

II.E.2 A Novel Slurry-Based Biomass Reforming Process

Sean C. Emerson (Primary Contact),
Thomas H. Vanderspurt (Principle Investigator)
United Technologies Research Center (UTRC)
411 Silver Lane
East Hartford, CT 06108
Phone: (860) 610-7524; Fax: (860) 660-9093
E-mail: emersosc@utrc.utc.com

DOE Technology Development Manager:
Mark Paster
Phone: (202) 586-2821; Fax: (202) 586-9811
E-mail: Mark.Paster@ee.doe.gov

DOE Project Officer: Paul Bakke
Phone: (303) 275-4916; Fax: (303) 275-4753
E-mail: Paul.Bakke@go.doe.gov

Contract Number: DE-FC36-05GO15042

Subcontractor:
Energy & Environmental Research Center
University of North Dakota, Grand Forks, ND

Project Start Date: May 2, 2005
Project End Date: February 27, 2009

Technical Targets

This project consists of three key elements: plant and system design, catalyst research, and a proof-of-concept demonstration. The information obtained from all three efforts will be used to demonstrate that the proposed H₂ production system will meet the DOE's 2012 Biomass Gasification/Pyrolysis Hydrogen Production energy efficiency and total hydrogen cost targets of 43% (based on feedstock LHV) and \$1.60/kg H₂. The current progress toward achieving the DOE's technical targets based on the preliminary plant and system design are shown in Table 1.

TABLE 1. Technical Targets for Biomass Gasification/Pyrolysis Hydrogen Production

Characteristics	Units	2012 Target	2007 Current Progress
Hydrogen Cost (Plant Gate)	\$/gge	1.60	1.58
Total Capital Investment	\$M	150	203
Energy Efficiency	%	43	46.6



Objectives

- Develop an initial reactor and system design with cost projections for a biomass slurry hydrolysis and reforming process for H₂ production.
- Develop a cost-effective catalyst for liquid phase reforming of biomass hydrolysis-derived oxygenates.
- Perform a proof-of-concept demonstration of a micro-scale pilot system based on liquid-phase reforming of biomass hydrolysis-derived oxygenates.
- Demonstrate that the proposed H₂ production system will meet the 2012 efficiency and cost targets of 43% lower heating value (LHV) and \$1.60/kg H₂.

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Production section (3.1.4) of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- (S) Feedstock Cost and Availability
- (T) Capital Cost and Efficiency of Biomass Gasification/Pyrolysis Technology

Approach

The basic concept for this project is shown in Figure 1. The initial feed is assumed to be a 10 wt% slurry of ground poplar wood in dilute acid. The acid will hydrolyze the cellulose and hemicellulose in the wood to produce a reformable mixture for the catalyst to be developed during this project. To avoid char formation and to reach hydrogen production goals, an optional hydrogenation step may be needed in conjunction with the hydrolysis step. The reformable mixture will be reacted in the liquid phase over a mixed metal Pt-based rafts (Pt-MM)/mixed metal oxide catalyst to convert the hydrolyzed biomass to hydrogen. A palladium alloy membrane will be used to remove the pure hydrogen thus limiting methane formation, while the retentate is used as fuel in the proposed plant.

The catalyst development approach is based on a paradigm used successfully in the past at UTRC to produce a high activity precious metal-based water-gas shift (WGS) catalyst that had a very low alkane (methane) production rate. This approach, shown in Figure 2, combines catalyst conceptual design, quantum mechanical atomistic modeling, and advanced catalyst synthesis techniques to determine the best catalyst formulations to focus the synthesis effort on prior to

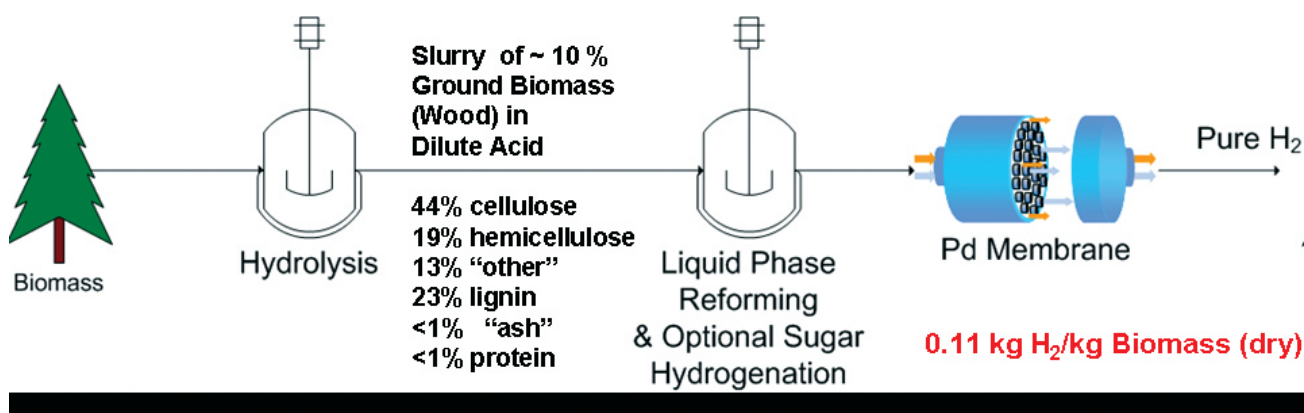


FIGURE 1. The UTRC Approach to Biomass Slurry Reforming

UTRC Catalyst Discovery Approach

Atomistic catalyst design, synthesis, characterization, reaction studies & kinetic analysis

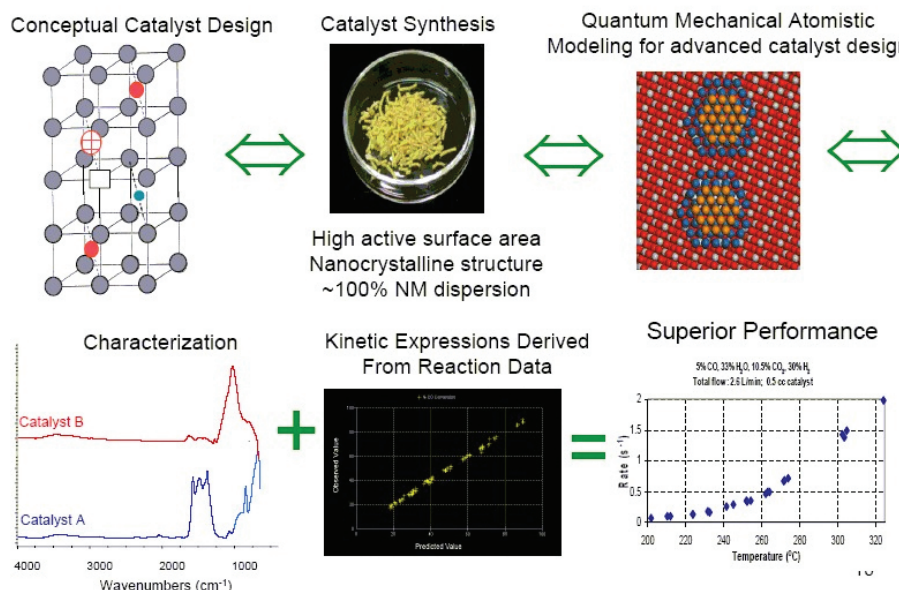


FIGURE 2. The UTRC Catalyst Discovery Approach

experimentation. Initially, a theoretical catalyst design is proposed to maximize high catalytic activity and selectivity and minimize less desired attributes such as diffusion limitations. Using atomistic modeling tools such as VASP, variations in catalyst formulations can be explored to define the best compositions and structures on which to focus the synthesis effort. Then, special synthesis techniques can be employed to make only the materials that will show the greatest promise. These materials are then characterized and tested under reaction conditions to feed back information to the design and modeling efforts in an iterative effort that will produce the optimal catalyst for a given process.

Accomplishments

- A baseline 2,000 ton/day biomass to hydrogen plant has been designed using the process simulator HYSYS which has a plant hydrogen efficiency of 46.6%.
- The preliminary economic analysis of the baseline plant design shows that a hydrogen production cost of \$1.58/kg H₂ is attainable.
- A statistically designed system model parameter study revealed the nine variables that had the strongest effect on system efficiency. The result of this study was the determination of an empirical function that describes the effect of changing

operating parameters on the system efficiency, taking into account any interactions between the parameters that occur.

- The parameter study revealed two key features of a biomass to hydrogen plant based on liquid phase reforming:
 - The reforming conversion of sugars such as glucose can be as low as 75% and still achieve the DOE's 2012 efficiency targets, and;
 - The production of alkanes, such as methane, is not detrimental to system efficiency, as the alkanes can be burned to produce energy to operate the chemical plant.

FY 2007 Publications/Presentations

Only one public presentation outside of DOE Hydrogen Reviews has been given:

1. She, Y.; Emerson, S.C.; Vanderspurt, T.H. Modeling and Simulation of Hydrogen Production from Biomass through Hydrolysis and Liquid-Phase Reforming Processes, Presented at the 231st ACS Meeting, Atlanta, GA, March 2006.