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Cellulosic Biofuel: The Importance of Managing Biomass Supply Chain

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Massive availability of agricultural waste, left unutilized in the field, and its potential to be converted to environmentally friendly biofuel has led to an increasing attention towards the advancement of cellulosic biofuel. Some studies have shown that the U.S. alone produces over 1 billion dry tonnes of terrestrial biomass annually that can be converted to biofuel without affecting food sources (unlike corn or sugarcane ethanol).

Cellulosic biofuel sector has immense potential, and advancements have been made in biotechnology that have significantly reduced the conversion cost of biomass to biofuel. However, despite decades of advancement, biomass supply chain challenges continue to be a major hurdle in the advancement of the industry. In the present context, biomass cost of feedstock delivered to biorefinery is around 70 percent of the cellulosic ethanol price.

Biomass Supply Chain Challenges

A corn stover-based 30 million gallon per year cellulosic biorefinery plant in U.S. Corn Belt requires more than 400 thousand metric tons (i.e., 450 thousand tons) of corn stover biomass. That amount is equivalent to around one million large rectangular bales (4-ft wide x 3-ft high x 8-ft long). To supply that quantity of bales to the biorefinery gate, feedstock supply chain, on average, requires around 150 windrowers, 135 balers, 55 stackers, 85 trucks and 55 loaders for feedstock transportation from field to storage, and additional 25 trucks and 10 loaders for feedstock transportation from storage to biorefinery. Execution of different activities for such a complex supply chain, requires around 250 thousand hours equivalent of labor and more than 4 million liters (i.e., more than 1 million gallongs) of diesel fuel each year. To put those numbers into perspective, fully achieving the U.S. cellulosic biofuels production target of 16 billion gal/year by 2022 set by the revised renewable fuel standard authorized under the Energy Independence and Security Act (2007) will require more than 500 of such biorefineries.

In addition to the logistics complexities, research by Golecha and Gan have shown that corn stover supply has 20 percent to 30 percent year to year supply variations due to variations in corn yield. Those study findings are eye-opening because the massive variations in supply pose a significant threat to consistent

biomass supply to biorefinery, exposing the cellulosic biofuel companies to massive financial risks due to biomass supply shortages.

Beside the above challenges, biomass supply chains have myriad numerous trade-offs, that all need to be considered in optimizing a value chain. Among different corn stover feedstock supply chain systems parameters, bale density and length, harvest rate, baler field efficiency and fuel consumption, dry matter loss, quantity of nitrogen removed from the field during stover collection, and harvest window are identified to be the most sensitive parameters with regards to influencing the overall cost, energy use and greenhouse gas emissions for biorefinery gate delivered feedstock.

Recent Advancements in Biomass Supply Chain Management

Recent studies by Golecha and Gan have provided strategies for mitigating the effect of biomass supply risks through use of a Derisked Supply Market Structure. Using Game Theoretic Analysis, their study finds that in the early stages of development it would be optimal for cellulosic biorefineries to set up long-term supply market arrangements with farmers based on a lower-than-average yield density of crop. Further, their studies have found that effectively managing trade-offs between farmer incentives, biomass transport and market structures can reduce biomass cost significantly. Those advancements are in the development of biomass supply chains. The market strategies provided by Golecha et al., combined with advancements in biomass storage and torrefaction could be the path forward to mitigate the risks with biomass supply chain and moving the industry forward.

In terms of logistics, our recent study shows that the following approaches are needed. First, a strategy is necessary to reduce the overall stover collection area. That reduction can be achieved by increasing the producers' participation in harvesting stover for biorefinery purposes or increasing the harvest rate of stover from the fields. Reducing dry matter loss is important to be able to reduce the collection area. Increasing producers' participation and harvest rate reduces the overall stover supply area due to the availability of higher quantities of corn stover in the vicinity of the biorefinery plant.

Second, it is necessary to reduce the overall bale supply quantity (volume) by increasing the bale density. Implementation of this strategy has the largest influence in the transportation activities at the two ends of the supply chain.

Third, it is necessary to reduce the quantities of in-field farm machineries required for different field operations. That reduction can be achieved either by increasing the efficiencies of the farm machineries or by widening the working durations of the field operations. In contrast to the former two strategies, this strategy affects their respective operations. Adjusting working durations depends on weather and other externalities; however, efficiencies can be improved with better management practices.

Conclusion

Considering the effect biomass supply cost has on the overall cost of cellulosic biofuel production, and the effect biomass supply chains could have on financial risk exposure of biorefineries, it is critical that serious consideration be given to development of biomass supply chain.

Therefore, it is extremely important that both the industry and academia put together a collaborative effort to mitigate this major challenge. Otherwise, supplying feedstock for biorefinery can be a major limiting factor for the successful commercial deployment of cellulosic biofuels industry.
Lead image: Supply Chain words under a magnifying glass. Credit: Shutterstock.

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