WOODY BIOMASS FEEDSTOCK SUPPLY SYSTEM

INL/EXT-10-20073

2012 DESIGN CASE SUMMARY

Conventional Feedstock Supply System—Woody

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The full report, *Uniform-Format Solid Feedstock Supply System: A Commodity-Scale to produce an Infrastructure-Compatible Biocrude from Lignocellulosic Biomass,* is available online from Idaho National Laboratory. The report was prepared in April 2009 for the U.S. Department of Energy.

Complete report available online at www.inl.gov/bioenergy/uniform-feedstock

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2012 DESIGN CASE SUMMARY

Conventional Feedstock Supply System—Woody

INL develops design scenarios to study the material flows and associated costs in the biomass feedstock supply system. The impact of unit operations on system cost is evaluated, and the results of this evaluation direct future research efforts.

A primary objective driving the feedstock supply system designs is the selection of technologies that are adaptable to existing local feedstock resources and infrastructures.

The Conventional design represents feedstock supply system technologies, costs, and logistics that are achievable today for supplying lignocellulosic feedstocks to pioneer biorefineries. Efforts are made to identify bottlenecks and optimize the efficiency and capacities of these supply systems, within the constraints of existing local feedstock supplies, equipment, and permitting requirements.

The feedstock supply system logistics operations encompass all of the activities necessary to move lignocellulosic biomass feedstock from the production location to the conversion reactor of the biorefinery (Figure 1).

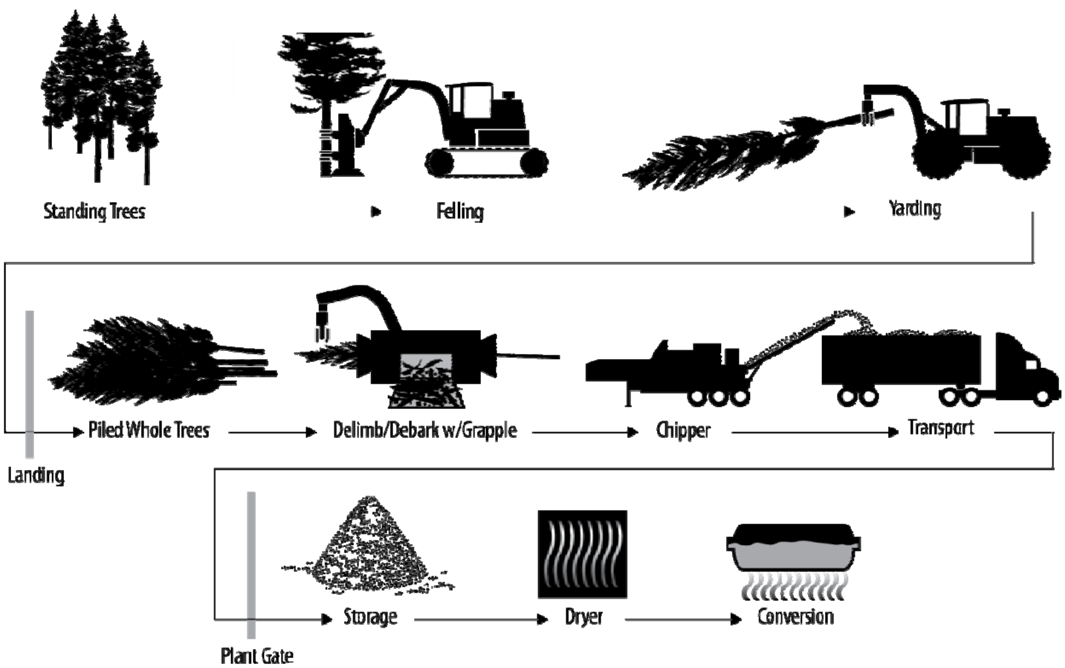

Figure 1. INL researches material properties and equipment performance from the point of harvest to infeed into the conversion reactor. The Conventional woody biomass feedstock supply system incorporates existing or near-term equipment and practices.

This Conventional feedstock supply system design scenario uses existing or near-term equipment. The modeled scenario uses transpirationally[1] dried southern pine as a feedstock to supply a biorefining facility with 800,000 DM ton of biomass annually (Table 1). This design is appropriate for both pioneer biochemical[2] and

[1] "Transpiration" refers to natural drying as a result of water loss by evaporation in terrestrial plants
[2] Aden A, M Ruth, K Ibsen, J Jechura, K Neeves, J Sheehan, B Wallace, L Montague, A Slayton, J Lukas (2002) Lignocellulosic Biomass to Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis for Corn Stover, NREL/TP-510-32438, http://www.nrel.gov/docs/fy02osti/32438.pdf

select thermochemical[3] conversion facility designs that depend on a year-round biomass delivery schedule. Although the design meets DOE cost targets, it is specific to the modeled feedstock only.

Table 1. The *Conventional woody biomass supply system scenario is scaled to support both biochemical and select 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 in Corn	100
% Farmer Participation	100
Acres Harvested Annually	59,095
Feedstock Supply Radius	5 miles

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

In the Conventional scenario, southern pine trees are harvested and piled in the forest. They are transpirationally dried prior to moving the material 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 biorefinery. At the biorefinery, chips are received and cleaned prior to storage. Stored chips are then queued for additional preprocessing, if required.

For the Conventional scenario, the modeled conversion process is gasification. Gasification requires additional drying prior to conversion infeed. Supply system costs include labor costs, fuels costs, material costs, and equipment costs (comprised of owner and operating costs) for all equipment necessary to move the biomass from standing in the field to the infeed of the conversion process.

[3] 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.

Cost Targets for the Conventional Design

Costs for the Conventional woody biomass scenario, using southern pine trees supplying a 800,000 DM ton/year biorefinery, were modeled using the feedstock supply system model Integrated Biomass Supply and Logistics Analysis – System Dynamics (IBSAL-SD). Baseline scenarios were developed for each year from 2009 through 2012 and incorporate design improvements in the system that have resulted from research efforts. The projected costs are shown in Table 2.

Table 2. Unit operation cost targets in the Conventional Feedstock Supply System through 2012 (2007 USD per DM ton), for the scenario using southern pine as a feedstock. Achieving these targets will support U.S. DOE biofuels production goals[4]. Grower payment is the cost value assigned to access a given quantity of biomass in the field.*

	Metric	2009	2010 Projected	2011 Projected	2012 Projected
	Year $ basis	2007	2007	2007	2007
Total Feedstock Cost to Gasifier	$/DM ton	$86.75	$83.20	$72.10	$62.07
Total cost of feedstock logistics to plant gate	***$/DM ton***	***$48.40***	***$46.90***	***$42.10***	***$39.10***
Capital Cost Contribution	$/DM ton	$14.00	$13.55	$13.40	$12.75
Operating Cost Contribution	$/DM ton	$34.40	$33.35	$28.70	$26.37
Total cost of feedstock handling and drying	***$/DM ton***	***$22.65***	***$20.60***	***$14.30***	***$7.25***
Capital Cost Contribution	$/DM ton	$5.45	$4.95	$4.60	$2.10
Operating Cost Contribution	$/DM ton	$17.20	$15.65	$9.70	$5.15
Total cost of grower payment **	***$/DM ton***	***$15.70***	***$15.70***	***$15.70***	***$15.70***
Harvest and Collection					
Total Cost Contribution	$/DM ton	$22.30	$21.30	$19.40	$18.75
Capital Cost Contribution	$/DM ton	$6.40	$6.00	$5.65	$5.60
Operating Cost Contribution	$/DM ton	$15.90	$15.30	$13.75	$13.15
Storage and Queuing					
Total Cost Contribution	$/DM ton	$0.00	$0.00	$0.00	$0.00
Capital Cost Contribution	$/DM ton	$0.00	$0.00	$0.00	$0.00
Operating Cost Contribution	$/DM ton	$0.00	$0.00	$0.00	$0.00
Preprocessing					
Total Cost Contribution	$/DM ton	$13.60	$13.60	$12.20	$11.42
Capital Cost Contribution	$/DM ton	$3.50	$3.50	$4.20	$4.20
Operating Cost Contribution	$/DM ton	$10.10	$10.10	$8.00	$7.22
Transportation and Handling					
Total Cost Contribution	$/DM ton	$12.50	$12.00	$10.50	$8.95
Capital Cost Contribution	$/DM ton	$4.10	$4.05	$3.55	$2.95
Operating Cost Contribution	$/DM ton	$8.40	$7.95	$6.95	$6.00
Feedstock Costs to Plant Gate					
Total Feedstock Cost	$/DM ton	$64.10	$62.60	$57.80	$54.80
Grower Payment		$15.70	$15.70	$15.70	$15.70
Logistics Capital Cost Contribution	$/DM ton	$14.00	$13.55	$13.40	$12.75
Logistics Operating Cost Contribution	$/DM ton	$34.40	$33.35	$28.70	$26.35
Feedstock Handling and Drying					
Total Cost Contribution	$/DM ton	$22.65	$20.60	$14.30	$7.25
Capital Cost Contribution	$/DM ton	$5.45	$4.95	$4.60	$2.10
Operating Cost Contribution	$/DM ton	$17.20	$15.65	$9.70	$5.15

*DM ton is dry matter ton

** Grower payment costs provided by Oak Ridge National Laboratory

[4] www.inl.gov/bioenergy/uniform-format

Conventional Feedstock Supply System—2012

As shown in Table 2, improvements in supply system design progressively reduce supply systems costs. These reductions demonstrate that the supply system can meet the U.S. Department of Energy target for 2012, which mandates a total feedstock logistics cost of no more than $35/DM ton. By the year 2017, the total amount of material required to move through the supply system to meet biofuels production targets will increase to approximately 200 million DM tons. This will require additional feedstock types to be included in the designs to respond to the increased biomass demand (Figure 2).

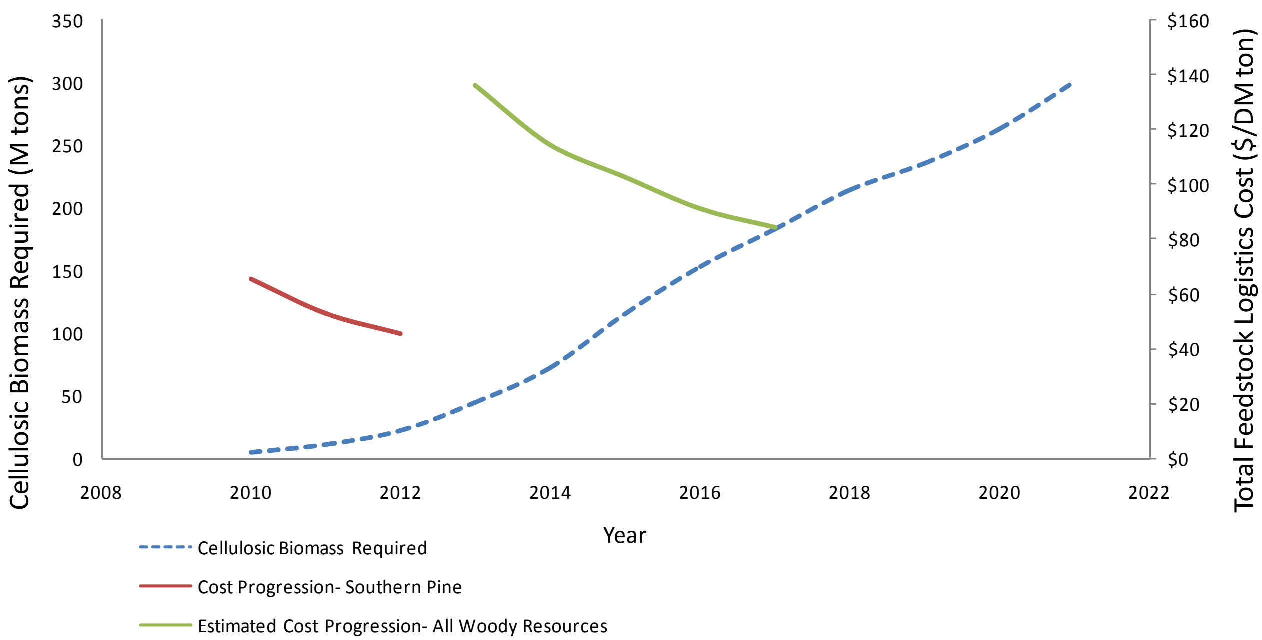

Figure 2. An increasing demand for biofuels increases the demand for biomass feedstock. This requires a diverse biomass base to ensure sustainable biomass supply. This diversity introduces many logistical challenges, including securing an economic, sustainable feedstock supply.

Cost Impact of Parameters

IBSAL-SD was used to conduct an analysis of the Conventional supply system scenario. This analysis identifies key equipment limiting the efficiency of biomass supply, and assists in focusing research dollars so as to have the highest impact on supply system economics. The bar chart shown in Figure 3 indicates that Harvest and Collection have a large impact on system costs, as does Chipping and Transportation.

Addressing the areas of highest influence shows cost reductions throughout the supply chain. For example, a decrease in moisture content during collection not only decreases collection cost, but also increases the efficiency of transportation and handling. Similarly, increasing bulk density also shows cost reductions in all of these operations.

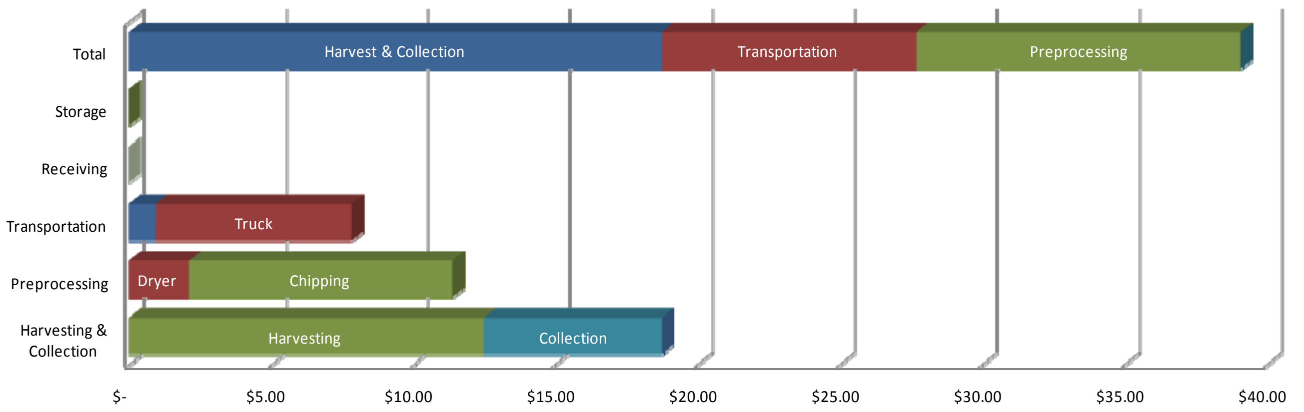

Figure 3. The total logistics cost for the Conventional biomass feedstock supply system for woody biomass is influenced by several unit operations. Each unit operation is comprised of several pieces of equipment, represented here as stacked bars. Key opportunities to reduce system costs lie in Harvest and Collection, and Preprocessing. Increasing bulk density and decreasing moisture content early in the supply chain creates savings throughout the system.

Conventional Feedstock Supply System—2012

Summary

This Conventional case study provides a baseline design for meeting the cost and quantity targets for 2012. Preliminary analyses reveal key parameters that pose challenges in meeting U.S. DOE biofuels cost targets. These challenges are inherent in moving large quantities of a bulky, unstable, non-flowable material. Figure 4 shows the progression towards meeting cost targets through to 2012, broken down into unit operations.

A summary of the research in progress and planned to achieve the cost reductions is shown in Table 3. Note that the research is focused on addressing the areas identified in the analysis (Figure 2) as having a high impact on system costs.

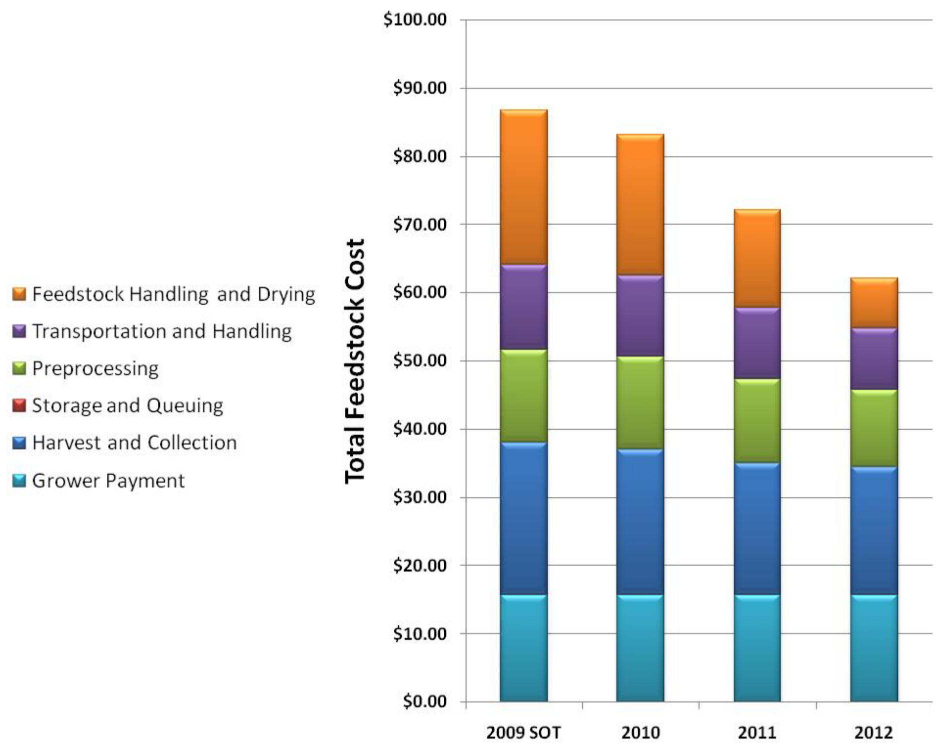

Figure 4. Through research, improvements in feedstock supply system unit operations have achieved significant cost improvements which support reaching U.S. DOE biofuels production goals.

Table 3. Long-term cost goals are met through on-going research efforts that target key, high-impact parameters including bulk density, moisture content, harvest efficiency, and grinder performance.

Material or Equipment Property Barrier	Ongoing and Planned Work to Address Barrier
Moisture content of woody biomass	Investigate effectiveness of transpirational drying to reduce (1) moisture content by at least 10%, (2) forced air ambient drying, and (3) drying during grinding
Cost of drying	Explore passing drying methods (see above); investigate potential of using waste heat to dry biomass, reducing natural gas consumption by over 20%
Ash content in woody materials	Investigate effectiveness of using pneumatics to separate fines and silt from chips during grinding; investigate effectiveness of using trammel screen to reduce ash content
Grinding cost	Explore opportunities for improvement, including using pneumatics to increase efficiency and optimizing grinder utilization through supply chain logistics
Harvest efficiency	Increase harvesting productivity by 15% using GPS on new harvest equipment
Dry matter loss during collection	Improve collection efficiency of smaller diameter trees (work done by U.S. Forest Service) through use of better piling techniques and different grapple heads to increase collection efficiency by 10%
Storage of woody biomass	Investigate self-heating during storage and potential impact on dry matter loss
Transportation and handling costs	Perform analysis of hot/cold logging to optimize costs; investigate opportunity to incorporate higher capacity chip trailers

Moving Beyond 2012

The southern pine resource modeled in this scenario meets the need of pioneer biorefineries, but moving beyond those requires additional resources, many of which come at an increased cost.

One of the principal challenges of establishing lignocellulosic biofuels as a self-sustaining enterprise is organizing the logistics of the woody biomass feedstock supply system such that it maintains the economic and ecological viability of supply system infrastructures while providing the needed quantities of resources.

The Advanced Uniform feedstock supply system is designed to be infrastructure compatible with the commodity-based grain supply system. Benefits of a commodity-based biomass supply chain include:

- *Reduces risk to biorefineries by producing a sustainable feedstock supply to biorefineries*
- *Increased availability of biomass resources*
- *Promotes crop diversification*

Infrastructure compatible with existing large capacity, efficient, proven, scalable, and economic handling and transport technologies

- *Biomass can be bought and sold on national and even international markets*
- *Prevents long-term contracting agreements*
- *Commodities are storable, transportable, and have many end uses*

The “Uniform-Format” feedstock supply system designs are based on the following assumptions:

(1) A highly efficient, large capacity, dependable feedstock supply system for bulk solid herbaceous biomass already exists with the nation’s commodity-scale grain handling and storage infrastructure.
(2) No existing supply system design for lignocellulosic biomass is capable of handling the large quantities as efficiently and reliably as the existing grain handling infrastructure.
(3) The national goal of annually supplying in excess of 700 million DM tons of biomass (530 million DM tons from a variety of lignocellulosic resources) to a bioenergy industry requires the development of harvesting and preprocessing systems that reformat lignocellulosic biomass resources into a “uniform-format” product that can be stored and handled in an expanded grain (i.e., bulk solids) commodity infrastructure.

This requires a strategy of progression from a variety of conventional SOT woody biomass supply systems to a commodity-scale, uniform-format supply system. The “Uniform-Format” Vision adapts supply systems incrementally as the industry launches and matures, providing progressive feedstock supply system designs that couple to and build from current systems and address science and engineering constraints that have been identified by rigorous sensitivity analyses as having the greatest impact on feedstock supply system efficiencies and costs.

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[5] 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

5. 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.

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., corn stover, 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 4 shows a schematic of the end-state commodity supply system for all types of lignocellulosic biomass resources.

Biomass commodities are storable, transportable, and have many end uses. Implementing a commodity-based feedstock supply system promotes cropping options beyond local markets, which in turn promotes crop diversity and enhances crop rotation practices.

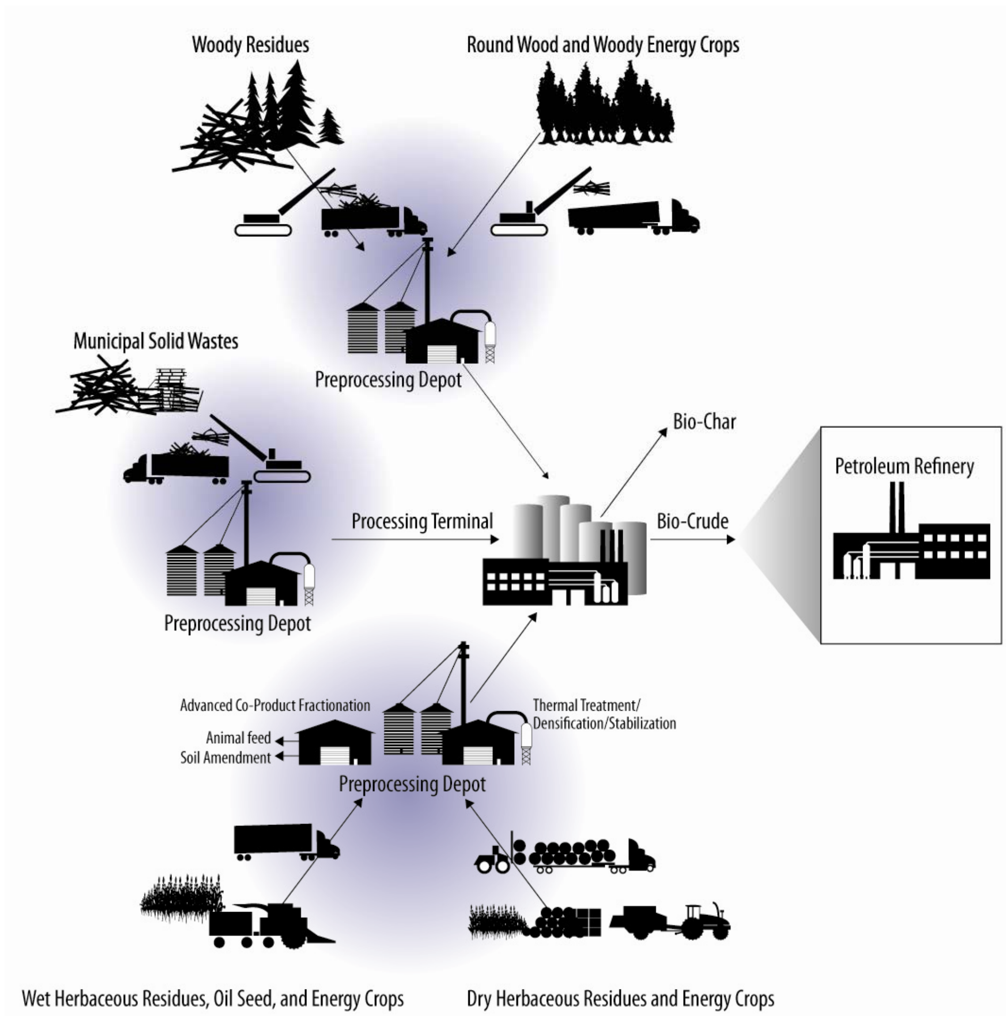

Figure 5. The Advanced Uniform-Format feedstock supply system resembles the grain commodity system, which manages crop diversity at the point of harvest and/or the storage elevator, allowing subsequent supply system infrastructure to be similar for all biomass resources.

Full report, *Uniform-Format Solid Feedstock Supply System: A Commodity-Scale to produce an Infrastructure-Compatible Biocrude from Lignocellulosic Biomass,* is available online at

www.inl.gov/bioenergy/uniform-feedstock

On-going research at Idaho National Laboratory (INL) identifies and addresses barriers to an economic and efficient supply of quality feedstocks to biorefineries for the production of biofuels.