The Economics of Crop Residues: Corn Stover

Transition to a Bioeconomy: The Role of Extension in Energy

June 30 – July 1, 2009

Little Rock, AR

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Biomass / Crop Residue

- Biomass
  - Any plant or plant-derived material
    - Includes anything from corn stover, forest residue, animal manure, urban waste, to "energy crops" like switchgrass and giant miscanthus
- Crop Residue
  - Biomass resulting as a "by-product" or crop production
- Corn Stover
  - Cobs, stalks, and leaves
  - U.S. produces 75 million dry tons annually
    - By comparison, the next most abundant source is manure (35 million dry tons annually)

Corn Stover

- Land Footprint
  - Corn stover to grain ratio is 1:1
    - 56 lbs of stover produced for every bushel of grain produced (assumes 15% moisture)
    - Thus, stover production estimates usually based on grain output

Stover Yields at various corn yields

Corn Yield (bu/ac)	**125**	**150**	**175**
Stover Yield (dry tons/ac)	2.9	3.5	4.1
Harvestable Stover (dry tons/ac)*	1.0	1.2	1.4

* Assuming 34% harvest efficiency

Conversion to Ethanol

- Maximum Theoretical Yield
  - 113 gallons / dry ton of corn stover
  - Note well that this is *maximum* and *theoretical*
- 2002 study by DOE
  - Assumed 89.7 gal / dry ton (79% of MTY)
- Several other studies assume 70 gal / dry ton (62% of MTY)
- Conversion technology not yet commercially viable
  - High-cost enzymes

Harvest

- Harvest can be accomplishing using existing farm equipment
  - Tractor w/ baler, bale mover,
  - also rake, stalk shredder
- Harvest limited to about a 3-week window following grain harvest (may be longer depending on fall weather conditions)
  - Equipment may be tied up in grain harvest activities
  - Additional equipment likely needed to accommodate harvest in short window
  - Creates need for long-term storage

Storage

- Storage site needs
  - good drainage
  - Concrete or gravel surface
  - Could require covered/indoor storage if bales not wrapped in plastic

Ethanol (MM gal/yr)	**25**	**50**	**100**
Storage acreage req'd	238	476	952
# 10-ac storage sites	24	48	96
# of days supply per site	15	7	4

Stover Densification

- Potential to signif. reduce transportation and storage costs, improve material handling processing
- However, assuming densifying takes place at storage site (i.e., not on-farm):
  - Stover must be hauled to storage site as bales
    - No transport cost savings for this segment
  - Bales would arrive at site at rate exceeding densification
    - Would need to be stored as bales, mitigating much of potential for storage cost savings
  - Densification would improve transport efficiency to conversion facility for round bales (bulky), but not necessarily for square bales
  - Densification process not free (~$23 / dry ton)
    - Cost savings may not outweigh cost addition

Cost of production

- Cost of stover delivered
  - $76-90 per dry ton
- Assuming 70 gal / dry ton conversion rate:
  - Feedstock harvest, storage, and delivery account for
    - $1.09- - $1.29 / gallon ethanol produced
  - Sensitivity analysis indicates cost to be most sensitive to assumptions on :
    - Bale-moisture content
    - Harvest efficiency
    - Producer participation rate (ability to harvest from a given farm/field)

Environmental Impact

- Carbon sequestration
  - I don’t see a lot of difference here, but if a gallon of residue-based fuel implies a gallon reduction of fossil-based fuel, then there is potential for carbon reductions
- Erosion
  - Stover historically left in field as cover to reduce erosion
    - If harvested in excess of recommended levels
      - Could produce erosion problems in steeply-sloped fields
- Nutrients removed per ton stover
  - 6 lbs phosphate
  - 33 lbs potash

Potential of other crops

- Sorghum and Wheat
- Comparison with corn stover on potential for ethanol production
- Ethanol: carbohydrates (starch, sugar, cellulose, hemicellulose)
- Steam/Electricity: lignin

Comparison of corn stover to other residue feedstocks of interest.

	Residue/Crop Ratio	*Dry Matter (%)*	*Carbohydrates (%)*	*Lignin (%)*	*Ethanol Yield (gal/dry ton)*
Corn stover	**1.0**	**79**	**58**	**19**	**69.5**
Sorghum straw	1.3	88	61	15	64.7
Wheat straw	1.3	90	54	16	69.5

Web links and key references

- ***Useful web links for further information:***
  - Department of Energy's Biomass Program – Information Resources, *http://www1.eere.energy.gov/biomass/information_resources.html*
  - Biomass Feedstock Composition and Property Database, *http://www1.eere.energy.gov/biomass/information_resources.html*

- ***Key References:***

  - Eidman, V., D. Petrolia, L. Pham, H. Huang, and S. Ramaswamy. 2009. "The Economic Feasibility of Producing Ethanol from Corn Stover and Hardwood in Minnesota." Applied Economics Staff Paper P09-3, Univ. of Minnesota. *http://ageconsearch.umn.edu/bitstream/47055/2/p09-03.pdf*
  - Kim, S. and B.E. Dale. 2004. "Global potential bioethanol production from wasted crops and crop residues." *Biomass & Bioenergy* 26:361-75.
  - Petrolia, D.R. 2008a. "The Economics of Harvesting and Transporting Corn Stover for Conversion to Fuel Ethanol: A Case Study for Minnesota." *Biomass & Bioenergy* 32:603-12.
  - Petrolia, D.R. 2008b. "An Analysis of the Relationship between Demand for Corn Stover as an Ethanol Feedstock and Soil Erosion." *Review of Agricultural Economics* 30:677-91.

Questions or Comments

- Thank you for your time

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