Feedstock Logistics

Michael Bomford
Ken Bates
Sustainable feedstock logistics

• Energy
  – Supply system must consume (much) less energy than biomass contains
  – Ideal: Supply system runs on renewables

• Greenhouse gas
  – Production, conversion and use must contribute less GHG than comparable fossil fuels
  – Advanced biofuel requirement: 50% less GHG

• Other environmental impacts
  – Land and environment must be maintained or improved

• Economics
  – Financially self-sustained
Feedstock yield impacts

Higher yield benefits
• Less land required
• Reduced transport distance and cost
• Economies of scale

Higher yield drawbacks
• High input use
• Reduced soil fertility, organic matter
• Erosion

• Higher yields are not necessarily more sustainable
• Assumptions of higher yields are not necessarily realized
• Life cycle impact depends on production, logistics, and conversion as unified whole, not separate elements
Perennial grass crops

Hay

\[ y = -0.0005x^2 + 1.9008x - 1897.7 \]

\[ R^2 = 0.9327 \]

Sugarcane

\[ y = -0.0019x^2 + 7.554x - 7307.6 \]

\[ R^2 = 0.475 \]
Total Energy Consumed in US Farms in 2002
Total = 1.7 Quadrillion BTUs

- Fertilizers: 28%
- Diesel: 27%
- Electricity: 21%
- Natural Gas: 4%
- Gasoline: 9%
- Pesticides: 6%
- LP Gas: 5%

John Miranowski, Iowa State University
“Because of its reduced energy inputs, organic agriculture is the ideal production method for biofuels.

[...] As the aim of biofuels is to reduce dependency on non-renewable energy sources and to mitigate environmental damage of fossil fuel emissions, organic production of biofuels furthers these goals in a way that conventional agriculture does not.”
Small, organic, sustainable

- Smaller farms tend to use land more efficiently
- Organic farms tend to use energy more efficiently
  - Synthetic fertilizers and pesticides can account for 30-50% of energy involved in grain production
- Need alternative feedstock crops
  - Compatible with small farms, organic farms, southern farms
  - Higher ethanol yield than corn
  - Compatible with decentralized processing
  - Low input
Governor’s plan: 2025

1 TWh of clean electricity
- 40% woody biomass, mostly co-firing with coal

775 million gallons of renewable transportation fuel
- Corn starch for 1st generation ethanol
- Switchgrass and crop residues for 2nd generation ethanol
- Canola for biodiesel
Governor’s vision: Crop shift

- Less
  - Hay
  - Soybean
  - Winter wheat

- More
  - Switchgrass
  - Corn
  - Canola

![Crop Shift Graph](chart.png)

- 2007 vs 2025:
  - Winter wheat
  - Soybean
  - Canola
  - Corn
  - Switchgrass
  - Hay

![Million Acres Chart](chart2.png)
Biomass taskforce goal, 2025

<table>
<thead>
<tr>
<th></th>
<th>Electricity</th>
<th>Liquid fuel</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass (million dry tons)</td>
<td>15</td>
<td>10</td>
<td>25</td>
</tr>
<tr>
<td>Type</td>
<td>Woody</td>
<td>Grasses/oilseeds</td>
<td></td>
</tr>
<tr>
<td>Area needed (million acres)</td>
<td>&gt;3</td>
<td>&gt;1.5</td>
<td></td>
</tr>
<tr>
<td>Area needed (proportion)</td>
<td>&gt;22% of forest</td>
<td>&gt;16% of fields</td>
<td>&gt;17%</td>
</tr>
<tr>
<td>Conversion</td>
<td>Co-firing</td>
<td>Alcohol, biodiesel</td>
<td></td>
</tr>
<tr>
<td>Product</td>
<td>23 TWh</td>
<td>775 million gallons</td>
<td></td>
</tr>
<tr>
<td>Energy (quadrillion BTU)</td>
<td>0.25 (consumed), 0.08 (available)</td>
<td>0.06</td>
<td>0.31</td>
</tr>
<tr>
<td>Fossil fuel displaced</td>
<td>25% of coal</td>
<td>8% of petroleum</td>
<td></td>
</tr>
<tr>
<td>Proportion of current energy</td>
<td>12%</td>
<td>3%</td>
<td>15%</td>
</tr>
<tr>
<td>Fossil inputs</td>
<td>~20%</td>
<td>25-75%</td>
<td></td>
</tr>
<tr>
<td>Renewable contribution</td>
<td>10%</td>
<td>2%</td>
<td>12%</td>
</tr>
</tbody>
</table>
KY Energy Consumption, 1960-2025

1960-2007 data from DOE-EIA, 2008

"Business as usual" from 2008
KY energy plan = +40%
Continuation of ‘96-’07 linear trend = +15%
Continuation of ‘96-’07 quadratic trend = -25%
Peak oil, carbon tax, continued volatility & rising energy prices = -40%?
US Energy Consumption, 1950-2025

1950-2006 data from DOE-EIA, 2008
Land use efficiency

Fossil energy replaced (GJ/ha)

- Heat
- Electricity (gasification)
- Combined heat and power
- Ethanol
- Methanol

Herbaceous biomass

• Corn stover, switchgrass
• Bale system
  – Preferable for centralized processing
  – In-field drying and storage; haul later
• Forage system
  – Coupled harvest and hauling
  – Expensive drying, or use wet biomass
  – Practical for highly decentralized processing (sweet sorghum?)
Different harvest windows

- **Canola**
  - Short spring harvest window determined by seed moisture content
  - Stores well

- **Sweet sorghum**
  - August-October (frost sensitive)
  - Does not store well

- **Corn**
  - August-November
  - In-field drying saves energy; lose grain with excessive delay

- **Switchgrass, mixed prairie grasses**
  - August-March

- **Woody biomass**
  - Year-round
  - Dry or frozen soil best
Woody Biomass to Energy

1. Forest
   - Raw material
     - Grind/Chip

2. Transport
   - Truck

3. Terminal
   - Dry
     - Store
       - Grind/Chip/Pellet

4. Transport
   - Truck
   - Rail
     - Barge

5. Energy Conversion
   - Home heat
     - Industrial Combustion (e.g. co-firing)
     - Gasification
       - Ethanol
Herbaceous Biomass to Energy

- **Field**: Harvest, Bale, Dry, Store
- **Transport**: Truck
- **Terminal**: Dry, Store
- **Transport**: Truck, Rail, Barge
- **Energy Conversion**: Home heat, Industrial Combustion (e.g. co-firing), Gasification, Ethanol
Business models

• Decentralized terminals
  – Concentrate biomass before hauling
  – Storage, blending, consolidation, chipping, pelletizing, other pre-processing
  – Contract with energy plant

• Hauling method
  – Trucking cost: 20-60¢ per dry ton mile
  – Train is 90% less expensive than truck (>6¢)
  – Barge is 66% less expensive than train (>2¢)

• Loading and unloading costs independent of distance
## Moving Woody Biomass vs. Coal

<table>
<thead>
<tr>
<th>Woody biomass</th>
<th>Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.5 million BTU/ton</td>
<td>21 million BTU/ton</td>
</tr>
<tr>
<td>23 lbs/cubic foot (pulpwood)</td>
<td>50 lbs/cubic foot</td>
</tr>
<tr>
<td>14 lbs/cubic foot (chips)</td>
<td></td>
</tr>
<tr>
<td>6 lbs/cubic foot (logging residue)</td>
<td></td>
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</tbody>
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Replacing each truckload of coal will require five truckloads of woodchips.

Replacing 25% of coal with biomass will double traffic to power plant.
<table>
<thead>
<tr>
<th>Barge</th>
<th>Hopper car</th>
<th>Semi</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,500 ton</td>
<td>100 ton</td>
<td>26 ton</td>
</tr>
<tr>
<td>52,500 bu</td>
<td>3,500 bu</td>
<td>910 bu</td>
</tr>
<tr>
<td>453,600 gal</td>
<td>30,240 gal</td>
<td>7,865 gal</td>
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</table>

1 barge = 15 jumbo hopper cars = 58 semi trailers

http://kentuckyriverports.com/water_transport_benefits/
Bio Fuel Estimation

<table>
<thead>
<tr>
<th>Coal Fired Power Plants</th>
<th>Land Cover</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Water</td>
</tr>
<tr>
<td></td>
<td>Agricultural</td>
</tr>
<tr>
<td></td>
<td>Urban</td>
</tr>
<tr>
<td></td>
<td>Forested</td>
</tr>
<tr>
<td></td>
<td>Wetland</td>
</tr>
</tbody>
</table>

Distance to nearest coal-fired power plant

Distance (mi)
- 25
- 50

Buffer Zones in Miles

Area (Million acres)

Needed <25 miles <50 miles >50 miles

Forest Field

Kentucky State University

Ken Bates, KSU GIS lab
KY Freight Volume

- Truck
- Train
- Barge

US-DOT Federal Highways Administration, 2002
Thanks to
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• Brian Geier
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• CASS program
• Post Carbon Institute

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