THE 2001 NET ENERGY BALANCE OF CORN ETHANOL

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INTRODUCTION

• In the United States and many countries in the world, ethanol is used as a gasoline additive, not as a fuel. The only exception is Brazil.

• Prices of ethanol, crude oil, and petroleum refined products such as gasoline and methyl tertiary butyl ether (MTBE) are subsidized.

• Gasoline and MTBE prices do not reflect the external costs of burning fuel such as health and environmental effects.
Why Ethanol

- Ethanol is mostly produced in countries that have surplus of agricultural commodities, excess natural resources, high greenhouse gas emissions (GHG), and high dependency to imported oil.
- Examples are grains and oilseeds in the United States; sugarcane and oilseeds in Brazil; grains, oilseeds, sugar beets, and wine in European Unions; sugar cane in India; and grains in China.
OVERVIEW

• The Net Energy Balance of Corn Ethanol:
  - Energy used in production of corn
  - Energy used to transport corn to ethanol plant
  - Energy used to convert corn to ethanol and byproducts
  - Energy used in ethanol distribution
Sources of Data

• USDA/ Economic Research Service (ERS), 2001 Agricultural Resources Management Survey (ARMS)

• USDA/ National Agricultural Statistics Service (NASS), 2001 Agricultural Chemical Usage and 2001 Crop Production

• Stokes Engineering Company, energy used in production of fertilizers
Sources of Data--Continued

- Greenhouse Gas Regulated Emissions and Energy Use in Transportation (GREET) model, energy used in production of chemicals
- 2001 survey of ethanol plants, BBI International, thermal and electrical energy used in ethanol plant
- ASPEN Plus, a process simulation program, to allocate energy used in ethanol plant to ethanol and byproducts
Exclusion

• Energy used in production of farm machinery and equipment
• Energy used by farm labor (food, clothing)
• Energy used in production of cement, steel and stainless steel
The Corn Producing States

- States included in the study: IA, IL, IN, MI, MN, NE, OH, SD, and WI.
- The above states account for 79% and 92% of U.S. corn and ethanol production capacity.
- Farm input use for each state is used to estimate the 9-State weighted average of input levels for corn production.
Energy Used in Corn Production

• Direct energy:
  Gasoline, diesel fuel, LPG, natural gas, and electricity

• Indirect energy:
  Fertilizers (nitrogen, phosphate, potash, and lime) and pesticides (herbicides and insecticides)

• Others:
  Seed, purchased water, custom work, grain dying, and inputs hauling
Energy-Related Inputs Used to Grow Corn, 9-State Weighted Average

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>9-State Weighted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed</td>
<td>Kernels/acre</td>
<td>28,739</td>
</tr>
<tr>
<td>Fertilizer:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td>Pounds/acre</td>
<td>133.5</td>
</tr>
<tr>
<td>Potash</td>
<td>Pounds/acre</td>
<td>88.2</td>
</tr>
<tr>
<td>Phosphate</td>
<td>Pounds/acre</td>
<td>56.8</td>
</tr>
<tr>
<td>Lime</td>
<td>Pounds/acre</td>
<td>15.7</td>
</tr>
<tr>
<td>Energy:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diesel</td>
<td>Gallons/acre</td>
<td>6.9</td>
</tr>
<tr>
<td>Gasoline</td>
<td>Gallons/acre</td>
<td>3.4</td>
</tr>
<tr>
<td>LPG</td>
<td>Gallons/acre</td>
<td>3.4</td>
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<tr>
<td>Electricity</td>
<td>Kwh/acre</td>
<td>33.6</td>
</tr>
<tr>
<td>Natural gas</td>
<td>Cubic ft/acre</td>
<td>246</td>
</tr>
<tr>
<td>Custom work</td>
<td>Dollars/acre</td>
<td>10.1</td>
</tr>
<tr>
<td>Chemicals</td>
<td>Pounds/acre</td>
<td>2.66</td>
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<tr>
<td>Purch. Water</td>
<td>Dollars/acre</td>
<td>0.2</td>
</tr>
<tr>
<td>Average yield</td>
<td>Bushels/acre</td>
<td>139.3</td>
</tr>
</tbody>
</table>
Fertilizers and Chemicals

• New estimates of energy used for production and delivery of nutrients to farm:
  – Nitrogen  24,500 Btu per pound of N
  – Phosphate  4,000  Btu per pound of P$_2$O$_5$
  – Potash       3,000  Btu per pound of K$_2$O

• Energy used in production of pesticides:
  – Herbicides  153,000 Btu per pound
  – Insecticides 158,000 Btu per pound
Fuels and Electricity

• Btu content (LHV):
  - Diesel fuel     128,450     per gallon
  - Gasoline        116,090    per gallon
  - LPG                 84,950     per gallon
  - Natural gas            983    per cubic ft.
  - Electricity           3,412    per kwh
  - Coal                     9,773   per pound
  - Ethanol               76,330   per gallon
Total Energy Requirement of Farm Inputs, 9-State Weighted Average, Btu per Bushel of Corn, 2001
Transporting Corn to Ethanol Plant

• Energy used:
  – 5,636 Btu per bushel
  – 2,120 Btu per gallon
Energy Used in Conversion

• 2001 survey of ethanol plants, BBI international:
  – Dry mill, 34,700 Btu of thermal energy and 1.09 kwh of electricity per gallon of ethanol
  – Wet mill, 47,116 Btu of energy per gallon of ethanol
Net Energy Value of Corn-Ethanol Without Byproduct Credits, 2001

<table>
<thead>
<tr>
<th>Process</th>
<th>Dry Mill</th>
<th>Wet Mill</th>
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</thead>
<tbody>
<tr>
<td>Corn production</td>
<td></td>
<td></td>
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<tr>
<td>Corn transport</td>
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<tr>
<td>Ethanol conversion</td>
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<tr>
<td>Ethanol distribution</td>
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<tr>
<td>Total energy</td>
<td></td>
<td></td>
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<tr>
<td>Ethanol energy</td>
<td></td>
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<tr>
<td>Net energy</td>
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</tbody>
</table>

Btu per gallon
Ethanol Plant Outputs

• Wet mill:
  Corn-ethanol, corn gluten meal, corn gluten feed, corn oil, $\text{CO}_2$, and other products

• Dry mill
  Corn-ethanol, distillers dried grains with soluble, modified distillers grains, wet distillers grains, condensed distillers Soluble, and $\text{CO}_2$
How to Allocate Total Energy to Ethanol and Byproducts

• Methodology:
  – Energy content
  – Market value
  – Output weight basis
  – Replacement value
  – Process energy for energy used in plant and % weight of starch and non-starch for energy used to grow corn and transport corn to ethanol plant
Allocation Rules

• Energy used in corn production:
  – 66% to ethanol and 34% to byproducts

• Energy used in transporting corn to ethanol plant:
  – 66% to ethanol and 34% to byproducts

• Energy used in conversion of corn to ethanol and byproducts, ASPEN Plus:
  – Wet mill, 64% to ethanol and 36% to byproducts
  – Dry mill, 59% to ethanol and 41% to byproducts
Energy Use and Net Energy Value of Corn-Ethanol with Byproduct Credits, 2001

Btu per gallon

Corn production, Corn transport, Ethanol conversion, Ethanol distribution, Total energy, Ethanol energy, Net energy

Dry mill, Wet mill
Net Energy Value of Corn-Ethanol and 9-State Average Corn Yield per Acre
Corn: Harvested Area and Yield per Acre, 1965-03
Bushels of Corn per Pound of Fertilizer, 1966-02
Bushels of Corn per Pound of Pesticides, 1991-02

The chart shows the number of bushels of corn produced per pound of pesticides used from 1991 to 2002. The data indicates a general increase in bushels produced per pound of pesticides over the years.
Dry-Mill: Thermal Energy Use per Gallon of Ethanol and Ethanol Yield per Bushel

BTU

Gallons per bushel


Dry mill  Gal./bu
Conclusions

• Corn yield per acre will continue to increase
• Fertilizer industry has become more energy efficient
• Energy used to produce a bushel of corn will continue to decline
• Ethanol yield per bushel of corn will increase to its theoretical limit
• Ethanol plants will become more energy efficient
• Net energy value of corn-ethanol will continue to improve