Coal & Biomass Based Transportation Fuel Manufacturing and Sustainability Assessment: A Case Study in Kentucky

REU Fellow: Chandni Joshi, University of Kentucky
Mentor: Dr. Yinlun Huang

Introduction

- **Challenge:** Kentucky’s biofuel blend rate expected to increase 15% by 2022
- **Demand:** 775 million gallons of fuel needed per year
- **Solution:** Generation of transportation fuel from Coal and Biomass Co-Fired Plants
- **Supply:** Fraction of 80.6 million tons of coal; 2.6 million tons of biomass from agricultural residue

Relation to Sustainable Manufacturing

- Targeting major manufacturing impact areas at macro production level
- Sustainable design
- Efficient energy and material use
- Monitoring airborne emissions
- Water usage and wastewater
- Alternative solution for meeting consumer demands based on regional resources

Approach

- Simulate complex process plant via Aspen HYSYS
- Raw material conversion, mass & energy balances, recycling, fuel production, extraction of valuable side products and CO2 removal
- Conduct sustainability assessment using IChemE Metrics and Inherent Safety Index
- Economic, environmental and social responsibilities

Process Background

- Process description of Coal and Biomass Co-Fired Plants:
  - 85% coal, 15% biomass by weight
  - Air Separation Unit: O2 production
  - Gasification: Syngas production
  - Selexol Unit: Removal of H2S & CO2 from syngas
  - Claus Plant: Conversion of H2S into elemental Sulfur
  - Pressure Swing Adsorption: Removal H2 from syngas
  - Fischer Tropsch Synthesis: Hydrocarbon (C11-C30) production
  - Product Distillation: Conversion of C11-C30 into diesel & naphtha
  - CO2 removal: Collection & compression of CO2

Plant complexity: 167 process units of 11 types

Results of Simulation

<table>
<thead>
<tr>
<th>Feedstock Input (tons/year)</th>
<th>Coal</th>
<th>Energy Input (GW/y)</th>
<th>Product Output (tons/year)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>6.37E+06</td>
<td>1.77E+03</td>
<td>Diesel</td>
</tr>
<tr>
<td>Biomass</td>
<td>1.14E+06</td>
<td>7.74E+03</td>
<td>Hydrogen</td>
</tr>
<tr>
<td>Catalyst</td>
<td>1.98E+05</td>
<td>1.14E+13</td>
<td>Water</td>
</tr>
<tr>
<td>Water</td>
<td>6.37E+06</td>
<td>7.74E+03</td>
<td>Naphtha</td>
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<tr>
<td></td>
<td>1.14E+06</td>
<td>1.98E+05</td>
<td>Nitrogen</td>
</tr>
<tr>
<td></td>
<td>4.61E+07</td>
<td>1.14E+13</td>
<td>Sulfur</td>
</tr>
</tbody>
</table>

Results of Sustainability Assessment

**Economic Sustainability:**
- Plant operation feasible at diesel prices of approx. $4/gal.

**Environmental Sustainability:**
- 8.69E+6 tons/year of CO2 prohibited from atmosphere via Carbon Sequestration

**Social Sustainability:**
- 1,680 jobs created
- Safety measures needed as Inherent Safety Index value is too high (39 out of 50)

Process Recommendations

- Recycle cooling water
- Discard Selexol catalyst recovery, decreasing equipment costs
- Add vessel jackets & pressure relief valves, increasing safety
- Consider transportation of goods to determine optimum plant capacity

Conclusions

- Successful simulation of entire plant process
- Comprehensive sustainability assessment conducted
- Improved understanding of the use of this technology
- Future works:
  - Process improvement
  - Strategic planning feasibility study for Kentucky

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