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A Techno-Economic Assessment of Hydrogen Production by Gasification of Biomass

> Poster Presented By:
David A. Bowen
Gas Technology Institute

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Project Team

> Project sponsored by U.S. Dept. of Energy (EERE), Hawaii Electric, Gas Technology Institute (GTI), Electric Power Research Institute (EPRI), and the University of Hawaii.

> DOE Program Manager: Mr. Douglas Hooker

> **GTI Team Members**
  – Francis S. Lau
  – David A. Bowen
  – Remon J. Dihu
  – Shain J. Doong
  – Robert J. Remick
  – Rachid B. Slimane
  – Robert F. Zabransky

> **Other Team Members**
  – Scott Q. Turn, HNEI
  – Evan E. Hughes, EPRI

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Project Objectives

> Determine the technical and economic potential of producing hydrogen from biomass with an end-use in PEM fuel cells

> Project outline:
>> Develop a biomass resource assessment
>> Collect information on feeding systems
>> Simulate gasification with biomass
>> Determine gas cleaning requirements
>> Determine hydrogen production costs
>> Assess public programs and initiatives
>> Determine barriers to commercialization

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Project Timeline

Task		Task Name	Months From Start of Project														
			01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
1.0		Resource Assessment of Biomass Feedstocks															
	1.1	Bagasse, Switch Grass, and Nut Shell Availability and Cost	█	█	█	█	█	█									
	1.2	Process Scale Determination	█	█	█	█	█	█									
2.0		Hydrogen Production via Gasification/Pyrolysis of Biomass															
	2.1	Identification/Evaluation of Solids Handling Systems	█	█	█	█	█	█	█	█	█						
	2.2	Modeling for Gasification of Three Feedstocks and Analysis	█	█	█	█	█	█	█	█	█	█	█	█			
	2.3	Gas Purification/Cleanup Requirements	█	█	█	█	█	█	█	█	█						
3.0		Cost of Hydrogen Production and Cost Sensitivity Analysis									█	█	█	█			
4.0		Assessment of Public Programs and New Policy Initiatives	█	█	█	█	█	█	█	█	█	█	█	█			
5.0		Market Barries and Commercial Opportunites	█	█	█	█	█	█	█	█	█	█	█	█			
6.0		Final Report													█	█	█

Figure 2. Project Schedule (Start Date: September 15, 2001 / End Date: December 15, 2002)

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Project Relevance

> Biomass represents an alternative, low cost fuel source that has potential to produce a high value end product, hydrogen.

> Biomass gasification is a source of non-fossil based energy and chemical production.

> Hydrogen production from domestic biomass resources can alleviate foreign dependence on fossil fuels while producing a clean fuel for PEM fuel cells.

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Technical Approach

> A resource assessment was performed to determine plant size capacities

> A GTI proprietary, empirical model was used to simulate gasification of biomass

> A HYSYS® design and simulation package was used to simulate hydrogen production

> The economic analysis was performed utilizing data from EPRI's existing database

Project Assumptions

Technical Assumptions for Gas Purification

- Fuel gas can be cleaned at gasifier temperature
- Reformer Requirements
  - H_2S less than 100 ppmv
- PEM Fuel Cell Requirements
  - H_2S less than 1 ppmv
  - NH_3 less than 1 ppmv
  - CO less than 10 ppmv
- 80% recovery in PSA with 99.9% purity H_2

Economic Assumptions

- Power law scaling for increased capacity
- Linear hydrogen production with increased plant size capacity

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Resource Assessment

> Three Feedstocks Selected:
  - Bagasse, Switchgrass, and a Nutshell Mix

> Bagasse
  - Delivered cost of $30 - 40 / tonne
  - Potential availability of 700 – 5200 tonnes / day

> Switchgrass
  - Delivered cost of $27 – 46 / tonne
  - Availability undetermined

> Nutshell Mix
  - 40% almond shell, 40% prunings, 20% walnut shells
  - Delivered cost of $12 – 44 / tonne
  - Potential availability of 500 tonnes / day

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Process Flow Diagram
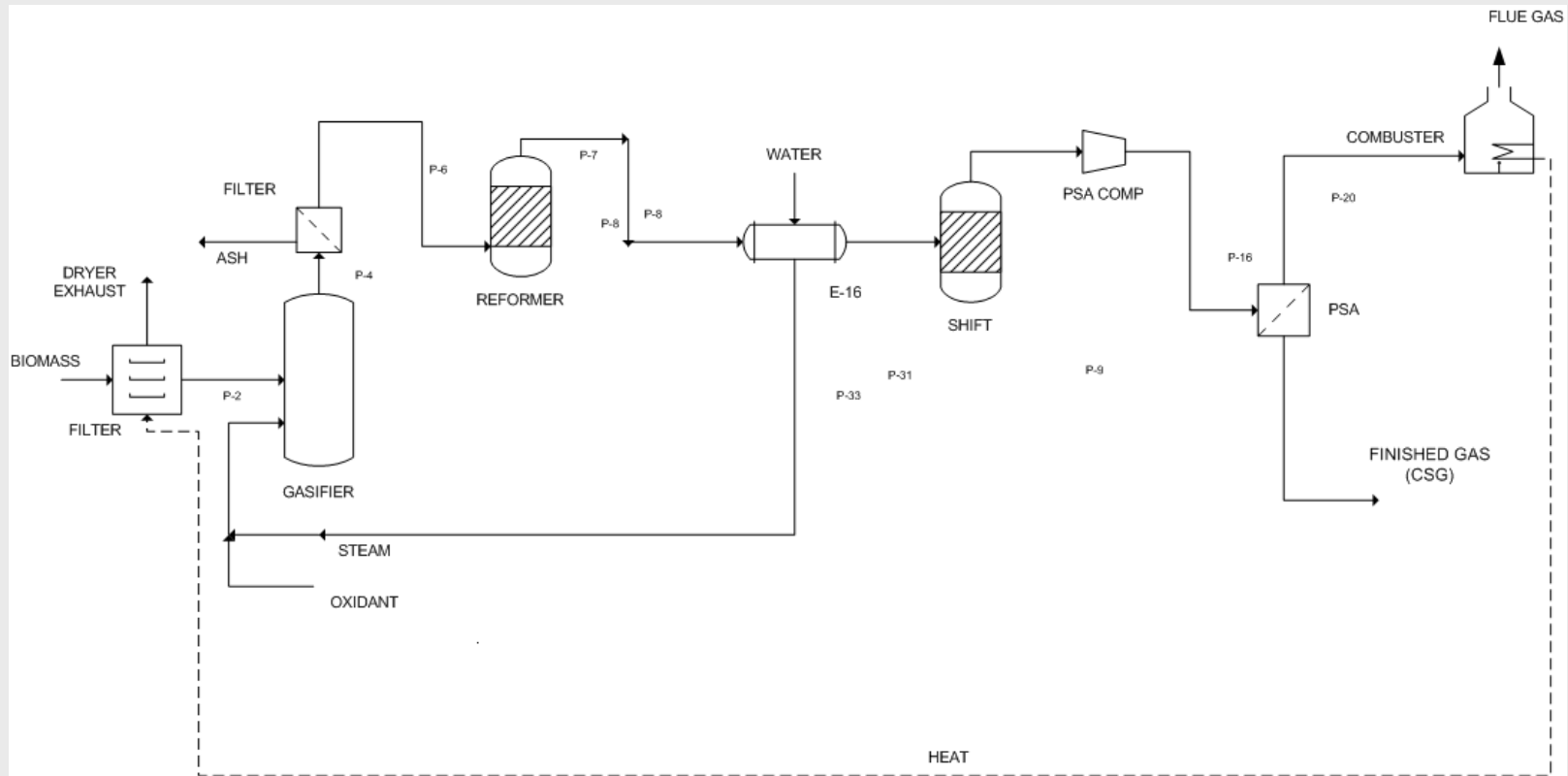
Bagasse Process Flow Diagram

Simulation Results

	Bagasse	Switchgrass	Nutshell Mix
Heat Used in Reformer [GJ/h]	24.8	25.7	24.2
Heat Used in Dryer [GJ/h]	45.8	0	0
Heat Recovered from PSA Reject [GJ/h]	60.0	80.5	89.0
Heat Recovered from Reformer Stream [GJ/h]	19.1	8.1	5.3
Net Heat from the system [GJ/h]	8.5	62.9	70.1
Power Used in PSA Compressor [GJ/h]	6.97	8.20	8.45
Power Used for Air Separation [GJ/h]	5.90	5.10	4.10
Total Heating Value of H_2 Product [GJ/h]	186	220	230
Total Heating Value of Dry Biomass Feed [GJ/h]	297	342	361
Cold Efficiency	0.628	0.644	0.637
Effective Thermal Efficiency	0.583	0.744	0.756
H_2 / Dry Biomass [g/kg]	78.1	84.1	88.3

BASIS: 500 tonnes / day at gasifier fed moisture content

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Economic Results

Feedstock	Gasifier Feed Rate	Hydrogen Produced		Feedstock Cost	Capital Cost	H$_2$ Cost 15% IRR
	Dry Tonnes / Day	Tonnes / Day	Nm^3 / Day	US $ / GJ	US $ Million	US $ / GJ
Bagasse	400	31.2	347,000	1.50	37.0	9.13
	800	62.5	695,000	1.50	61.1	7.64
	1600	125	1,390,000	1.50	100.9	6.57
Switchgrass	440	37.0	412,000	1.50	36.5	7.95
	880	74.0	824,000	1.50	60.6	6.73
	1760	148	1,648,000	1.50	100.9	5.86
Nutshell Mix	438	38.7	488,000	1.50	36.3	7.72

Commercialization Barriers

> Technical Barriers
  - Materials handling
  - Cleaning and purification

> Economic Barriers
  - Hydrogen infrastructure (chicken and egg)
  - Supply and demand of waste crops
  - High cost fuel compared to available sources

> Psychological Barriers
  - Hindenburg and Challenger disasters
  - Educational programs

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Conclusions

> Hydrogen Can Be Produced Economically From Biomass
  – Costs are competitive with SMR and potentially better with lowered fuel costs through the inception of public programs

> Areas Deserving Further Research
  – Gas Clean Up
  – Membrane Separation
  – Feeding Systems
  – Development of a Hydrogen Infrastructure

Future Plans

> Address the technical issues found in the conclusion of this report

> Build on the expertise gained in this paper study and apply it to an experimental study of hydrogen production from biomass

> Commercialize the process of hydrogen production from biomass gasification using GTI's fluidized bed, RENUGAS technology

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2002 Merit Review Responses

> Comment:
  – Would it make more sense to take a low-tech approach to crop residue? If burning it to make steam and generate electricity is not profitable, then trying to make hydrogen will not be either.

> Response:
  – Electricity production is more efficient using gasification than combustion. Energy is also not the only use for hydrogen. Hydrogen produced from biomass for other processes may prove more cost effective.

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