Hydrogen from Biomass
Catalytic Reforming of Pyrolysis Vapors
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National Bioenergy Center in
Collaboration with the Clark Atlanta University Team
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Project Goals

- Demonstrate the production of hydrogen from biomass by pyrolysis –steam reforming for $2.90/kg by 2010

- Barriers:
  - Vapor Conditioning
  - Catalyst Development and Regeneration
  - Reactor Configuration
  - Heat Integration
  - Deployment: H2 + Co-products

- **Milestone:** Verify advanced catalysts and reactor configuration for fluid bed reforming of biomass pyrolysis liquid at pilot scale (500 kg H2/day) with catalyst attrition rates < 0.01%/day. 4Q, 2009
Biomass Feedstocks

$$6 \text{ CO}_2 + 6 \text{ H}_2\text{O} \overset{\text{sunlight}}{\rightarrow} \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{ O}_2$$

Potential: 15% of the world’s energy by 2050.

Crop residues
Forest residues
Energy crops
Animal waste
Municipal waste

*Issues: Biomass Availability and Costs*

[Graph showing Georgia Biomass Feedstock Supply]

- ~150 PJ of H2 energy
- 5% of GA energy use

Million Dry tons

2000 2010 2020 2030 2040 2050
Pyrolysis Process Concept

Biomass $\rightarrow$ PYROLYSIS $\rightarrow$ Carbon Residue

$\downarrow$

Bio-oil $\rightarrow$ Co-products

$\downarrow$

SEPARATION $\rightarrow$ Phenolic Intermediates

$\downarrow$

H$_2$O $\rightarrow$ CATALYTIC STEAM REFORMING

$\downarrow$

H$_2$ (and CO$_2$)

e.g., Resins
Octane additives
Fine Chemicals
Biocarbon-Based Fertilizers

Biomass $\rightarrow$ Char $\rightarrow$ $N_2$ $\rightarrow$ $CO_2$ $\rightarrow$ $H_2$ $\rightarrow$ Catalysis $\rightarrow$ $NH_3$ $\rightarrow$ $NH_4HCO_3$ or $(NH_2)_2CO$

Courtesy D. Day, Eprida/Scientific Carbons Inc.

Formation of Ammonium Bicarbonate Inside the 15min Char Interior
Phase 2 System

Biomass [100]

Pyrolysis

bio-oil [30]
H₂O [30]
Gas [5]

Eductor

Filter

Preheater

Char [35]
Steam [15]

Super Heater

Flue Gas

Phase 3 Design Challenges
- Reformer Preheater
- Heat Recovery and Integration
- Compression
- Conditioning
- Coproduct Optimization
- Pyrolyzer Heat Optimization

Reformer

H₂ [7]
+ CO₂ [60]
+ CO [11]
+ CH₄ [2]

Filter

Catalyst Fines
Pyrolysis Unit Performance

- O2 Sensor after Char bed
- O2 Sensor before Char bed
- Char Bed Temp
- Exit Gas Temp

Temperature (°C)

Time, hrs

Present <-> O2 --> Absent
Reformer Performance

- Reformer Bed Temp
- Orifice Plate Temp
- Reformer DP
- Orifice Plate DP

Graph shows temperature and differential pressure over time, with axes labeled:
- Y-axis: Differential Pressure (in H2O)
- X-axis: Time, hrs
- Temperature, C
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Circulating Fluid Bed

- Smaller Catalyst Particles \( \rightarrow \) Harder
- Fluid Dynamics \( \rightarrow \) Higher Gas Flows
- Direct Heating \( \rightarrow \) Partial Oxidation
- Optimized Catalytic Coke Gasification

Reforming: \( C_xH_yO_z + H_2O \rightarrow H_2 + CO_x \)

Water gas shift: \( CO + H_2O \rightarrow CO_2 + H_2 \)

Coke Gasification: \( C + H_2O \rightarrow CO + H_2 \)
Project Time Line

Best option (BB vs CFB) - Scale up at 3X

Bubbling Bed @ 10X

Circulating Bed

Go/No Go: CFB@ 10X

Milestone

Year

2003 2004 2005 2006 2007 2008 2009
What are the Advantages of Pyrolysis/CSR vs Gasification/WGS?
- Distributed Resource $\rightarrow$ Centralized Reforming
- Coproduct $\rightarrow$ Better Economics
- Smaller Scale $\rightarrow$ Lower Capital + Feedstock Cost

Maintain a Communication Plan
- RACI Analysis for Phase III

“Watch out for Safety”
- Feature Safety in Phase 3
- Change Site to University of Georgia Biomass Research Facility to promote safety development and education and tech transfer to biomass industry
Safety Approach

U of GA Facility:
- Train the Trainers
- Process control for safety AND efficiency (lower cost)

Must Develop:
- A Facility to study system safety boundaries
- A Statistical Basis for Safety Confidence