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SIMULATION AS A TOOL FOR EVALUATING BIOENERGY FEEDSTOCK SUPPLY CHAINS

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ABSTRACT

Biomass is a renewable feedstock for production of biofuels, bioproducts and biopower. Securing and maintaining a reliable year-round supply of biomass that meets quality specifications at a reasonable cost is a significant barrier for conversion facilities. Simulation tools to evaluate equipment design and operational parameters aid in identifying and prioritizing R&D needs, determining required resources, and estimating costs. The Integrated Biomass Supply Analysis and Logistics (IBSAL) decision support system, developed at Oak Ridge National Laboratory for the Department of Energy, is a dynamic, discrete-event framework written in ExtendSim. IBSAL simulations were successfully used to evaluate the impact of advanced technologies demonstrated by FDC Enterprises and their project partners on reducing the delivered cost of corn stover as a bioenergy feedstock.

1 IBSAL MODEL DESCRIPTION

Biomass, plant material such as grasses, wood chips, and agricultural residues, is a renewable feedstock for the production of biofuels, bioproducts and biopower. Securing and maintaining a reliable year-round supply of biomass that meets quality specifications at a reasonable cost has become one of the most significant obstacles for conversion facilities. The risks of process disruptions due to the lack of affordable regional feedstock supplies and reductions in conversion efficiency due to off-spec biomass are barriers for new facility investment and operation. Building a commercial-scale industry capable of achieving U.S. cost and volume targets for bioenergy will require careful consideration of the complex interactions of feedstock supply chain operations. To produce fuels, products, and power from cellulosic biomass at as low a cost as possible, improved feedstock supply chains are needed to increase system efficiencies and capacities, preserve or enhance quality, and minimize risk of supply disruption and cost fluctuations.

Though field demonstrations are the best way to study equipment and process development, they are very expensive and resource intensive. As an alternative, simulation tools to evaluate the impacts of equipment design and system operational parameters are useful in identifying and prioritizing R&D needs, determining required resources, and estimating costs of commercial-scale systems. Specifically, simulations are needed for assessing the impacts of moisture content, bulk density, losses during storage, feedstock diversity, transportation distances, and quality improvement technologies. In our research, simulation models are also used to evaluate the effects of variability in operating conditions and feedstock characteristics on system design and operating decisions. The primary metric for evaluating system performance is the cost of feedstocks delivered to a conversion facility.

The Integrated Biomass Supply Analysis and Logistics (IBSAL) decision support system is a dynamic, discrete-event framework developed at ORNL for simulating biomass supply chains (Sokhansanj, Wilkerson, and Turhollow 2008). IBSAL is supported by the Department of Energy (DOE) Bioenergy Technologies (BETO) for the purposes of prioritizing R&D efforts to de-risk the development of commercial bioenergy industries and demonstrating the impacts of lab and field demonstrations in the larger supply chain. Our simulations assist national lab, academic, and industry researchers understand how individual technologies interact with other supply chain components and the impact of these interactions on cost. Such analysis avoids the system inefficiencies that can occur when component technologies are blindly selected without consideration of how they impact or are affected by other supply chain design decisions.

IBSAL simulations, written in ExtendSim (www.imaginethatinc.com), mathematically describe continuous processes such as field drying (e.g., switchgrass or stover left to dry in a windrow on the field after cutting), wetting, and dry matter loss (e.g., biological degradation during storage or material lost during handling). The events are operations such as baling, loading, transporting, stacking, grinding, and storing. The model interacts with an external Excel spreadsheet used to estimate the hourly cost to operate machinery, input data, and output data. The model estimates the costs, energy usage, labor and machinery requirements, and biomass dry matter losses for harvest, transport, storage, and preprocessing (size reduction, densification, etc.). The IBSAL model has been used for a variety of feedstocks including switchgrass (Sokhansanj et al. 2009), corn stover (Sokhansanj et al. 2010), wheat straw (Ebadian et al. 2011), and wood (Mahmoudi, Sowlati, and Sokhansanj 2009). Goals for current and future development of IBSAL include: incorporating algorithms for blending biomass feedstocks, simulation of operations within preprocessing depots, simulation of algae oil and biomass supply chains, and linking IBSAL simulations with spatial optimization analysis for siting biomass facilities.

2 IBSAL SIMULATION CASE STUDY

The IBSAL model was successfully used to quantify the cost savings that could be realized in a commercial-scale corn stover supply system by implementing new technologies developed and demonstrated as part of a DOE-funded demonstration project led by FDC Enterprises (FDCE) and managed by the Antares Group. In the FDCE project, field trials to assess the performance of a self-propelled high-density baler with front-mounted rake, high-capacity bale pick-up truck, and self-loading/unloading trailer were conducted. Machine performance and cost data from these field trials were used in an IBSAL simulation to show that the FDCE system could deliver corn stover to a biorefinery at a cost of $12.89/dry ton or 25% lower than a conventional system using currently available equipment.

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