Life Cycle Analysis of Distributed-Scale Biomass Conversion Technologies (BCTs)

Presented by:
Sevda Alanya-Rosenbaum, Ph.D.
Forest Service, Forest Products Laboratory Madison, WI

U.S. DEPARTMENT OF ENERGY

HUMBOLDT STATE UNIVERSITY

For more information please visit WasteToWisdom.com

Sub-task Collaborators

- Elaine Oneil, Ph.D., University of Washington

- Maureen Puettmann, Ph.D., WoodLife Environmental Consultants, LLC

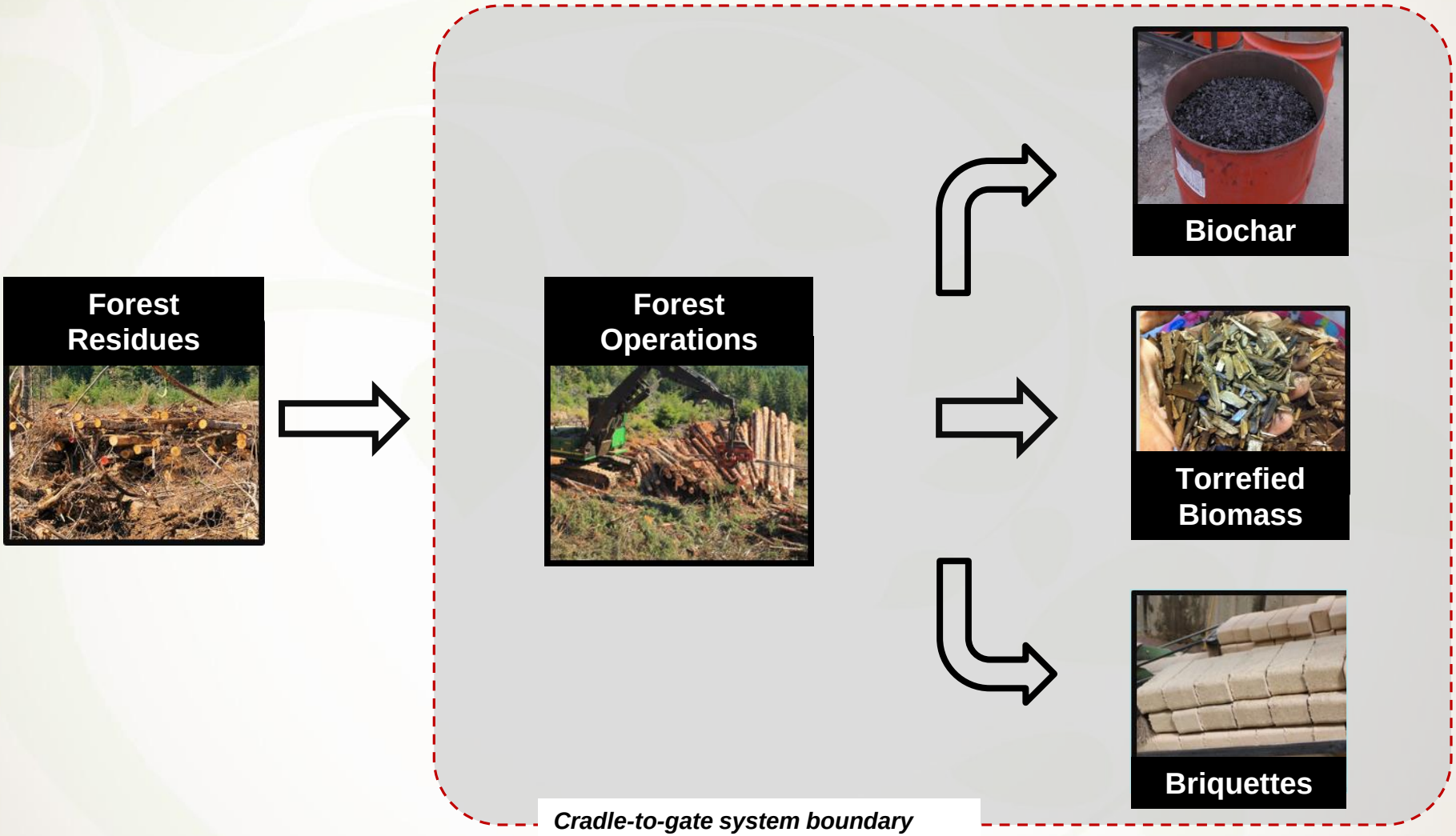
- Richard Bergman, Ph.D., USFS-FPL

Goals of Conducting Life Cycle Assessment (LCA)

Determining environmental success of utilizing forest residues for production of bioenergy and biobased products (an attributional process-based approach)

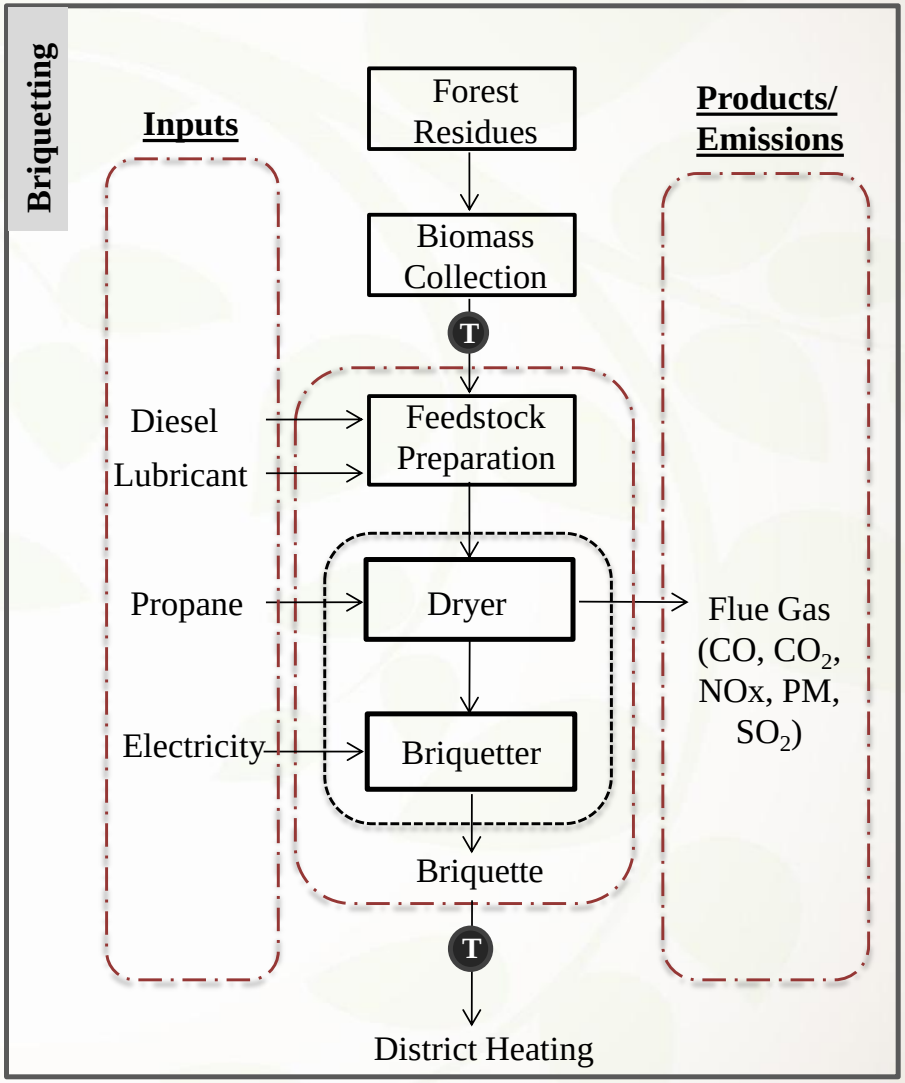
- ✓ Develop a cradle-to-gate life cycle inventory (LCI) for the in-woods biomass operations
- ✓ Quantify the life cycle environmental impacts of forest operations
- ✓ Develop a cradle-to-gate LCI for biomass conversion technologies (BCTs): biochar, torrefaction, and briquetter
- ✓ Quantify the life cycle environmental impacts of the individual BCTs
- ✓ Explore options on cradle-to-grave activities

Life Cycle System Boundary



System Boundaries of Briquetting

- ✓ Preliminary analysis performed using Briquetter Phase II data, Big Lagoon, CA (RUF200 model briquetter, RUF Briquetting Systems)
- ✓ LCI inventory developed for six Douglas-fir feedstock samples
- ✓ LCA analysis were focused on the selected samples
- ✓ LCA analysis will continue with environmental impact assessment of processing other species

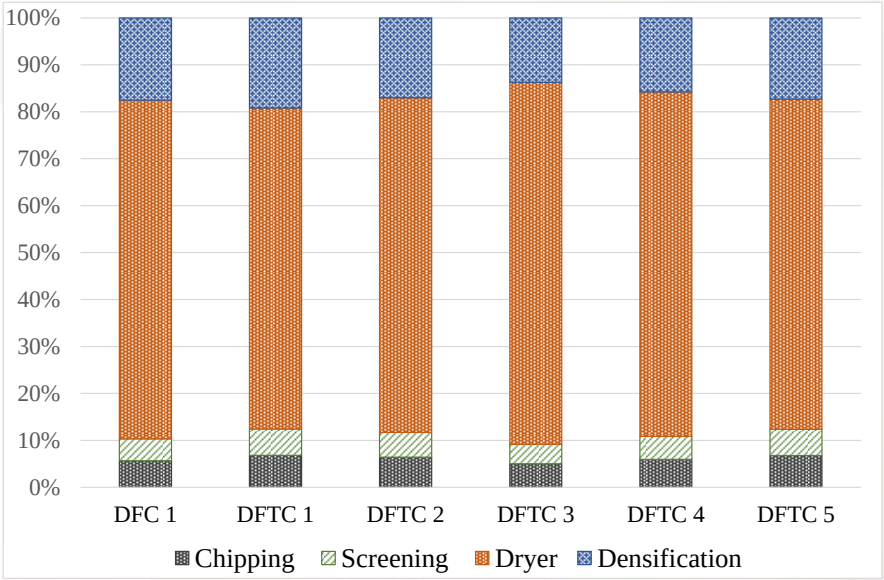


System Boundaries of Briquetting

Fuel	DFC 1	DFTC 1	DFTC 2	DFTC 3	DFTC 4	DFTC 5
Wood fuel (%)	0.0	0.0	0.0	0.0	0.0	0.0
Gas, natural, in ground(%)	78.2	73.4	75.5	80.1	77.1	74.6
Coal, in ground (%)	9.3	10.9	9.9	8.1	9.3	10.1
Oil, crude, in ground (%)	9.8	12.4	11.7	9.3	10.9	12.3
Uranium oxide, in ore (%)	2.7	3.3	3.0	2.4	2.8	3.0
Renewables (%)	0.0	0.0	0.0	0.0	0.0	0.0
Total (%)	100	100	100	100	100	100
Cumulative (MJ/MJ)	0.099	0.085	0.089	0.114	0.094	0.084

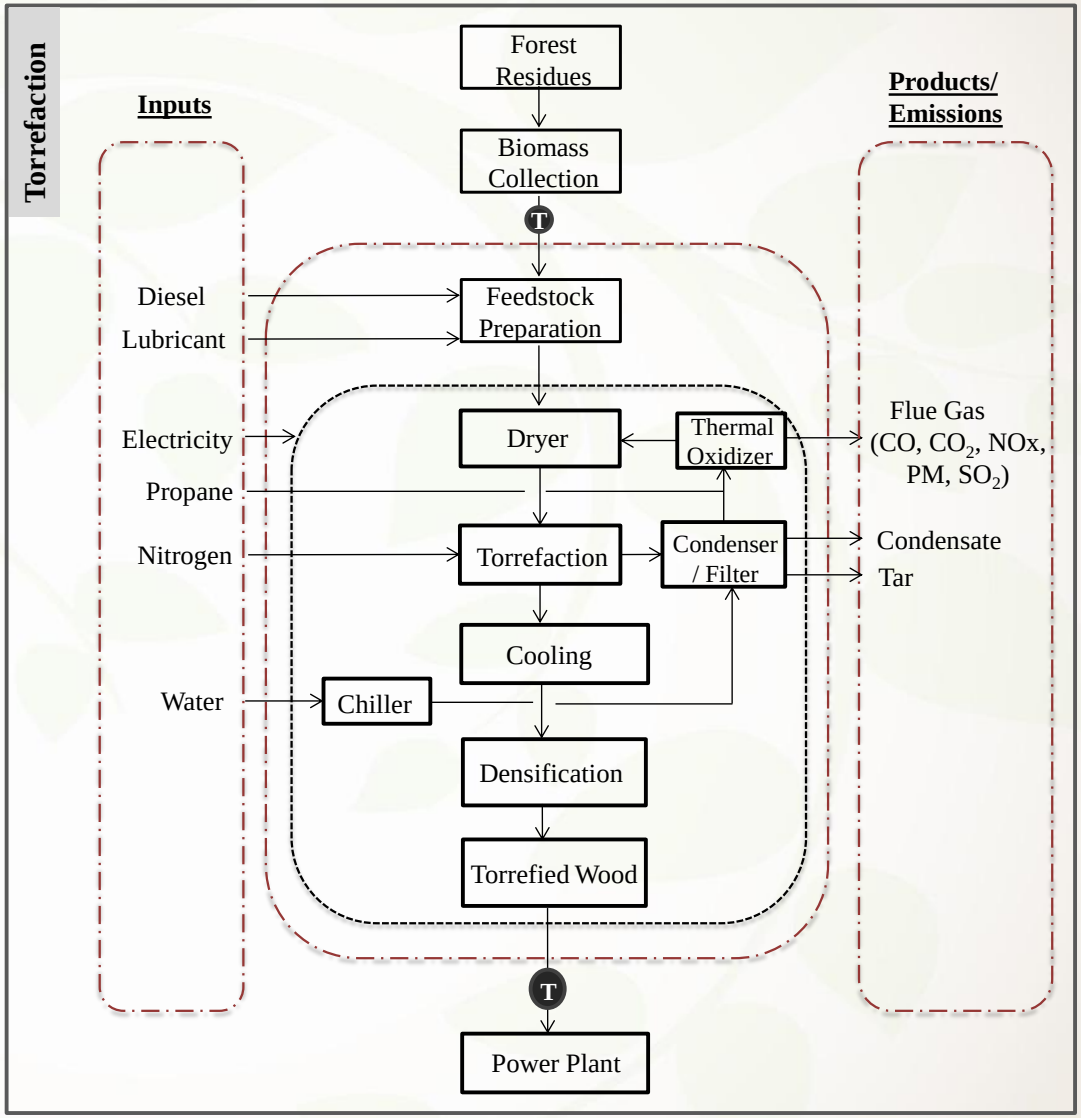
Gate-to-gate primary energy consumption per 1 MJ of energy in briquette

Distribution of primary energy consumption to unit processes for briquetted post-harvest forest residues.



System Boundaries of Torrefaction

- ✓ Preliminary LCA analysis were completed based on pilot-scale torrefaction tests (Norris Thermal Technologies) for feedstocks with favorable results.
- ✓ Analysis were based on the Torrefier Pilot Unit data, Big Lagoon, CA
- ✓ LCA work will continue and focus on scaled-up unit data for more accurate data inventory and analysis
- ✓ Missing input-output data

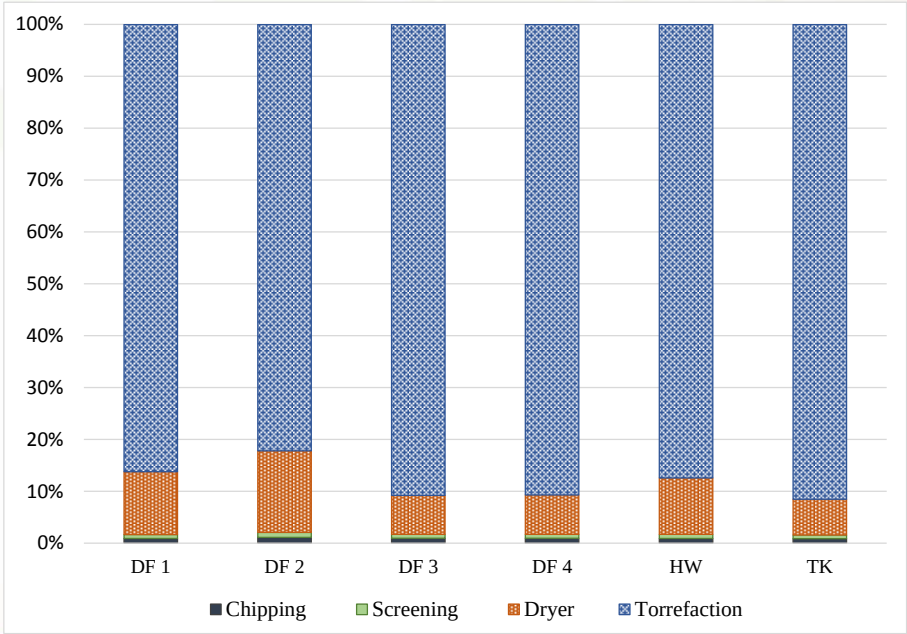


System Boundaries of Torrefaction

Fuel	DFC 1	DFTC 1	DFTC 2	DFTC 3	DFTC 4	DFTC 5
Wood fuel (%)	0.0	0.0	0.0	0.0	0.0	0.0
Gas, natural, in ground(%)	47.8	49.6	45.2	45.3	47.1	44.9
Coal, in ground (%)	38.1	36.4	40.0	39.9	38.6	40.3
Oil, crude, in ground (%)	3.0	3.4	3.1	3.1	3.1	3.0
Uranium oxide, in ore (%)	11.1	10.7	11.7	11.7	11.3	11.8
Renewables (%)	0.0	0.0	0.0	0.0	0.0	0.0
Total (%)	100	100	100	100	100	100
Cumulative (MJ/MJ)	0.845	0.702	0.663	0.677	0.682	0.787

Primary energy consumption per 1 MJ of energy in torrefied wood

Distribution of primary energy consumption to unit processes for torrefied post-harvest forest residues.



Full-scale Torrefaction Unit Tests

Have following data requirements:

- ✓ Tor-gas: Composition, production rate, heating value [after condensation]
- ✓ Bio-oil and tar production
- ✓ Water used for cooling
- ✓ Nitrogen purged
- ✓ Feedstock and torrefied wood characteristics (HHV, Ash, VM, FC, etc.)
- ✓ Dryer run data: if running propane/ torgas consumption

Briquetter Phase II Data

Missing data:

- ✓ Results of grinding tests
- ✓ Missing electricity consumption for some of the tests

Remote Electricity Generation

Have following data requirements:

- ✓ All Power Labs Biomass Gasifier run data to include in syngas generator operation.
- ✓ On-site electricity produced from diesel generator for powering the BCTs.

Scenario Analysis

- ✓ Keeping **base** scenario for LCA analysis as wood power- transportation distances
- ✓ Clarify any changes if any regarding the **six** alternative scenarios developed.

	Scenario	Scale	volumes/acre	Field Ops Season	Landing Use	Baler	Chipper	Grinder	BCT Ops Season	Chipper	Grinder	star screener	Deck Screener	BCT Power Source (grid, diesel, gasifier)	Dryer?	Biochar ?	Torrefier?	Briquetter?
Default Scenario	0	30-50,000 tpy	30-50 BDT	200 days	Post-harvest forest residues are ground and trucked out to biomass power plant for electricity generation			X										
	1	30-50,000 tpy	30-50 BDT	200 days	Processed tops trucked out, limbs baled	X			250 days	X	X	X		Diesel/grid/gasifier	X	X	X	X
	2	15-30,000	15-30	200 days	processed tops trucked out, limbs baled	X			250 days	X	X	X		Diesel/grid/gasifier	X	X	X	X
	3	6?-15,000	6-15	200 days	processed tops trucked out, limbs baled	X			250 days	X	X		X	Diesel/grid/gasifier	X	X	X	X
	4	30-50,000 tpy	30-50 BDT	100 days	Processed tops chipped, limbs burned		X		250 days			X		Diesel/grid/gasifier	X	X	X	X
	5	15-30,000	15-30	100 days	Processed tops chipped, limbs burned		X		250 days			X		Diesel/grid/gasifier	X	X	X	X
	6	6?-15,000	6-15	100 days	Processed tops chipped, limbs burned		X		250 days				X	Diesel/grid/gasifier	X	X	X	X
Description		Scale: High end, medium end, and low end feedstock production is considered. Feedstock production scales are based on economics, equipment and regional capacity.		Seasonal operation is considered-excluding weekends and holidays	Two logistic options are considered for the process tops: (1) transporting with trucks or (2) chipping at the central landing. The process tops are trucked to the market (i.e. power plant, post and pole market) or to the BCT site where they are chipped.The options for limbs are: (a) Burning at the site or transporting to the BCT site then grinding.		Process tops are chipped at the Central Landing or at the BCT site.		A year–round operation of BTCs is considered-excluding weekends and holidays		Limbs are transported to BCT site then grinded or burnt on-site				Considered different variations in BCT operation: (a) Running BCT units simultaneously (b) Units operate individually.			

Cradle-to-grave LCA:
Combustion testing for torrefied wood

Total mass required to complete one test day is approximately 350 lbs (159 kg).

Cost:

- Cost of the proposed work is based on $12,000/day Combustion Test Facility (CTF) operations at the ***Western Research Institute in Laramie, WY***, which includes fuel analysis (PROX/ULT/BTU), system recovery and formal reporting including experimental data spreadsheets. Additional costs to be incurred such as coal/fuel charges, biomass milling, fly ash and slag analysis are shown below in the budget breakdown and will only be charged if conducted.

Budget Breakdown

- Daily Run Cost: $12,000.00
- Daily Coal/Fuel Cost: $1,500.00
- Biomass Milling per 350 lb Sample: $1,500.00
- Elemental Ash Analysis ATSM D4326 (per sample) No. of samples TBD: $300.00 each
- Ash Fusion (Reduction /Oxidation.) ASTM D1857 (per sample) No. of samples TBD: $120.00 each