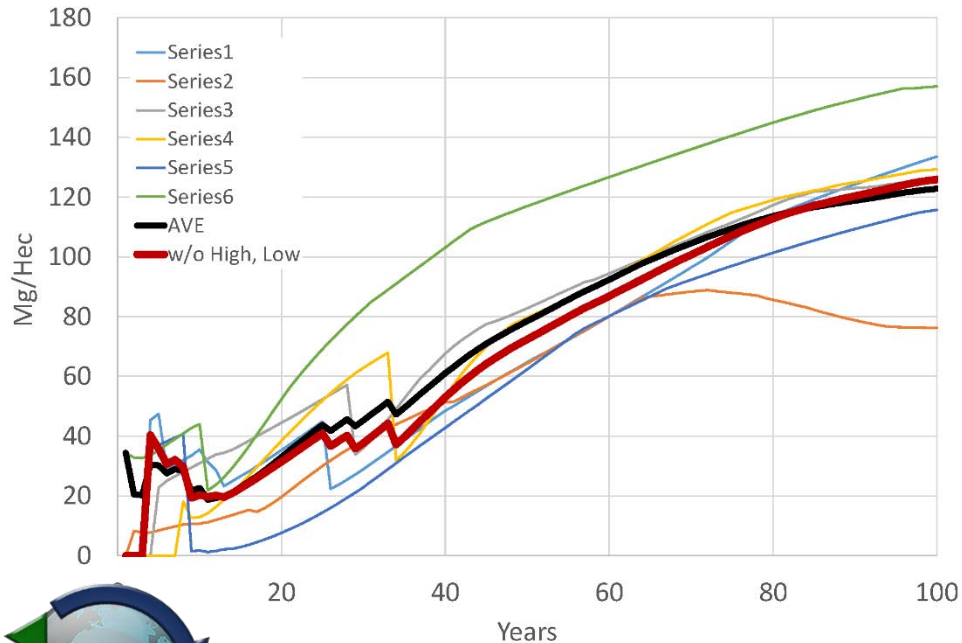
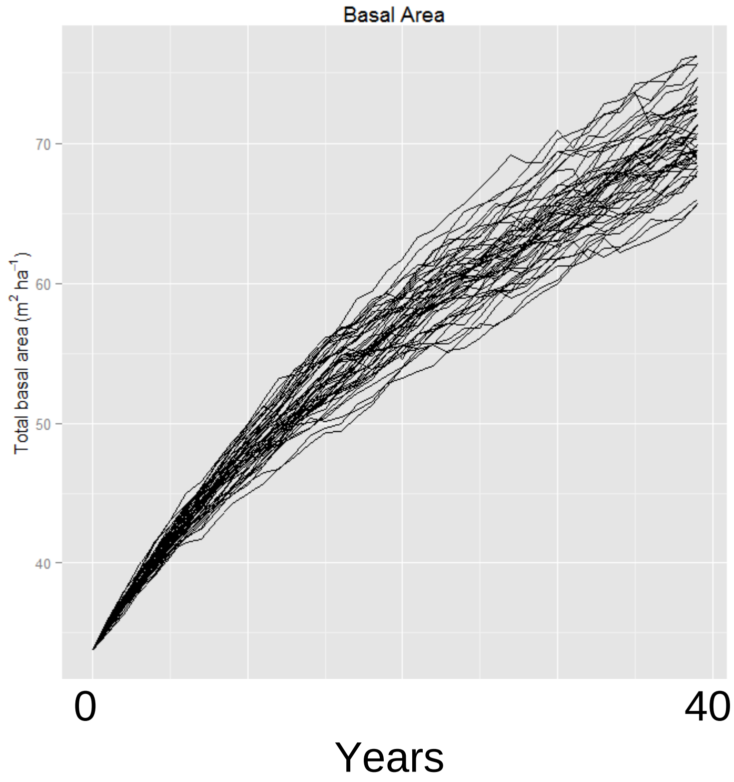
3 – Technical Accomplishments/ Progress/Results

- Reviewed USFS FIA data, conducted growth and yield modeling

- Greater uncertainty at longer times.
- Greatest impact on 'counterfactual'





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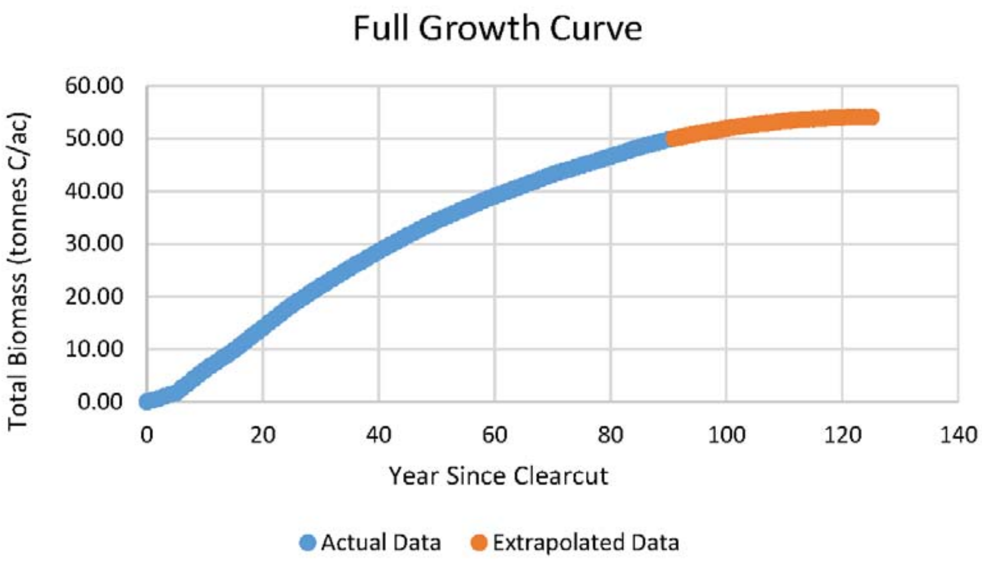
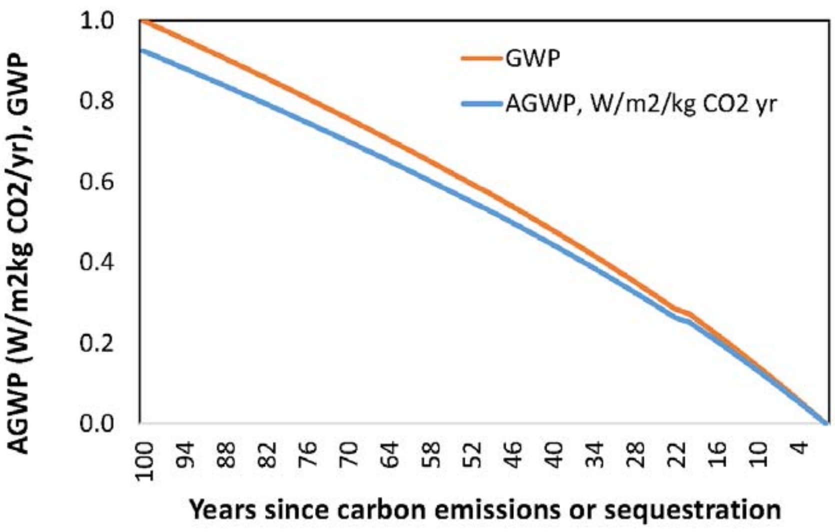
3 – Technical Accomplishments/ Progress/Results

- ANL and CORRIM team agreed on assumptions for discounting
- Tradeoff between future ‘uncertainty’ and discounting





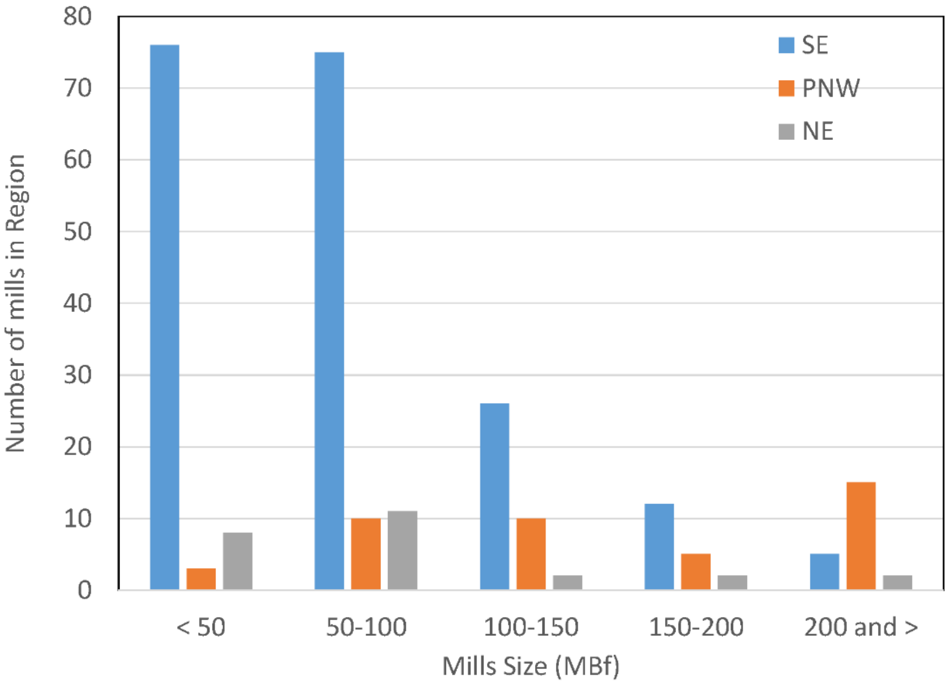
3 – Technical Accomplishments/ Progress/Results

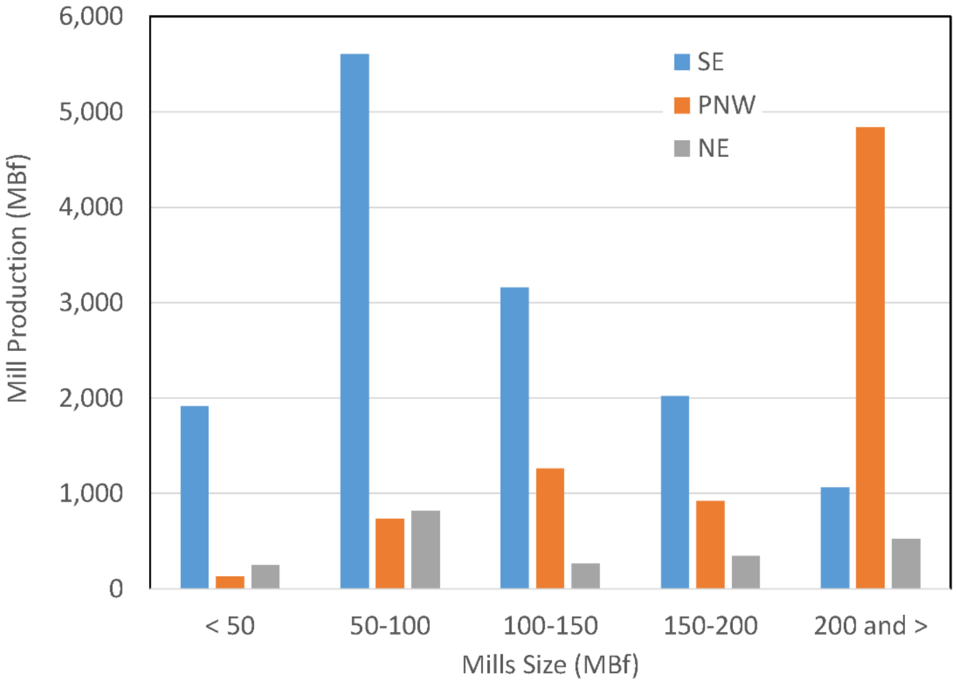
- Well-developed growth and yield models for the three regions.
- But still many assumptions of site index (productivity), local infrastructure and landowner goals and resources, e.g., strict economic return, limited resources or mixed use goals

Region	Initial Density (tpa)	Above ground biomass available at year 15 (tons/acre/yr)	Biomass removed at year 15 for biofuels (tons/acre/yr)	Biomass at thinning (tons/acre)	Above ground biomass available for HWP and P&P	Above ground biomass available for biofuel (tons/acre)
Coastal Plains	600	4.4	1.7	26.0	67.8	11.4
	800	4.7	2.0	30.2	68.1	11.5
	1000	4.9	2.3	33.9	68.4	11.5
	1200	5.2	2.5	37.1	68.6	11.5
	1400	5.3	2.7	39.9	68.7	11.6
Piedmont	600	3.7	1.2	18.6	64.9	11.2
	800	3.9	1.5	22.5	65.3	11.2
	1000	4.1	1.7	25.2	65.5	11.3
	1200	4.3	1.8	27.6	65.7	11.3
	1400	4.5	2.0	29.9	65.9	11.4

3 – Technical Accomplishments/ Progress/Results

- CORRIM data on mill infrastructure and log allocation





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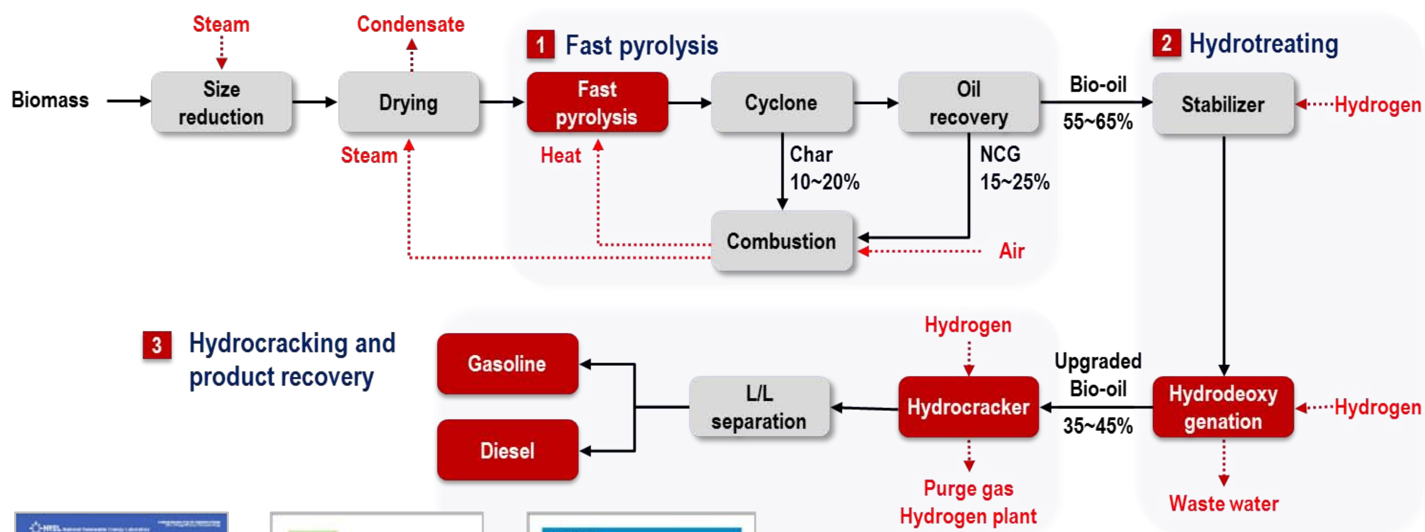
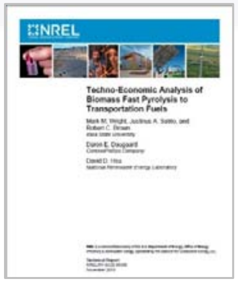
3 – Technical Accomplishments/ Progress/Results

- Updated the TC ASPEN model with advice from PNNL, NREL and INL
- Leverage from *DOE Next Gen Logistics* (Rials, UT, Wed, 1:30)





3 – Technical Accomplishments/ Progress/Results

- Created empirical equations for ASPEN bio-oil process model using data from NCSU (18), PNNL (8), VTT (8) to connect biomass composition to product yield
  - Reasonable correlations for Ash - bio-oil, water and char
  - Limited correlations for carbon - and bio-oil, water and char

- Included lab based extraction process (VTT) to allow for estimates of gas and diesel, which is needed for GREET

- Included a turbogenerator to allow for recovery of useful heat

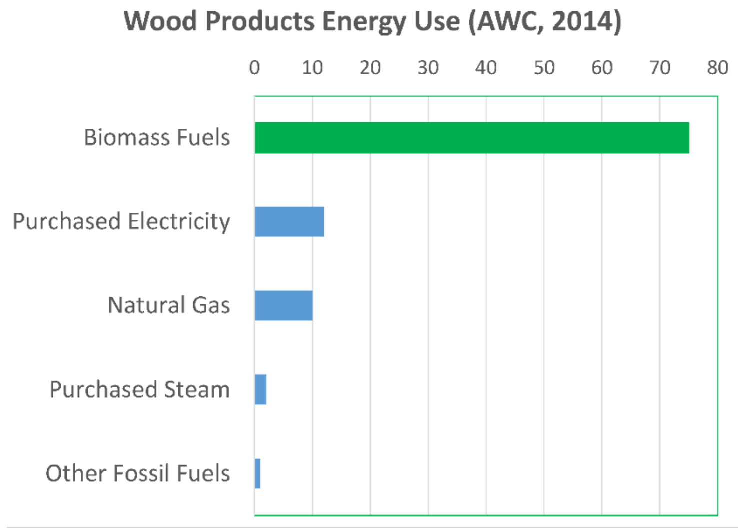
3 – Technical Accomplishments/ Progress/Results

Carbon (%)	Ash (%)	MC (%)	Bio-oil (kg/hr)	Gasoline yield (kg/hr)	Diesel yield (kg/hr)	Natural gas use (kg/hr)	H2 use (kg/hr)	Net Power (KW)	*Net CO2 emissions* (kg/hr)
44	3	35	13,916	2,306	2,679	2,778	868	-4,649	21,229
46	3	35	13,539	2,130	2,566	2,662	832	-5,890	19,644
48	3	35	13,161	1,958	2,452	2,546	796	-7,122	18,055
50	3	35	12,817	1,659	2,466	2,432	760	-8,340	16,424
46	**1**	35	15,004	2,351	3,220	3,166	990	-3,641	23,187
46	**3**	35	13,539	2,130	2,566	2,662	832	-5,890	19,644
46	**5**	35	12,073	1,793	1,950	2,169	678	-8,112	16,140
46	**7**	25	10,607	724	1,974	1,593	498	-11,497	11,838
46	3	**15**	13,539	2,129	2,566	2,662	832	-8,153	18,585
46	3	**25**	13,539	2,130	2,566	2,662	832	-7,155	19,052
46	3	**35**	13,539	2,130	2,566	2,662	832	-5,890	19,644
46	3	**45**	13,539	2,130	2,566	2,662	832	-4,150	20,459

- Change 46 to 50 %C – 21% incr. Total HC, 30% incr. in net CO_2
- Change 1 to 7 % ash – 107% decr. Total HC, 96% decr. in CO_2
- Change MC 15-45% - no change Total HC, 10% incr. in CO_2

3 – Technical Accomplishments/ Progress/Results

- Wood products mill energy cycles, effects of allocating mill residues



Substitution effect switching from BAU energy fuels which includes self-generated biofuels to 100% natural gas[13]		
	% **decrease** in CO2 biogenic	% **Increase** in Fossil CO2
PNW Lumber	97%	218%
SE Lumber	85%	244%
SE Hardwood Lumber	100%	187%
NENC Lumber	98%	68%
NENC Hardwood Lumber	98%	130%

3 – Technical Accomplishments/ Progress/Results

- Counterfactual – ASSUMPTIONS, discounting
- LCA study, but counterfactuals need to be realistic

- **Easy counterfactual – current systems, w/o bioenergy**
  – Use the same growth and yield projections
  – No collection of thinnings or forest residues
  – Use of mill residues for process heat
  – Assume decay of wood residue in forests, did not include fire, disease

- **'Hard' Counterfactual – 'natural regeneration' and/or no harvest for 100 years; large variations by region**
  – Is it realistically going to happen?
  – 'natural regeneration' standard in NE, uncommon but present in SE, not allowed in PNW
  – Assume delays in establishment and competition that will limit maximum carbon on land, lower forest health, fire

4 – Relevance (DOE)

- Understanding sustainability of forest systems, with there very real and political overlays, is a major barrier for the large scale commercialization of 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, with the current demands for commercial DWP and P&P, and the high sensitively to the unique aspects of forests, will attract more attention than many other biomass sources
  - **St-D; Improved Indicators and Methodology** – Regional LCI, WP and P&P LCA, counterfactuals are all required

4 – Relevance (Wider)

- The initial ‘customer’ for this work is the DOE GREET team.
- Additional customers include the USFS and the current DWP and P&P industries, and rapidly growing wood pellet industry.
- Forest carbon cycle are complex! Many groups are looking for better LCA data and also ways of ‘decoupling’ supply of wood and paper, from harvesting of ‘native’ forests, e.g., WWF ‘Next Generation Plantations’ (http://newgenerationplantations.org/)
- This work will insure that GREET has high quality LCA data on woody feedstocks,
- DOE has an understanding of the effects of variations in woody feedstock quality on biofuels production

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5 – Future Work

- Task 3 – LCA of the impacts of using woody biomass as a feedstock for different biochemical and thermochemical biofuels production processes
  - *clear pathway, use updated TC model, aver. biomass chem.*

- Task 4 – analysis of the impacts of natural variations in wood composition and production scenarios on the LCA of wood based biofuels
  - *have tools for identifying and evaluating high impact steps*

- Task 5 – analysis of the carbon storage implications of using woody feedstocks for the production of both biofuels and the current commercial suite of DWP and P&P
  - *final step to bring DWP and P&P, and biorefinery 'systems' together*
  - *counterfactuals highly varied, and will have large impact on the final differences in GWP*

- *Budget under spent, but new postdocs coming on line in Jan, 2017*

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Summary

- Strong team between CORRIM and ANL GREET
- Project on track, on schedule, on budget
- Initial LCI for 6 feedstocks complete, discounting methods defined
- Allocation of biomass to product ‘pools’ has been defined, specific data being developed
- Sources of ‘variation’ have been identified
  - Forestry growth
  - Effects of chemistry on TC conversion
  - End of life for DWP and P&P
  - Forestry counterfactual