Re-imagining Biomass Supply Chains for Food, Fuel, and Rural Prosperity

Tom Richard, Penn State University

What are the Carbon and Greenhouse Gas issues for Feedstock Logistics?

There are two important ways that feedstock logistics can have significant impacts on carbon and greenhouse gas emissions associated with biofuels. The most obvious is the emissions associated with energy use in the feedstock supply chain for materials handling, processing, and transport. But there is another factor, biomass preservation, that is equally critical but often overlooked. Depending on the selected harvest and storage strategy, biomass losses can range from less than 5% to over 25%. The higher range of losses, usually associated with dry storage of bales that did not stay dry, is a serious risk in most areas where rainfall is sufficient for substantial biomass growth. This dry matter is primarily lost as CO_2 via aerobic biodegradation, but if bales are saturated it could also include CH_4, with a much greater global warming impact. This loss represents an emission in and of itself, but also a waste of all the fossil fuel that had been used to grow, harvest, and store the lost fraction of that particular crop. Thus effective storage, with minimal dry matter losses, is critical to staying on the path to a low carbon fuel.

Most life-cycle analysis primarily uses fuel consumption to estimate the energy and associated greenhouse gas impacts associated with the feedstock supply chain. Depending on the feedstock, transport distances, and methods, often 20% to 30% of the total energy associated with biofuel production is consumed in these operations. The largest component of that logistics contribution is on-farm fuel consumption for planting, and especially harvest of the crop. Transportation of the feedstock is second, where distance and efficient hauling strategies play a critical role. Intermediate processing, such as drying and densification, is also significant in some situations, while transport of crop inputs like fertilizers will usually play a minor role.

There have been a number of strategies developed to reduce harvest and transport energy costs. Minimizing handling operations can save both money and energy, and should be considered both an economic and environmental goal. For crop residues and grasses, the single pass harvest strategies pioneered by Kevin Shinners at the University of Wisconsin and others can reduce the number of handling operations significantly. Similarly, the work of Richard Hess and colleagues at the Idaho National Lab has demonstrated that there are significant benefits to reducing energy requirements in the transportation system. There are also synergies in integrating these systems, as Jude Liu at Penn State has demonstrated by efficiently coupling harvest with transport of wet biomass, using a self-compacting forage wagon that is very effective for short to moderate hauling distances. And, as John Cundiff will share, creative thinking about centralized vs. decentralized systems and satellite processing often makes sense.

While many different supply chain models will be evaluated in the coming years, the principles of 1) minimizing dry matter loss, 2) reducing materials handling operations, and 3) using efficient transportation modalities, will continue to make good economic as well as environmental sense.

How does Feedstock Logistics play into the land issue debate?

Concerns about indirect land use are based on the premise that production of biomass feedstocks reduces the supply of food and feed from existing agricultural lands. While we could have a vigorous debate about the merits of different approaches to determining whether, how much, and what kind of land elsewhere may fill that void, I suggest we start from a different premise. What if we designed agricultural ecosystems that were vastly more productive than the ones we have today, and that integrated energy crops with food and feed crops in synergistic ways? For over half a century the problem of agriculture in North America and the other functional breadbaskets of the world has been overproduction. As a result, we have developed systems that focus on a few subsidized commodity crops, with few incentives to diversify and "ecologically intensify" production. Biofuel feedstocks present a host of opportunities to conserve soil and nutrients by integrating perennials on steep slopes and streamside buffers throughout our working landscapes, to increase biodiversity by interjecting cover crops and perennials into annual crop rotations, and to compensate the soil for above-ground biomass removal with even greater biomass root production. This is a new model for agricultural intensification… with both biomass and enhanced ecosystem services as the result.

Cropping systems scientists are developing such rotations in many regions of the U.S., but thus far there has been little interaction with the feedstock logistics specialists. Yet many of the most important challenges to ecological intensification require new logistics strategies. Harvesting equipment must be able to traverse steep slopes and wet floodplains safely and without degrading the soil. To maximize year-round soil coverage in annual systems, we need to seed cover crops before the summer crop is harvested, and then find ways to harvest that crop and its residues without destroying the seedlings coming up. We need adjustable harvest equipment that can vary the amount of residue collected based on real-time measurements of crop yield and the characteristics of the soil. Finally, can we develop uniform feedstock platforms that can handle diverse feedstocks harvested from a diversified landscape in an efficient, cost-effective way? Clearly we can and we must.

What are specific issues in Feedstock Logistics for oilseeds, starches, sugars, or woody cellulosics, and for herbaceous cellulosics

Many first-generation biofuel feedstocks, including oilseeds and starches, benefit from a mature, well developed supply chain where most of the logistics issues were long ago worked out. However, the emergence of single-pass harvest systems may change these supply chains in ways that are difficult to predict. While current configurations assume the seeds and residues will leave the field separately, there are advantages to equalizing the packing density in transport by collecting them separately and moving the combine operation to a satellite facility. For sugar crops like cane and beets (and associated starches in root crops) long-term storage is a critical need. Sugar beets have a short harvest window in much of the U.S., resulting in processing campaigns of a just a few weeks or months before the feedstock spoils. Sugar cane is even more perishable. Brazil stretches its sugar cane harvest for 8 months, but closes its sugar/ethanol factories every day it rains since they can't get cane from the fields.

Woody and herbaceous cellulosic feedstocks offer a whole new suite of challenges. For woody feedstocks, tradeoffs of manual vs. mechanical harvest, what to leave and what to take, and emerging markets for slash, small diameter, and low use wood create openings for significant changes in the way forest lands are managed. Short rotation woody crops like poplar and high-yield herbaceous feedstocks like miscanthus will require heavy duty equipment for harvest and transport. And storage will be an issue for these crops as well. Wet storage or dry? Chopped to what size? Will we recover nutrients and protein for livestock feed or fertilizer, and if so, how? Where? The answers to these questions will emerge over time, and will likely depend on the feedstocks, the processing facilities, and the incentives that are in place. Stay tuned!