Liquid Transportation Fuels from Coal and Biomass

Technological Status, Costs, and Environmental Impacts

America’s Energy Future Study
Panel on Alternative Liquid Transportation Fuels

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PANEL ON ALTERNATIVE LIQUID TRANSPORTATION FUELS

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CHARGE TO THE PANEL

• Evaluate technologies for converting biomass and coal to liquid fuels that are deployable by 2020.
  • Current and projected costs, and CO₂ emissions.
  • Technically feasible supply of liquid fuels.
  • R&D needs.

• Estimate the potential supply curves for liquid fuels produced from biomass and coal.

• Evaluate environmental, economic, policy, and social factors that enhance or impede development and deployment.

• Today, we will focus biomass feedstock and conversion.
PANEL’S APPROACH

• Estimated supply and costs of different cellulosic feedstocks.

• Estimated costs and yields of the biochemical and thermochemical conversion processes.

• Estimated life cycle CO2 emissions from conversion and burning fuel.

• Estimated amount of fuel that is technically feasible to deploy by 2020.

• Estimated market penetration of fuels in 2020 and 2035.
Panel’s Analyses Showed That

1. About 500 million tons/year of biomass can be sustainably produced in the US without incurring significant direct or indirect greenhouse gas emissions.

2. Cellulosic ethanol and other liquid fuels made from this biomass or from coal-biomass mixtures with CCS, markedly reduce greenhouse US gas emissions and increase US energy security.

3. Timely commercial deployment may hinge on adoption of low carbon fuel standards, a carbon price, and accelerated federal investment in technologies.
### Estimated Cellulosic Feedstock That Could Potentially Be Produced for Biofuel

<table>
<thead>
<tr>
<th>Feedstock Type</th>
<th>Current</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Millions of dry tons</td>
<td></td>
</tr>
<tr>
<td>Corn stover</td>
<td>76</td>
<td>112</td>
</tr>
<tr>
<td>Wheat and grass straw</td>
<td>15</td>
<td>18</td>
</tr>
<tr>
<td>Hay</td>
<td>15</td>
<td>18</td>
</tr>
<tr>
<td>Dedicated fuel crops</td>
<td>104</td>
<td>164</td>
</tr>
<tr>
<td>Woody residues&lt;sup&gt;a&lt;/sup&gt;</td>
<td>110</td>
<td>124</td>
</tr>
<tr>
<td>Animal manure</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Municipal solid waste</td>
<td>90</td>
<td>100</td>
</tr>
</tbody>
</table>

**TOTAL**                     | 416     | 548  |

<sup>a</sup>Woody residues currently used for electricity generation are not included in this estimate.
BIOMASS COSTS

Biomass costs include costs of:

• Nutrient replacement.
• Harvesting and maintenance.
• Transportation and storage.
• Seeding.
• Opportunity cost (e.g., cropland rental cost).
## BIOMASS COSTS

<table>
<thead>
<tr>
<th>Biomass</th>
<th>Estimated in 2008&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Projected in 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn stover</td>
<td>110</td>
<td>86</td>
</tr>
<tr>
<td>Switchgrass</td>
<td>151</td>
<td>118</td>
</tr>
<tr>
<td>Miscanthus</td>
<td>123</td>
<td>101</td>
</tr>
<tr>
<td>Prairie grasses</td>
<td>127</td>
<td>101</td>
</tr>
<tr>
<td>Woody biomass</td>
<td>85</td>
<td>72</td>
</tr>
<tr>
<td>Wheat straw</td>
<td>70</td>
<td>55</td>
</tr>
</tbody>
</table>

<sup>a</sup>2008 costs = baseline costs
SUPPLY OF CELLULOSIC ETHANOL—TECHNICALLY FEASIBLE

Biochemical Conversion: Ethanol Costs and Quantities

- Estimated Costs in 2020
- From Crude @ $60
- From Crude @ $100

Assumed Carbon Dioxide Price: $50/tonne of CO₂ eq
No Indirect Impacts on Land Conversion

Dollars Per BBL Gasoline Equivalent

Woody Biomass
Straw
High-Yield Grasses
Corn Stover
Hay
Normal-Yield Grasses

Millions of Barrels Gasoline Equivalent Per Day

0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2
SUPPLY OF ALTERNATIVE LIQUID FUELS—COMMERCIAL DEPLOYMENT

Cellulosic Ethanol
• 0.5 million bbl of gasoline eq./day by 2020,
• Then 1.7 million bbl of gasoline eq./day by 2035.
• CO2 emissions close to zero

Coal-and-Biomass-to-Liquid (CBTL) Fuels
• CBTL fuels could reach 2.5 million barrels of gasoline eq./day by 2035.
• CO2 Emissions close to zero with CCS

Coal-to-Liquid (CTL) Fuels
• Then CTL fuels can reach 3 million bbl of gasoline eq./day by 2035, with a 50 percent increase in US coal production.
• If CCS used, CO2 emission equivalent to petroleum fuels
COMPARISON OF LIFE-CYCLE COSTS

Miscanthus used as feedstock in all comparisons
# Effect of Life-Cycle Greenhouse Gas Price on Fuel Cost – for $0 and $50/tonne CO\textsubscript{2eq} Price

<table>
<thead>
<tr>
<th>Fuel Product</th>
<th>Cost without CO\textsubscript{2} Equivalent Price ($/bbl gasoline equivalent)</th>
<th>Cost with CO\textsubscript{2} Equivalent Price of $50/tonne ($/bbl gasoline equivalent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline at crude-oil price of $60 and $100/bbl</td>
<td>75, 115</td>
<td>95, 135</td>
</tr>
<tr>
<td>Cellulosic ethanol</td>
<td>115</td>
<td>105</td>
</tr>
<tr>
<td>BTL without CCS</td>
<td>140</td>
<td>130</td>
</tr>
<tr>
<td>CTL with CCS</td>
<td>70</td>
<td>90</td>
</tr>
<tr>
<td>CBTL without CCS</td>
<td>95</td>
<td>120</td>
</tr>
<tr>
<td>CBTL with CCS</td>
<td>110</td>
<td>100</td>
</tr>
</tbody>
</table>
CONCLUSIONS

Liquid transportation fuels from coal and biomass have potential to supply 2-3 MBPD of oil equivalent fuels with significantly reduced CO2 emissions by 2035

• And thus play an important role in addressing issues of energy security, supply diversification, and CO₂ emissions

• But their commercial deployment by 2020 will require aggressive large-scale demonstration in the next few years.

• Investor confidence will most likely require a carbon price or low carbon fuel standards requiring specified reductions in GHG emissions
Thank You!

• Any Questions?
COMPARISON OF CO₂ LIFE-CYCLE EMISSION

Analysis assumes that conversion plants sell net electricity to the grid. Electricity-related CO₂ emissions are dependent on the case: IGCC venting CO₂ for vent cases, and IGCC-CCS(90%) for CO₂ storage cases.
BARRIERS TO DEPLOYMENT

- Developing a well-organized and sustainable cellulosic biofuel industry
- Implementing commercial demonstrations of conversion processes ASAP
- Completing megatonne geologic storage demonstrations ASAP
- Developing more efficient, economical pretreatment and improving enzymes to free up sugars
- Permitting and constructing tens to hundreds of conversion plants
- Approaches that recognize commodity prices, especially oil prices, vary widely.
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