HYDROGEN FROM BIOMASS FOR URBAN TRANSPORTATION

K. B. Bota and Z. Wang
Clark Atlanta University

&

Y. Yeboah
Penn State University

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DOE Hydrogen Program Review
Project ID #: TVP1

This presentation does not contain any proprietary or confidential information
Overview

Timeline

- Project start date: 2003
- Project end date: 2005
- Percent complete: 100%

Barriers

- Feedstock cost and availability
- Efficiency of pyrolysis and reforming technologies
- Durable, efficient and impurity tolerant catalysts
- Hydrogen separation and purification
- Market and delivery

Partners

- National Renewable Energy Lab
- Eprida, Inc.
OBJECTIVES

• Undertake the engineering research and pilot scale process development studies relating to:

  - Production of hydrogen from biomass (e.g., agricultural residues) for $2.90/kg H₂ by 2010; $2.30 by 2015
  - Separation, safe storage and utilization of the hydrogen
  - Production and identification of uses of the co-products
APPROACH

- Develop process based on pyrolysis of biomass and steam reforming of pyrolysis vapors (bio-oils and gases).
- Perform catalytic steam reforming in a fluidized-bed (25-250 kg/day H₂ production)
- Conduct pyrolysis at: T: 500°C; P: 10 psig; Feed Rate: 50-500 kg/hr pelletized peanut shells
- Study reforming at: T: 850°C; P: 6 psig; H₂O/C = 5, Catalyst: nickel-based (300-500 microns)
The Peanut Shell to Hydrogen Cycle

Stationary fuel cell power generation
Schematic Flow Diagram of the Biomass Pyrolysis-Reformer Process
Photograph of Hydrogen Production System
Major Components

- Feeder & Pyrolysis Unit
- Superheater & Baghouse
- Pre-heater & Reformer
- Cooler & Condenser
- Control and Monitoring System
Hydrogen Production Control
Photograph of Hydrogen Flame
Total Gas Composition vs Time (24 hrs)
Nitrogen free-Base Gas Composition vs Time (24hrs)
Typical Analysis of Peanut Shell Feedstock

• Component

- Lignin
- Glucan
- Extractives
- Protein
- Xylan
- Ash
- Arabinan
- Galactan
- Mannan
- Others (e.g., free carbohydrates)

%  
34.8  
21.1  
14.2  
11.1  
7.9  
3.4  
0.7  
0.2  
0.1  
6.5
<table>
<thead>
<tr>
<th></th>
<th>TYPICAL PRODUCT COMPOSITION/ YIELDS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pyrolyzer (Yields)</td>
</tr>
<tr>
<td></td>
<td>Reform (Gas product composition, on dry N₂-free basis)</td>
</tr>
<tr>
<td>Char</td>
<td>32%</td>
</tr>
<tr>
<td>Water</td>
<td>32%</td>
</tr>
<tr>
<td>Bio-Oils</td>
<td>31%</td>
</tr>
<tr>
<td>Gases</td>
<td>5%</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>49%</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>36%</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>9%</td>
</tr>
<tr>
<td>Methane</td>
<td>8%</td>
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Pyrolysis Bio-Oil Product

• Empirical Formula: \( \text{CH}_{1.9}\text{O}_{0.7} \)
• Water: 15 – 25%
• Organics: 75 – 85%
  – Aldehydes, alcohols and acids from carbohydrate fraction
  – Phenolics from lignin fraction

• Representative Compounds

<table>
<thead>
<tr>
<th>Water</th>
<th>Ethanol</th>
<th>Methanol</th>
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</thead>
<tbody>
<tr>
<td>Cyclohexanol</td>
<td>Formic Acid</td>
<td>Acetic Acid</td>
</tr>
<tr>
<td>Glucose</td>
<td>Phenol</td>
<td>O-cresol</td>
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<tr>
<td>2-Butanone</td>
<td>Dodecanoic acid</td>
<td>Tannin</td>
</tr>
</tbody>
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ACCOMPLISHMENTS

• Completed design, construction and testing of reformer (Phase 1)
• Completed integration of reformer with pyrolyzer (Phase 2)
• Completed 100 hours of successful operation of pilot unit (Phase 2)
• Completed modifications for 1,000 hours operation
• Completed 24 hours catalyst and process testing
• Identified potential co-products options
• Developed partnership and collaboration with potential companies/organizations
• Trained students
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• **Partners**
  - Clark Atlanta University
  - Eprida Scientific Carbons Inc.
  - Enviro-Tech Enterprises Inc.
  - Georgia Institute of Technology
  - Oak Ridge National Lab, Oak Ridge, TN
  - National Renewable Energy Laboratory, CO
  - University of Georgia, Athens