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CBTL Design Case Summary Conventional Feedstock Supply System -- Woody

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2012 DESIGN CASE SUMMARY

Conventional Feedstock Supply System—Woody

A conventional woody feedstock design has been developed that represents supply system technologies, costs, and logistics that are achievable today for supplying woody biomass as a blendstock with coal for energy production. Efforts are made to identify bottlenecks and optimize the efficiency and capacities of this supply system, within the constraints and consideration of existing local feedstock supplies, equipment, and permitting requirements.

The feedstock supply system logistics operations encompass all of the activities necessary to move woody biomass from the production location to the conversion reactor ready for blending and insertion (Figure 1). This supply system includes operations that are currently available such that costs and logistics are reasonable and reliable. In fact, depending on the quality of woody material needed, a second material stream consisting of slash (the limbs and tops of trees) can be fed through the chipper to decrease total system dry matter loss, or can be discarded to remove higher ash containing bark. The system modeled for this research project includes the use of the slash stream since it is a more conservative analysis and represents the material actually used in the experimental part of the project. A schematic of the system is shown in Figure 1.

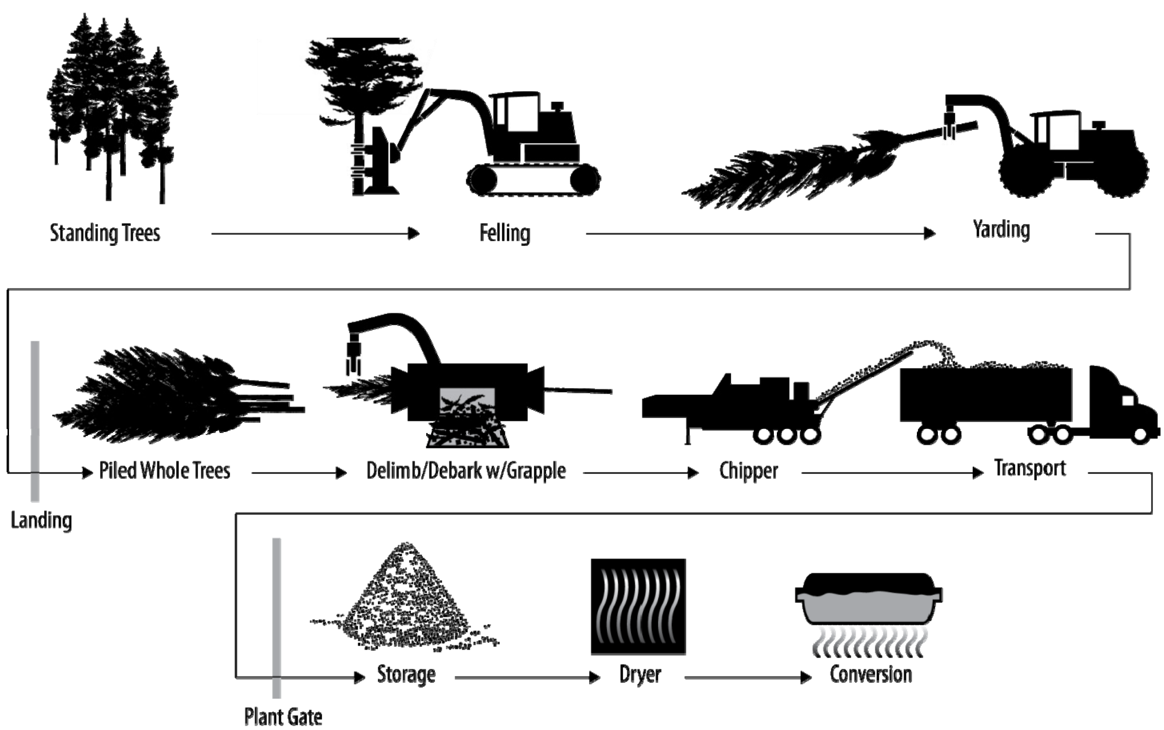

Figure 1. INL researches material properties and equipment performance from the point of harvest to infeed into the conversion reactor. The Conventional woody biomass feedstock supply system incorporates existing or near-term equipment and practices.

A baseline set of parameters have been established so that the modeled supply system design can feed conversion facilities that have similar demands as previously reported thermochemical[1] pathways (Table 1). Thus the modeled design uses transpirationally[2] dried fir and pine (Northwest US varieties) as a feedstock to supply a conversion facility that depends on a year-round biomass delivery schedule with 800,000 dry metric (DM) tons of biomass annually.

Table 1. The *Conventional woody biomass supply system scenario is scaled to support current baseline thermochemical conversion facility designs.*

	Woody Biomass
Plant Operation Size (delivered tons[a])	800,000 DM ton/yr
Feedstock Harvested Annually[b]	1,403,500 DM ton/yr
% Supply Area Under Cultivation	100
% Cropland in Supply Area Cultivated	100
% Farmer Participation	100
Acres Harvested Annually	59,095
Feedstock Supply Radius	50 miles

a. U.S. short ton = 2,000 lb.
b. Extra tonnage harvested to account for supply system losses.

In the Conventional scenario, fir and pine trees are harvested and piled in the forest. The trees are transpirationally dried prior to being moved to the landing, where they are stacked and loaded into a flail debarker to remove bark and limbs. The delimbed, debarked trees are fed into a chipper, which ejects material into a chip van for transport to the conversion facility. A second material stream is created by feeding the limbs through the chipper, which reduces dry matter losses in the system. At the conversion facility, chips are received and placed into storage. Stored chips are then queued for additional preprocessing and blending prior to insertion.

The modeled conversion size specification is a nominal particle size of 3/16-inch (based on grinder screen size). Through experimentation, this size of particles has exhibited satisfactory flow and blending characteristics necessary for a suitable blendstock with coal. Table 2 shows the mean particle size of the pine material compared with corn stover (CS) and switchgrass (SW). The mean particle size is 0.735 mm with a distribution represented in Figure 2.

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[1] Phillips S, A Aden, J Jechura, D Dayton, T Eggeman (2007) Thermochemical Ethanol via Indirect Gasification and Mixed Alcohol Synthesis of Lignocellulosic Biomass, NREL Technical Report, TP-510-41168, National Renewable Energy Laboratory, Golden, Colorado.

[2] "Transpiration" refers to natural drying as a result of water loss by evaporation in terrestrial plants

Table 2. *Particle characteristics. X_c min represents the geometric mean diameter (d_{gw}) with the geometric mean diameter standard deviation (S_{gw}) shown in parenthesis. The sphericity (SHPT) and aspect ratio are also listed, where the aspect ratio is the ratio between X_c min and X_{fe} max.*

Particle Characteristics	CS	SW	PC
X_c min (s_{gw}), mm	0.582 (0.817)	0.678 (1.122)	0.735 (0.771)
X_{fe} max (s_{gw}), mm	1.351 (2.076)	1.744 (2.857)	1.652 (1.784)
1/SPHT[b]	2.456 (0.164)	2.784 (0.052)	2.525 (0.029)
Aspect Ratio[b]	0.475 (0.007)	0.431 (0.002)	0.470 (0.002)

[a] Number enclosed in the parenthesis were standard deviation with n = 3
[b] Aspect ratio and SPHT are dimensionless parameters.

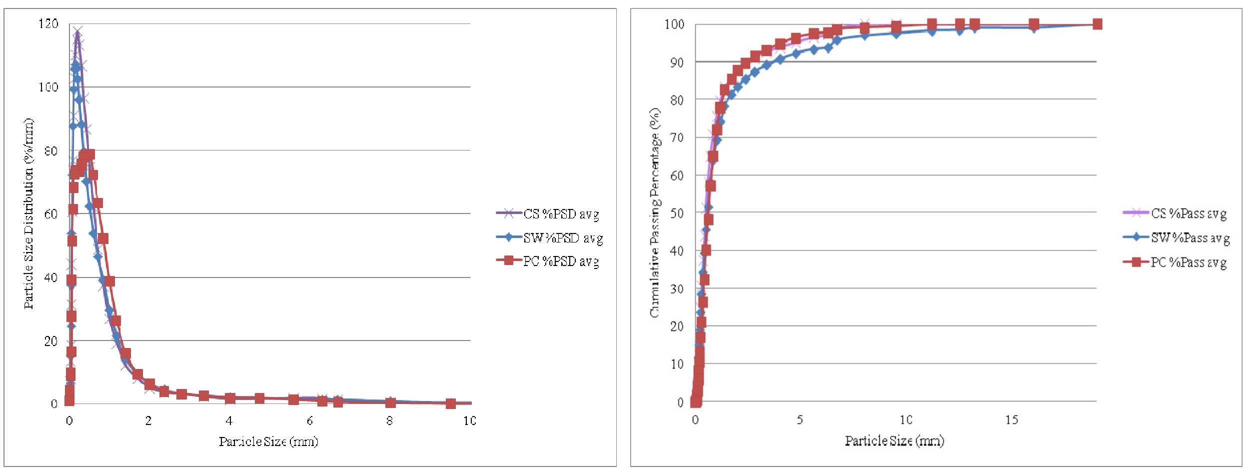

Figure 2. Particle size distribution. The derivative of the cumulative passing size distribution, %/mm, (Rhodes & Ebooks, 2008), (4a) and cumulative passing,% (4b) of nominal 3/16-inch pine grind.

Conventional Design Costs

Costs for the conventional woody biomass design used in this project were modeled using the feedstock supply system model developed at INL. A baseline scenario was established using metrics that are consistent with current thermochemical conversion pathway reports since these reports use woody biomass as the feedstock source. These costs include labor, fuel, material, and equipment (comprised of owner and operating costs) for all operations necessary to move the biomass from standing in the forest to the point of blending with other feedstock or directly feeding the conversion process. The modeled costs are shown in Table 2.

Table 2. Unit operation costs in a Conventional Feedstock Supply System (2007 USD per dry matter (DM) ton), for the scenario using mixed pine as a feedstock.*

Cost Summary in 2007 USD	
	$/DM ton
Total Feedstock Cost	**82.00**
Total Logistics Cost	**66.80**
Total Grower Payment[3]	**15.20**
Harvest & Collection	
Total Cost Contribution	19.40
Capital Cost Contribution	5.65
Operating Cost Contribution	13.75
Preprocessing	
Total Cost Contribution	12.20
Capital Cost Contribution	4.20
Operating Cost Contribution	8.00
Transportation & Handling	
Total Cost Contribution	10.50
Capital Cost Contribution	3.55
Operating Cost Contribution	6.95
Plant Receiving, Storage, Queuing, & In-Feed Processing	
Total Cost Contribution	24.70
Capital Cost Contribution	5.25
Operating Cost Contribution	19.45

* Grower payment estimates provided by Oak Ridge National Laboratory

Summary

This Conventional woody design is a baseline design for meeting the material specification targets set forth in the CBTL Project between INL and GE Global Research. This analysis reveals key parameters and unit operations that contribute to the cost of a conventional woody design. The challenges faced by this design, in terms of cost, are driven by the logistics of the system where moving large quantities of a bulky, unstable, non-flowable material is inherent. Despite these challenges, the technology exists that will allow for relatively large amounts of woody material to be harvested, collected, preprocessed, and delivered to a conversion facility as a standalone feedstock or as a blendstock for energy production.

[3] Langholtz, M., Graham, R.C., Eaton, L., Perlack, R., Hellwinckel, C., De la Torre Ugarte, D., in review. Price Projections of Feedstocks for Biofuels and Biopower in the U.S. Energy Policy.

Motivation for a Commodity-Driven System

The U.S. DOE aims to displace 30% of the 2004 gasoline use with biofuels (60 billion gal/yr) by 2030. Of those 60 billion gallons, 15 billion are projected to come from grains, and the remaining 45 billion from lignocellulosic resources. This means that of the 700 million DM tons of biomass required annually, 530 million DM tons will come from a diverse variety of herbaceous and woody lignocellulosic biomass resources (also referred to as "cellulosic" biomass). In order for the biofuels industry to be a self-sustaining enterprise, the lignocellulosic feedstock supply system logistics (all processes involved in getting the biomass from the field to the conversion facility) cannot consume more than 25% of the total cost of the biofuel production.

While national assessments[4] identify sufficient biomass resource to meet the production targets, much of that resource is inaccessible using current biomass supply systems because of unfavorable economics. Therefore, conventional biomass supply systems are incapable of meeting these long-term biomass use goals. Increasing the demand for lignocellulosic biomass introduces many logistical challenges to providing an economic, efficient, and reliable supply of quality feedstock to the biorefineries.

The design report, ***Uniform-Format Solid Feedstock Supply System: A Commodity-Scale Design to Produce an Infrastructure-Compatible Biocrude from Lignocellulosic Biomass***, documents an approach to address these logistic challenges by implementing a strategy of incremental change from existing biomass supply systems to economic and reliable commodity-scale supply systems that provide uniform, aerobically stable, quality-controlled feedstocks to biorefineries. This approach has been demonstrated and proven successful for feed grains. For woody resources, these design increments are termed "Conventional," which reflects current practice and was presented in this case study, "Pioneer Uniform," which uses current or very near-term technologies and offers incremental improvements over the Conventional Bale system, and "Advanced Uniform," which meets all cost and supply targets and requires some conceptual equipment, such as a single-pass harvester, to provide a commodity-scale bulk liquid feedstock.

The Pioneer Uniform design enables the transition from the Conventional to the Advanced Uniform supply system by developing the supply chain infrastructure required for forward-deployed preprocessing. The Advanced Uniform system brings biomass of various types (i.e., herbaceous, woody) and physical characteristics (i.e., bulk densities, moisture content) into a standardized format early in the supply chain. This uniform material format allows biomass to be handled as a commodity that can be bought and sold in a market, vastly increasing its availability to the biorefinery and enabling large-scale facilities to operate with a continuous, consistent, and economic feedstock supply. The commodity-scale system also releases biorefineries from contracting directly with local farmers for biomass feedstocks. Figure 3 shows a schematic of the end-state commodity supply system for all types of lignocellulosic biomass resources.

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4. Perlack RD, LL Wright, AF Turhollow, RL Graham, BJ Stokes, DC Erbach (2005) Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply, DOE/GO-102005-2135.

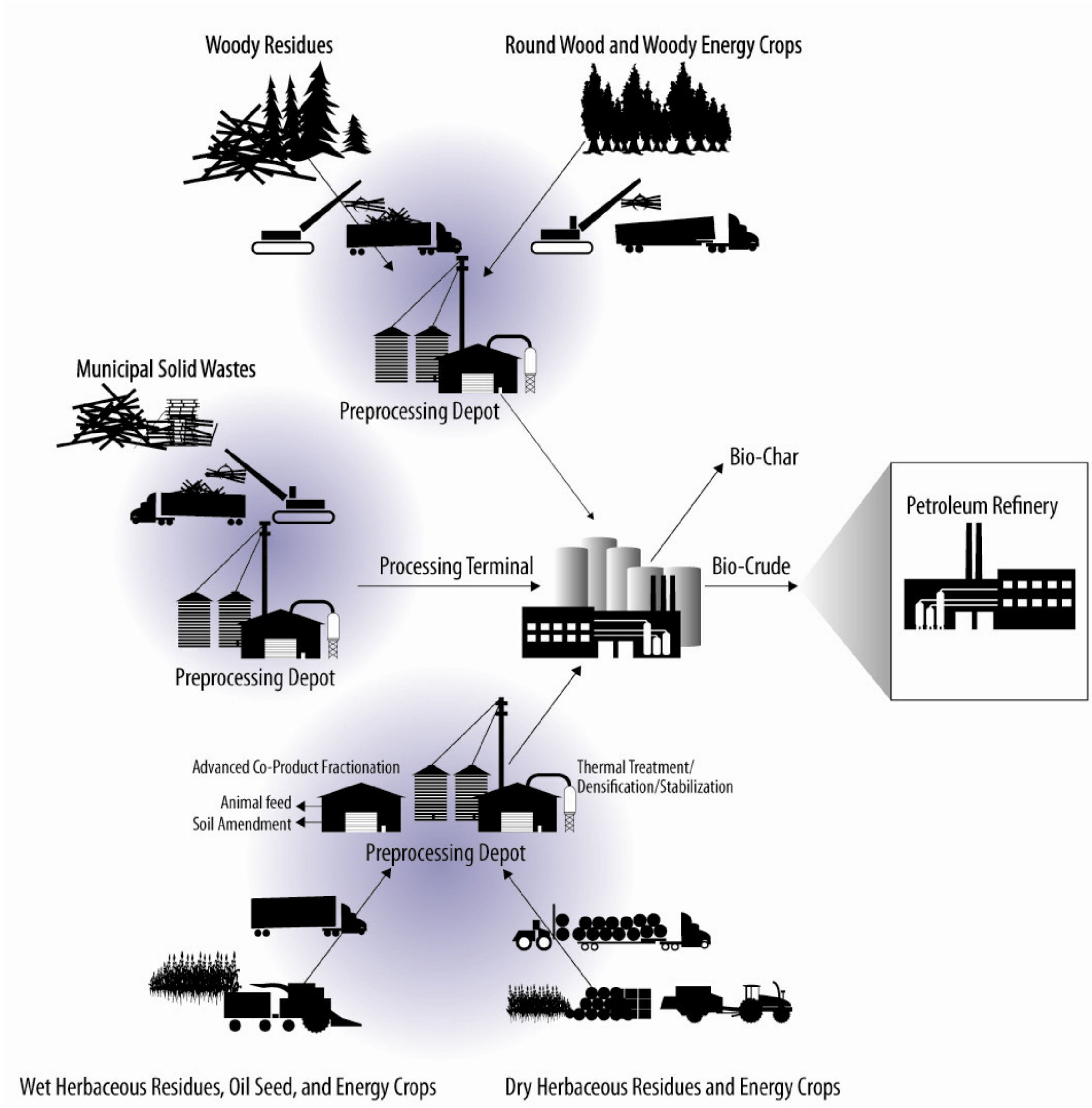

Figure 3. The Advanced Uniform-Format feedstock supply system resembles the grain commodity system, which manages crop diversity at the point of harvest and/or the storage elevator, allowing subsequent supply system infrastructure to be similar for all biomass resources.