Biofuels: The Good, the Bad and the Ugly

Dr. Tamara Sluss
Division of Mathematics and Sciences
Kentucky State University
Frankfort, KY 40601

US Energy Consumption by Source

- Coal
- Natural gas
- Petroleum
- Nuclear
- Hydro
- Geothermal
- Solar
- Wind
- Biomass

Exajoules (Home Heating, Vehicles, et al.)
Fossil Fuel Dependence

- Nonrenewable
- Mining is destructive
- Air, soil, water pollution
- Political and economic ramifications
- Greenhouse gases (GHG) exacerbates climate change

## How much is left?

<table>
<thead>
<tr>
<th></th>
<th>Conventional Reserves</th>
<th>Unconventional Reserves</th>
<th>Yet to find</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>~22 years</td>
<td>~11 years</td>
<td>~7 years</td>
</tr>
<tr>
<td>Gas</td>
<td>~31 years</td>
<td>~12 years</td>
<td>~24 years</td>
</tr>
<tr>
<td>Coal</td>
<td>~200 years</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Source: BP, Javed

*Based on current use*
Biofuels

• Fuel obtained from recently produced organic matter
• Domestic and rural
• Renewable
• Less GHG (if done correctly)
Biofuels

Biodiesel
• Produced from plants with high oil content or from recycled vegetable oil
• Lipids + ethanol + base \rightarrow \text{diesel}
• Soybeans, oil palm, algae

Ethanol
• Produced from plants high in sugar, starch, cellulose, or lignin

High Starch/sugar
• Sugar cane, sweet potatoes, corn (conventional)

Cellulosic
• Prairie switchgrass, wood chips/deadwood, bagasse, corn stover
Oil Palm (BAD)

- Destruction of biodiversity
- Less carbon sequestration
Ethanol is converted from sugars or sugar polymers (carbohydrates)
**Pathways from Biomass to Ethanol**

Michael Bomford, PhD

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**Biotic feedstock**

- Starch (e.g. corn grain, sweet potato)
- Cellulose (e.g. wood, switchgrass)
- Sugar (e.g. sugarcane, sweet sorghum)
- Syngas (carbon monoxide & hydrogen)

**Abiotic feedstock**

- Carbon-based material (e.g. coal, trash)

**Intermediate product**

- Wash (<20% ethanol)
- Fatty acid (e.g. thioacetic acid)
- Syngas (carbon monoxide & hydrogen)

**Fuel**

- Ethanol fuel (100% pure; mixes with gasoline)
- Synfuel (gasoline & diesel)

**Biotic process**

- Hydrolysis (low heat, enzymes)
- Fermentation (Saccharomyces cerevisiae)
- Distillation (high heat)
- Dehydration (pressure swing adsorption, membranes)

**Abiotic process**

- Pyrolysis (high heat, no oxygen)
- Fischer-Tropsch (high pressure and heat, metal catalysts, gas turbine)
- Hydrolysis/fermentation (Clostridium thermocellum)

**Mature technology**

- First Generation

**Emerging technology**

- Second Generation

**Synfuel**

- Fischer-Tropsch (gasoline & diesel)
- Electricity
Sugar Cane

- Golden child of the ethanol business
- High yield
- Bagasse can be co-fired
- Labor issues
  - Deadly Brew: The Human Toll of Ethanol
- Limited range in the United States
  - LA, SC, FL, parts of Southeast

### Top Ten Sugarcane Producers — 11 June 2008

<table>
<thead>
<tr>
<th>Country</th>
<th>Production (Tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>514,079,729</td>
</tr>
<tr>
<td>India</td>
<td>355,520,000</td>
</tr>
<tr>
<td>People's Republic of China</td>
<td>106,316,000</td>
</tr>
<tr>
<td>Thailand</td>
<td>64,365,682</td>
</tr>
<tr>
<td>Pakistan</td>
<td>54,752,000</td>
</tr>
<tr>
<td>Mexico</td>
<td>50,680,000</td>
</tr>
<tr>
<td>Colombia</td>
<td>40,000,000</td>
</tr>
<tr>
<td>Australia</td>
<td>3,600,0000</td>
</tr>
<tr>
<td>United States</td>
<td>27,750,600</td>
</tr>
<tr>
<td>Philippines</td>
<td>25,300,000</td>
</tr>
<tr>
<td>World</td>
<td>155,766,4978</td>
</tr>
</tbody>
</table>

Source: [Food And Agricultural Organization of United Nations: Economic And Social Department: The Statistical Division](http://www.fao.org)
Corn

- Only slightly positive energy balance 1:1.2
- Food crop for humans and as animal feed
  - ‘A crime against humanity!’ says Jean Ziegler of the UN.
  - Does ethanol production affect corn production?

- Corn prices affected?
  - Production costs?
  - Demand for biofuels?

Does increasing corn use for ethanol decrease amount available for human and cattle feed?
Comparison of US and Brazilian Ethanol Programs

<table>
<thead>
<tr>
<th></th>
<th>US</th>
<th>Brazil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedstock</td>
<td>Corn</td>
<td>Sugarcane</td>
</tr>
<tr>
<td>2007 production (million gallons)</td>
<td>6499</td>
<td>5019</td>
</tr>
<tr>
<td>Gallons/acre</td>
<td>424</td>
<td>800</td>
</tr>
<tr>
<td>Energy out/in</td>
<td>1.3 - 1.6</td>
<td>8.3 - 10.2</td>
</tr>
<tr>
<td>Greenhouse gas reduction (%)</td>
<td>10 - 30</td>
<td>86 - 90</td>
</tr>
<tr>
<td>2006 proportion of transportation fuel supply (%)</td>
<td>3.6</td>
<td><strong>20 Good!</strong></td>
</tr>
</tbody>
</table>
Corn ethanol is not the solution to fossil fuel use.

In 2007 the corn to ethanol program consumed 25% of our corn and displaced <1% of our fossil fuel use.

http://soilcrop.tamu.edu/photogallery/cornsorghum+/images/corn%20ears.jpg
Other Possible Bad Guys: Wood Chips

Biomass is everywhere in the forests. The stuff we’re after isn’t on anyone’s radar, and it can minimize the wildfire danger, improve forest ecosystems, and give us an energy source that doesn’t cut into our food or timber resources.”

--- Dr. Joe Roise, Forestry, North Carolina State University

The big red processor, pushed by a tractor on treads, uses carbide teeth to pulverize everything in its six-foot path. As the 56,000-pound behemoth cuts a trail, a belt-driven vacuum sucks the ground-up cuttings through an extended chute over the cab and into an agricultural silage wagon hitched to the tractor. Despite its weight, the machine produces ground pressure of only 7.1 pounds per square foot, so it moves easily over soft forest bed and pocosin.

The biomass harvester is being developed by North Carolina State University for Fecon Inc., manufacturer of the heavy equipment and attachments including Bull Hog commercial mulchers, in cooperation with Tim Tabak, a Craven County forestry management consultant.
Prairie Switchgrass (*Panicum virgatum*)

- Cellulosic ethanol
- Warm-season grass
- Perennial
- Erosion control
- High nutrient use efficiency
- Native to KY
- Difficult to establish

http://www.andersonprairie.org/pictorialguide/plantguide/switchgrass.jpg
### Cellulosic Ethanol Argument in Literature?

<table>
<thead>
<tr>
<th>Pimental and Patzek</th>
<th>ORNL, Bransby, et al.</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Not sustainable</td>
<td>• Sustainable</td>
</tr>
<tr>
<td>• Has negative GHG</td>
<td>• Positive energy</td>
</tr>
<tr>
<td>and energy balance</td>
<td>balance (500%)</td>
</tr>
<tr>
<td></td>
<td>• Negative GHG</td>
</tr>
<tr>
<td></td>
<td>• Argues that Pimental ignores coproduct use</td>
</tr>
</tbody>
</table>

Cellulosic Ethanol side steps food vs. fuel issue, unless cellulosic stocks are grown on crop land.
Greenhouse gas emissions from gasoline and ethanol

Is cellulosic ethanol the answer?

Assumptions may not be realistic

“Relatively modest changes in land use” could give 1.3 billion tons of biomass by 2030. Assuming:

1. Yields of all small grains increase by 50%  
   - Another 6 billion bushels of corn; 1 billion of wheat…which is  
   - Double the rate of increase over past 40 years
2. All cropland no-till (100%)  
   - Now ~30% of cropland after 40+ years of development
3. 55 million acres of perennial bioenergy crops  
   - ~12% of cropland
4. Recover 75% of all crop residues  
   - Sustainable?
5. Economical cellulosic ethanol production
The Bad and the Ugly

• Corn
  – Fertilizers
  – Low energy

• Deforestation for fuel
  – Oil palm
  – Small or fallen trees

• Fuel first, food second
• Long term viability?
• Large scale?

http://en.wikipedia.org/wiki/The_Good,_the_Bad_and_the_Ugly
Good?

• Small-scale:
  – Food first, Fuel second
  – Niche markets
• Grow stock in areas with an economic cost
• Polycultures/diverse plant communities
• Enzymes to increase production
• Artificial selection (breeding) of cultivars to increase production

http://en.wikipedia.org/wiki/The_Good,_the_Bad_and_the_Ugly
Low-input Biofuel Crops for Sustainable Renewable Energy Production on Small Farms

Michael Bomford, Jason Bradford, Julian Darley, Chris Hansen, Josh Puckett, John Rodgers and Tony Silvernail
Niche Market: Parallel Products

- Louisville, KY
- Converts ethanol from expired “products”
  - Liquor
  - Fruit, sport drinks
  - Damaged goods
- Use existing distillery equipment that is 100 years old
- Recycles all containers
- Employs about 80 workers
- Profitable, increased 20% from last year
- Reactant limited, operating under capacity

www.parallelproducts.com
Rights-of-way

- $4.356 Million at 4 cycles a year
- Not cropland
- Not “prime habitat”
- ARCGIS
- EPA P3 Grant
  - Bates, Hansford, Cook, Transportation

Ethanol produced (gallons) = Mowable area (acres) * Published Switchgrass Production Values (tonnes/acre) * Ethanol from Switchgrass conversion rate (gallons/tonnes)
Rights-of-Way Preliminary Results

- Approximately 4-8 million gallons of ethanol could be produced in KY Rights-of-way.

- Potential Problems
  - Difficult to get Switchgrass established
  - Increased roadkill?

- Future Work
  - Economic feasibility study
  - Ethanol production from existing plant communities in rights-of-way
Diverse Biostock Communities

- Tilman, Reich, and Knops
- Cedar Creek Long-Term Ecological Research (LTER) Cambridge, Minnesota.

"Diverse prairie grasslands are 240 percent more productive than grasslands with a single prairie species. That’s a huge advantage. Biomass from diverse prairies can, for example, be used to make biofuels without the need for annual tilling, fertilizers, and pesticides, which require energy and pollute the environment. Because they are perennials, you can plant a prairie once and mow it for biomass every fall, essentially forever.”  D. Tilman
Enzymes/Genetic Engineering

- Enzymes to breakdown cellulose are expensive
  - From microbes in termite and bovine GI systems
- Determine gene and sequence that codes for enzyme
- Insert gene into another microbe for mass production
- Costs must be reduced

Modified from http://www.bbc.co.uk/scotland/education/bitesize/standard/img/biology/genetic-eng.gif
For the first time, the group has genetically engineered a thermophilic bacterium, meaning it's able to grow at high temperatures, and this new microorganism makes ethanol as the only product of its fermentation.
Conclusion

- Ethanol from corn is not sustainable.
- Ethanol at a national scale is likely not viable.
- Ethanol cannot replace petroleum.
- We must decrease our fuel demand.
- Ethanol may be a way to buy some time until alternative vehicles are widely available and in use.
• Ethanol can contribute by
  – Small-scale production
    • On farm
    • Regional: Alltech Springfield, KY Cellulosic Plant
  – Niche markets
  – Prioritizing food before fuel
  – Utilizing land that is already at an economic cost
    • Rights-of-way
    • Under power lines

• Multidisciplinary issue
  – We can all play a role
  – Biological, agricultural, chemical, economic, sociological, political science, education
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• Transportation Cabinet
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• Dr. Charles Bennett
• EPA P3 Grant
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Mike Bomford, personal communication


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