The Economics of Crop Residues: Corn Stover

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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

<table>
<thead>
<tr>
<th>Stover Yields at various corn yields</th>
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<tbody>
<tr>
<td>Corn Yield (bu/ac)</td>
</tr>
<tr>
<td>Stover Yield (dry tons/ac)</td>
</tr>
<tr>
<td>Harvestable Stover (dry tons/ac)*</td>
</tr>
</tbody>
</table>

* 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

<table>
<thead>
<tr>
<th>Ethanol (MM gal/yr)</th>
<th>25</th>
<th>50</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage acreage req’d</td>
<td>238</td>
<td>476</td>
<td>952</td>
</tr>
<tr>
<td># 10-ac storage sites</td>
<td>24</td>
<td>48</td>
<td>96</td>
</tr>
<tr>
<td># of days supply per site</td>
<td>15</td>
<td>7</td>
<td>4</td>
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</tbody>
</table>
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:**
  - Biomass Feedstock Composition and Property Database, [http://www1.eere.energy.gov/biomass/information_resources.html](http://www1.eere.energy.gov/biomass/information_resources.html)

- **Key References:**


Questions or Comments

- Thank you for your time