HYDROGEN FROM BIOMASS FOR URBAN TRANSPORTATION

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Collaborating Project Team

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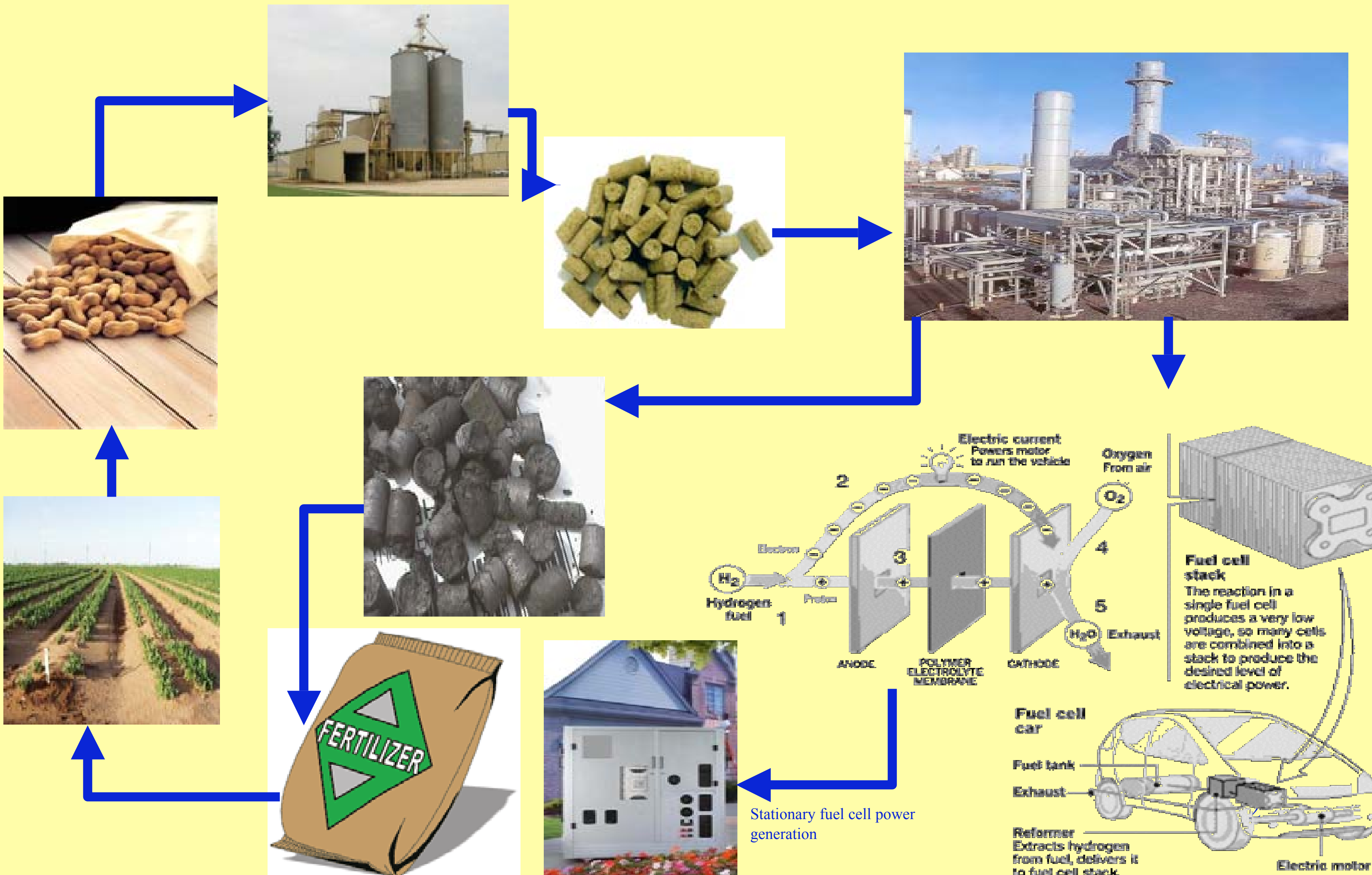
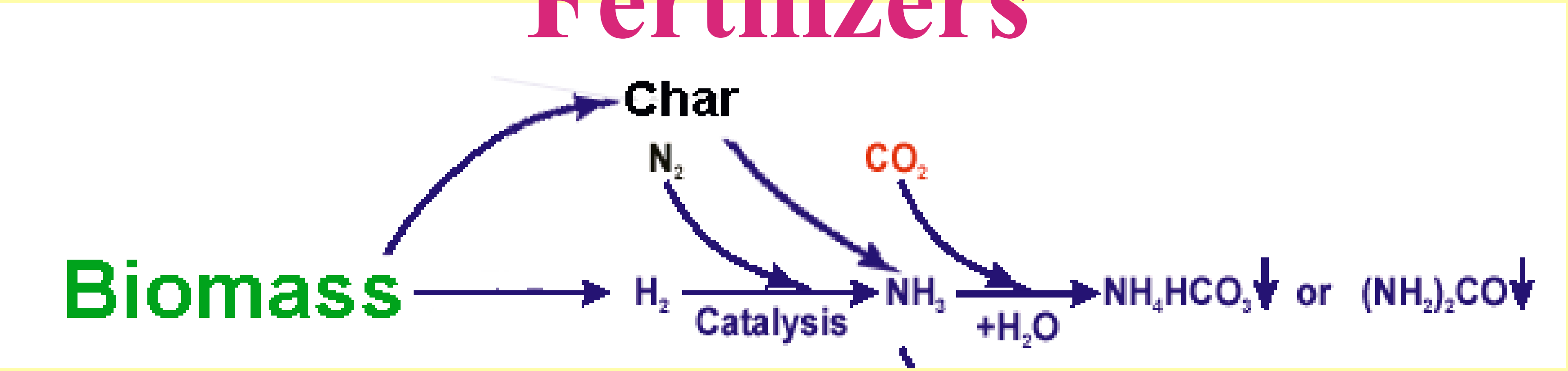
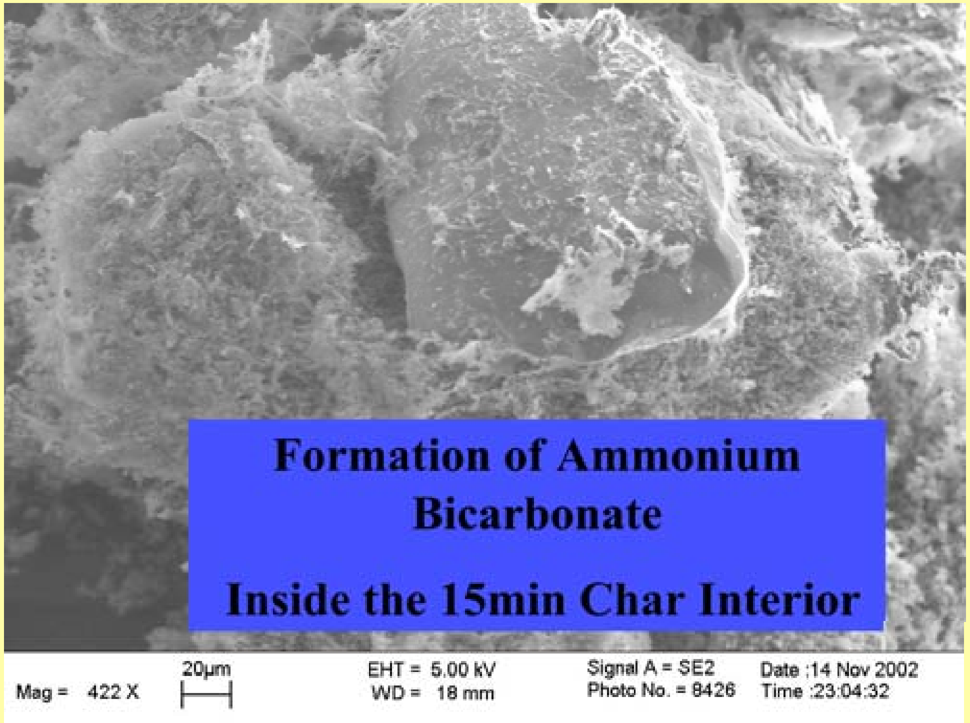
This presentation does not contain any proprietary or confidential information.

The Peanut Shell to Hydrogen Cycle



Biocarbon-Based Fertilizers





Courtesy
D. Day,
Eprida Scientific
Carbons 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 H_2 by 2010; $2.40 by 2015
  - Separation, safe storage and utilization of the hydrogen
  - Production and identification of uses of the co-products

- **Increase diversity of the Nation's workforce and the broader impact of the project through the education and training of underrepresented minorities.**

Budget

- Total Funding

	» DOE Share	Contractor Share
• Phase 1	$252 K	$63.1 K
• Phase 2	$500 K	$125 K
• Phase 3	$1.00 M	$250 K
• Funding in FY 2003	$600 K	$150 K

Technical Barriers: Hydrogen from biomass via pyrolysis and steam reforming

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

Technical Targets: hydrogen from biomass via pyrolysis and steam reforming

		Units	2003	2005	2010	2015
Biomass Feed	Cost	\$/kg H_2	0.80	0.80	0.70	0.60
Operations through pyrolysis	Cost	\$/kg H_2	1.90	1.90	1.50	1.20
	Energy Efficiency	% (LHV)	65	66	72	79
Reforming	Cost	\$/kg H_2	0.70	0.60	0.40	0.30
	Energy Efficiency	% (LHV)	83	84	87	91
Purification	Cost	\$/kg H_2	0.40	0.40	0.30	0.30
	Energy Efficiency	% (LHV)	74	74	77	82
Total	Cost	\$/kg H_2	3.80	3.70	2.90	2.40
	Net Energy Ratio		26	27	32	30

Relevance to DOE, FreedomCAR, and Hydrogen Initiative

- **Project is developing technology (pyrolysis-reformer process) that will:**
  - Produce hydrogen from biomass (e.g., peanut shells)
  - Utilize the biomass hydrogen for transportation and/or stationary power generation
  - Reduce cost, and develop improved technologies
- **Project addresses national and global issues related to**:
  - Improvement in America's energy security by reducing the need for imported oil
  - Improving air quality and reducing greenhouse gas emissions
  - Revitalization of rural economy (e.g., Georgia)
  - The four E's: Energy, Environment, Economy, and Education

APPROACH

- **Develop process based on biomass pyrolysis and steam reforming of pyrolysis vapors (bio-oils and gases).**
- **Perform catalytic steam reforming in a fluidized-bed (25-250 kg/day H_2 production)**
- **Conduct pyrolysis at: T: 500°C; P: 10 psig; Feed Rate: 50-500 kg/hr pelletized peanut shells. Gas and charcoal exit at 425 °C**
- **Study reforming at: T: 850°C; P: 6 psig; $H_2O/C = 5$, Catalyst: nickel-based (300-500 microns)**

APPROACH/ PROJECT TASKS

- **Task 1: Feedstock supply, process economics and deployment strategies (modeling, extraction, and property estimation)**
- **Task 2: Process modifications, integration, and shakedown**
- **Task 3: Long term (1,000 hours) catalyst and process testing**
- **Task 4: Hydrogen separation, storage, and utilization**
- **Task 5: Environmental and technical evaluation**
- **Task 6: Partnership building and outreach**

Project Safety

- Safety plan and facility changes coordinated with new applicable codes, national code experts & UGA Fire and Safety personnel.
- Site visit protocols established w/multi-language warning signs and designated viewing areas
- HYTEC regional hydrogen education center consulted for case study of safety plan.

PROJECT TIMELINE

Phase 1	Phase 2	Phase 3
2000-2001	2001-2002	2002-2003

Phase 1: Completed design, construction and testing of reformer

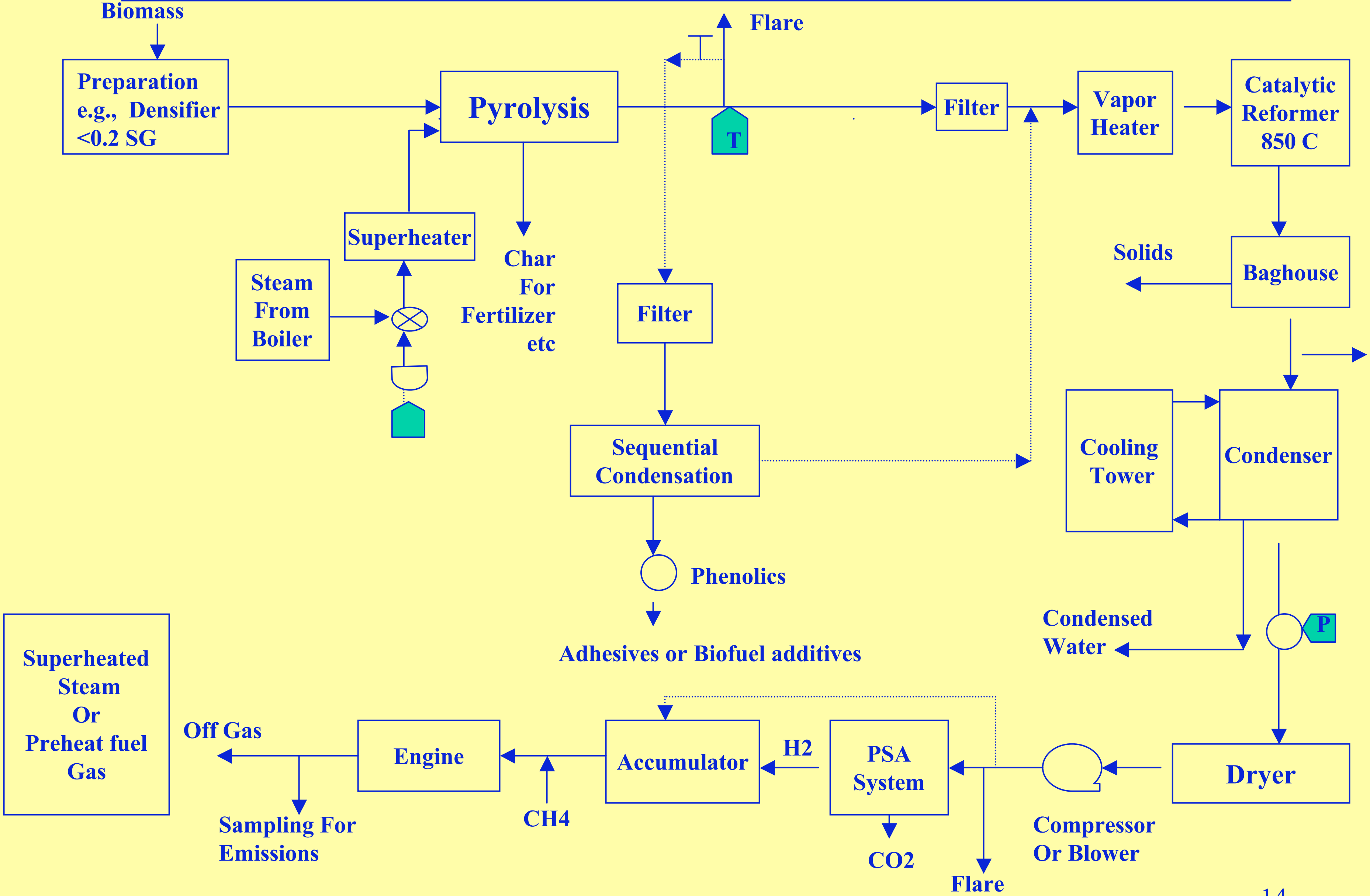
Phase 2: Completed integration of reformer with pyrolyzer and tested unit for 100 hours

Phase 3: Make modifications, move unit to UGA, Athens and test unit for 1000 hours

ACCOMPLISHMENTS/PROGRESS

- **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**
- **Initiated 1,000 hour run pilot operation of unit**
- **Identified potential co-products options**
- **Developed partnership and collaboration with potential companies/organizations**
- **Educated and trained several underrepresented minorities on project**

Schematic Flow Diagram of the Biomass Refinery for Hydrogen, Char and Chemicals



Blakely, Georgia Site

PICTURES OF PILOT PLANT BEING MOVED TO UGA, ATHENS

PICTURES OF UNLOADING AND REINSTALLATION OF PILOT PLANT AT UGA, ATHENS

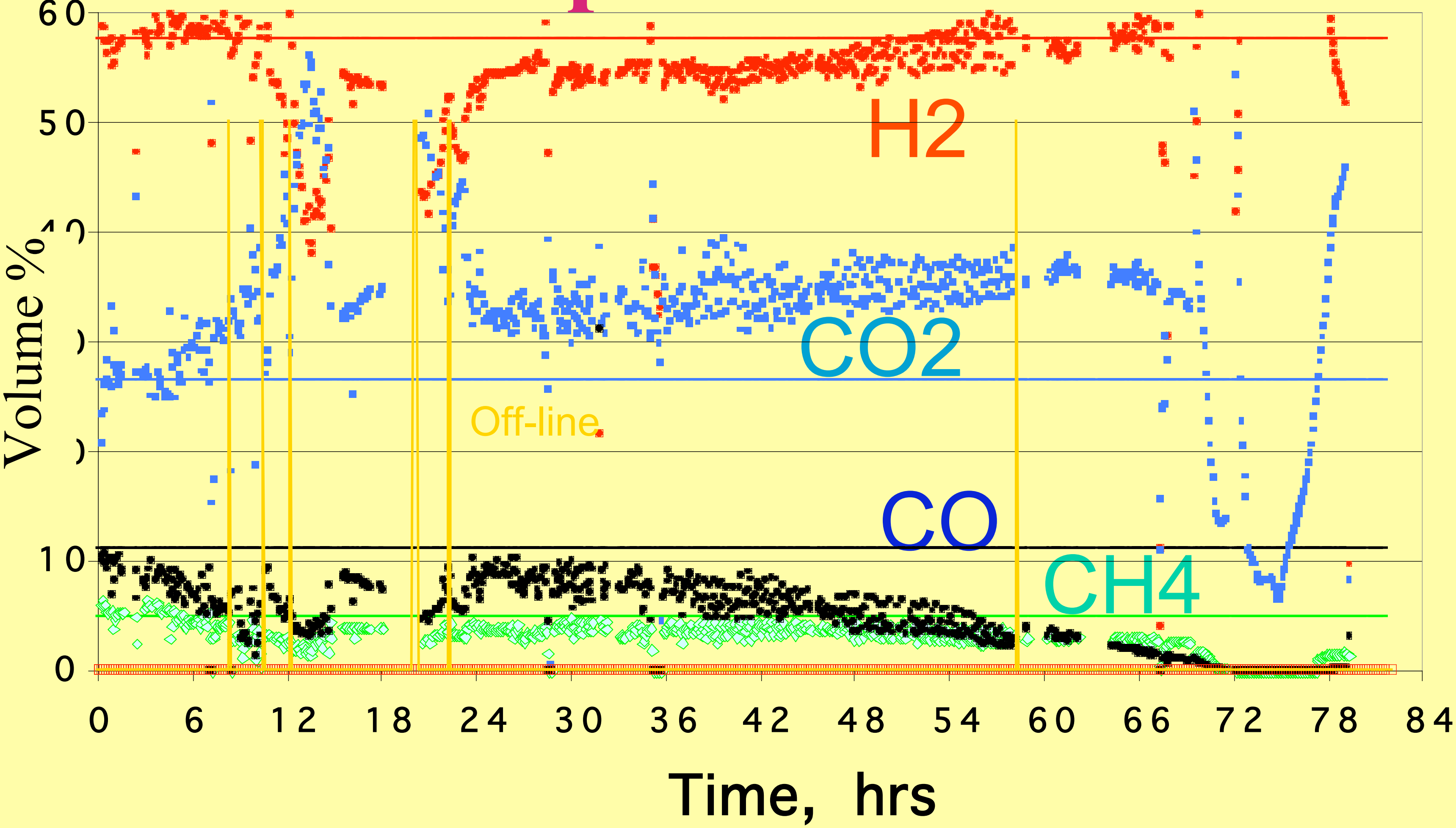
Typical Analysis of Peanut Shell Feedstock

- **Component** **%**
  - Lignin -- **34.8**
  - Glucan -- **21.1**
  - Extractives -- **14.2**
  - Protein -- **11.1**
  - Xylan -- **7.9**
  - Ash -- **3.4**
  - Arabinan -- **0.7**
  - Galactan -- **0.2**
  - Mannan -- **0.1**
  - Others (e.g., free carbohydrates) ------------------------------- **6.5**

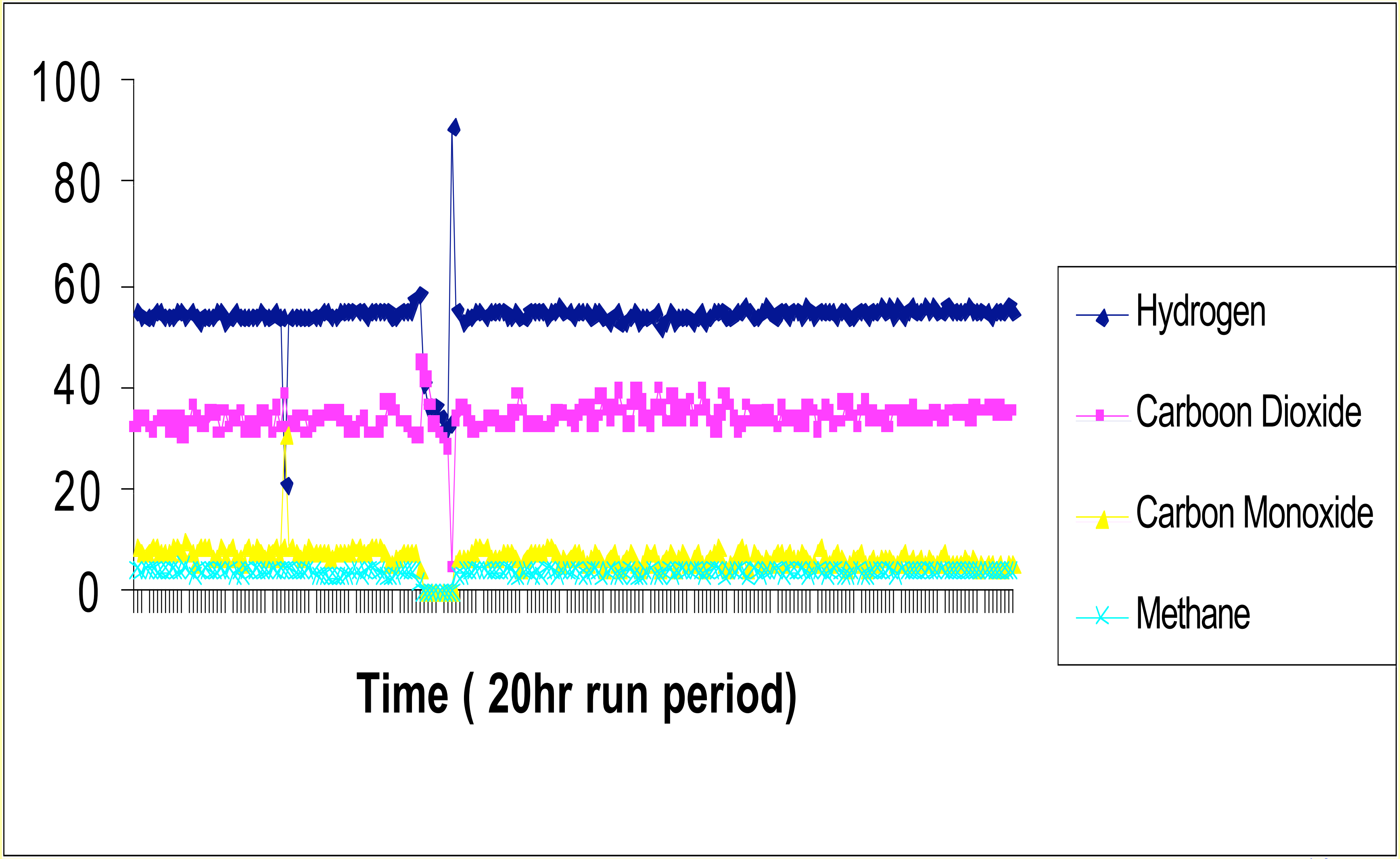
RESULTS: TYPICAL PRODUCT COMPOSITION/ YIELDS

Pyrolyzer (Yields)		Reformer (Gas product composition, on dry N_2-free basis)	
Char	**32%**	**Hydrogen**	**57%**
Water	**32%**	**Carbon Dioxide**	**26%**
Bio-Oils	**31%**	**Carbon Monoxide**	**12%**
Gases	**5%**	**Methane**	**5%**

Gas Composition



Plot of Gas Composition Vs.Time (hrs)



Pyrolysis Bio-Oil Product

- **Empirical Formula: $CH_{1.9}O_{0.7}$**
- **Water: 15 – 25%**
- **Organics: 75 – 85%**
  - Aldehydes, alcohols and acids from carbohydrate fraction
  - Phenolics from lignin fraction
- **Representative Compounds**

Water	Ethanol	Methanol
Cyclohexanol	Formic Acid	Acetic Acid
Glucose	Phenol	O-cresol
2-Butanone	Dodecanoic acid	Tannin

INTERACTIONS AND COLLABORATIONS

- **The project has resulted in significant interactions and collaborations between the following organizations:**
  - Clark Atlanta University, Atlanta, GA
  - EPRIDA Scientific Carbons Inc., Atlanta, GA
  - Enviro-Tech Enterprises Inc., Matthews, NC
  - Georgia Institute of Technology, Atlanta, GA
  - National Renewable Energy Lab, Golden, CO
  - Oak Ridge National Lab, Oak Ridge, TN
  - Southern Company, Atlanta, GA
  - The University of Georgia, Athens, GA

Previous Year Reviewers' Comments

- DOE needs to spend more effort on feed preparation
  - Different feedstocks have different feed handling issues
- Needs to define potential impact of the application of the process to the hydrogen supply base to be developed to support the hydrogen vision
- Future plans need to include system analysis for energy, carbon balance and projected economics

FUTURE WORK

- **Complete Phase 3 pilot demonstration and operability for 1,000 hours**
- **Undertake further research and development studies in a larger scale pilot plant (250 kg H_2/day).**
- **Develop process models for scale up and process optimization.**
- **Perform detailed techno-economic analysis based on pilot results.**
- **Identify and evaluate integrated bioconversion process for different feed stocks and product options.**

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  - Clark Atlanta University
  - EPRIDA Scientific Carbons Inc.
  - Enviro-Tech Enterprises Inc.
  - Georgia Institute of Technology
  - National Renewable Energy Laboratory
  - The University of Georgia, Athens