DEVELOPMENT OF A RENEWABLE HYDROGEN PRODUCTION AND FUEL CELL EDUCATION PROGRAM

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Project ID# ED007

Overview

Timeline
- Start – August 30, 2008
- Finish – Sept. 1, 2011
- 65% complete

Budget
- Total project funding
  - DOE – $300,150
  - Contractor – $74,966
- Funding for FY09
  - $147,366
- Funding for FY10
  - $52, 281 (Planned)

Barriers Addressed
- A – Available, objective, technically accurate information
- B- Clear message on technology readiness and fit into National Policy

Targets – undergraduate and graduate scientists and engineers

Partners
- NREL
- EERC
- Proton Energy Systems
- ND Energy Industry

Objectives / Relevance

The primary objective is to provide formal multi-disciplinary renewable hydrogen production and fuel cell training to undergraduate and graduate level engineers and scientists

Training at three levels to maximize program benefits

- Expose large number of students to basics of hydrogen technologies
- Provide "mid-level" training to moderate number of students
- Provide detailed training to smaller subset with interest and potential to make significant contributions to technology development

The ultimate goal is to provide students with technically relevant and objective training in hydrogen energy necessary to support research, development, and demonstration activities in the government, industry, and academic sectors

Approach

Task Overview

- Task 1: Development of Case Studies
- Task 2: New Course Development
- Task 3: Laboratory Experiments in Hydrogen
- Task 4: MS/PhD Teaching Experience
- Task 5: Summer Internship
- Task 6: Hydrogen Seminary Series
- Task 7: Develop Modules for PowerOn!

Approach: Task 1: Development of Case Studies

Concept: Imbed exposure to hydrogen technologies into many undergraduate courses

Delivery: Use hydrogen-based applications to support fundamental concepts of course content / Introduce to freshman – add depth throughout curriculum

Target Audience: freshmen through graduate level (Intro to Engineering, Mass and Energy Balances, Unit Operations, thermodynamics, Transport Phenomena, Process Dynamics, Power Systems, Professional Integrity)

Dissemination: UND H2Power web site, NSF sponsored Case Study Teaching in Science website, DOE

Expected Outcome: All UND ChE and EE students exposed to minimal level of training (~60 graduates/yr). Interest students into more detailed study of topic. Material will be available for adaptation by many universities.

Approach: Task 2: New Course Development

Concept: Develop new elective courses

Delivery: Traditional courses: 1) Hydrogen Production, Storage, and Transport 2) Hydrogen Utilization

Target Audience: junior/senior and graduate students

Dissemination: Traditional on-campus students, UND distance students, canned course available on-line

Expected Outcome: Provide strong foundation allowing graduates to work in hydrogen related field. Reach relatively large number of students

Approach: Task 3: Laboratory Experiments in Hydrogen

Concept: Enhance student hands-on laboratory experience

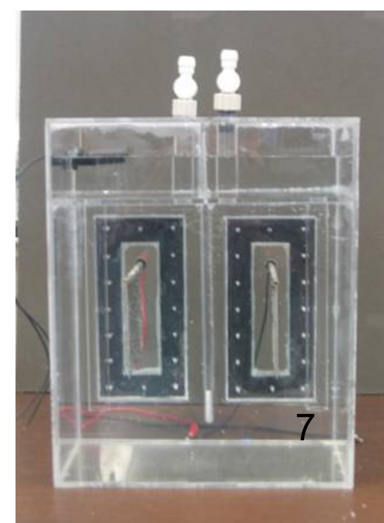
Delivery: Present meaningful laboratory experiences at all levels

Target Audience: All ChE and EE majors

Dissemination: distribute experiments throughout lab sequence. Copies available through UND's h2Power web site and DOE

Expected Outcome: All UND ChE and EE students will have hands-on exposure to electrolysis and fuel cell operations.

Labs available for adoption by other universities



Approach: Task 4: MS/PhD Teaching Experience

Concept: Provide graduate students experience in teaching hydrogen-related material

Delivery: MS/PhD students help develop and deliver material from Tasks 1-3

Target Audience: MS/PhD students

Dissemination: Requirement for all students with hydrogen-related research

Expected Outcome: Teaching combined with research provided through other funding will provide six experts trained at a high level

Approach: Task 5: Summer Internship

Concept: Provide experiential learning to undergraduate students

Delivery: Work with partners to provide internship opportunities

Target Audience: Sophomore and junior level ChE and EE students

Dissemination: Optional for students – will recruit students that have taken UND developed courses and/or involved in UND hydrogen research

Expected Outcome: Five to ten students completing high quality internships preparing them to make meaningful contributions to workforce after graduation

Approach: Task 6: Hydrogen and Fuel Cell Seminary Series

Concept: Utilize experts in field to exposure students to latest developments and career opportunities

Delivery: Establish a Hydrogen Energy Seminar Series / fall and spring seminar

Target Audience: All levels

Dissemination: Available to all on-campus students (not just majors). Recorded lectures made available through h2Power web site

Expected Outcome: Exposure of many students to relevant topics / Informal review of UND program for relevance to industry and government goals

Approach: Task 7: Develop Modules for PowerOn!

Concept: Use undergraduate students to develop training modules for middle school

Delivery: Provide guidance to students developing modules for middle school mobile lab – focus two modules on hydrogen (delivery to middle schoolers not funded under this program).

Target Audience: Undergraduate students

Dissemination: Learning experience limited to those involved in program. Middle schoolers will benefit from the projects developed by these students

Expected Outcome: Up to 10 undergraduate students will obtain additional training. At least two learning modules will be developed.

Approach – FY10 Milestones

Task Number	Project Milestones	Task Completion Date				Progress Notes
		Original Planned	Revised Planned	Actual	Percent Complete	
1	Develop and implement five new case studies	05/15/10		05/15/10	100%	Completed
1	Post new case studies on NSF sponsored web site	06/30/11	8/15/10		0%	Not started
2	Develop and teach new graduate level course	05/15/10		12/31/09	100%	Completed
3	Develop and teach 3 new undergraduate laboratory experiments	05/15/10			100%	Completed
4	MS/PhD students refine laboratory experiments	05/15/10		12/31/10	100%	Completed
5	Identify and place two interns	05/15/01		4/15/10	100%	Completed
6	Presentation for hydrogen seminar	3/15/10		3/15/10	100%	Completed
7	Deliver hydrogen related modules for PowerOn	08/15/10			25%	Ongoing

Approach - Evaluation

- Use ABET assessment tools
  - Student satisfaction with content and delivery
  - Extent exposure prepared for career in hydrogen energy
- Number of students directly impacted
- Number of students pursuing hydrogen related research projects
- Number of students hired to hydrogen related jobs
- Number of web hits for educational content

Technical Accomplishments

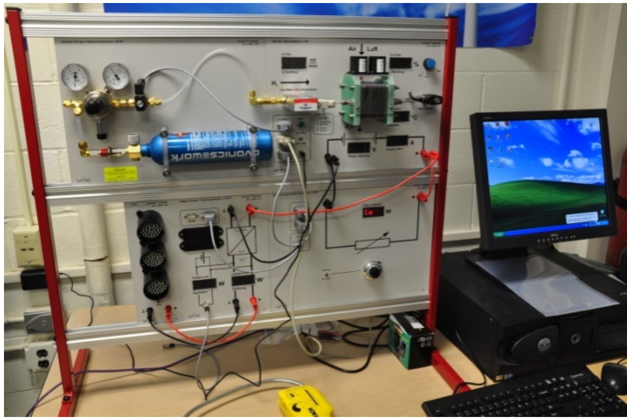
Task 1 – Case study development

- Case studies implemented into undergraduate curriculum
- Currently under revision for publication summer 2010

Task 2 – Development of new courses

- EE 522-Renewable Energy Systems, Fall 2008, modified to highlight fuel cells and electrolysis. Offered to all ChE, EE, and ME students. So far, 30-40 students per semester taking the class.
- Hydrogen production and storage taught Fall 2009
  - Taught simultaneously at undergraduate/graduate and DEDP
  - Recorded for potential rebroadcast / posting on web site
  - 22 students for first offering
- Two ChE and one EE senior design projects related to hydrogen

Technical Accomplishments



Task 3 – Laboratory Experiments in Hydrogen

- Hydro-geniuses lab
  - solar cell, a single cell PEM electrolyzer, two single cell PEM fuel cells, and a small resistive load.
  - I-V curves of fuel cell and the electrolyzer, system efficiencies. Fuel cells operated in series and in parallel.
  - EE 522 lecture course / ChE 322 junior lab
- HP 600 – currently developing lab experiments
  - 600 watt PEM fuel cell stack, a DC/DC and DC/AC converter, metal hydride storage, electric load, integrated control system
  - in-class demonstrations and new laboratory experiments
- Off-grid instructor
  - 40 watt fuel cell with integrated microprocessor, electronic load, metal hydride storage, and the constructor kit.
  - in-class demonstrations and new laboratory experiments

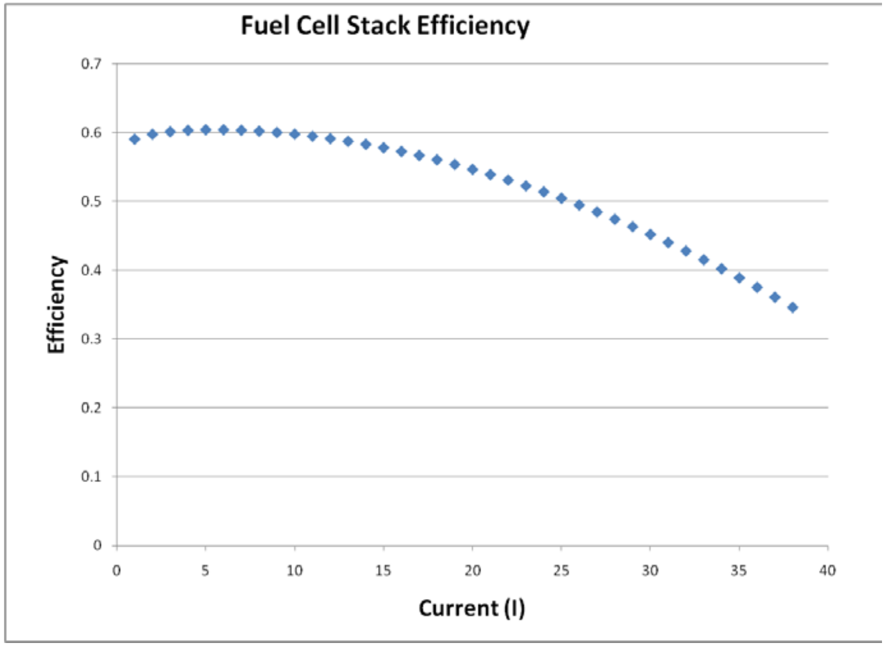
Technical Accomplishments HP600 Laboratory Experiments

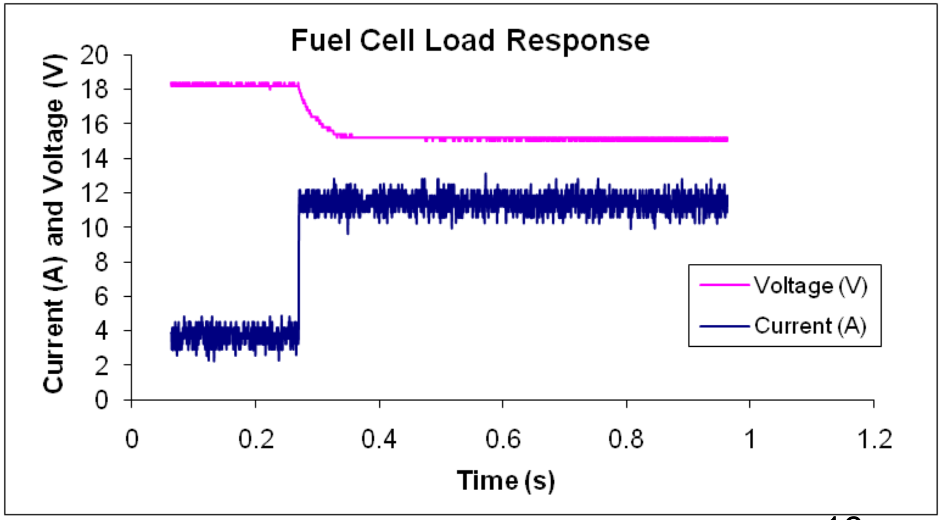
FC behavior knowledge

- Stack efficiency
- Characteristic curves

FC as a power supply

- Load response
- Regulated and unregulated voltage





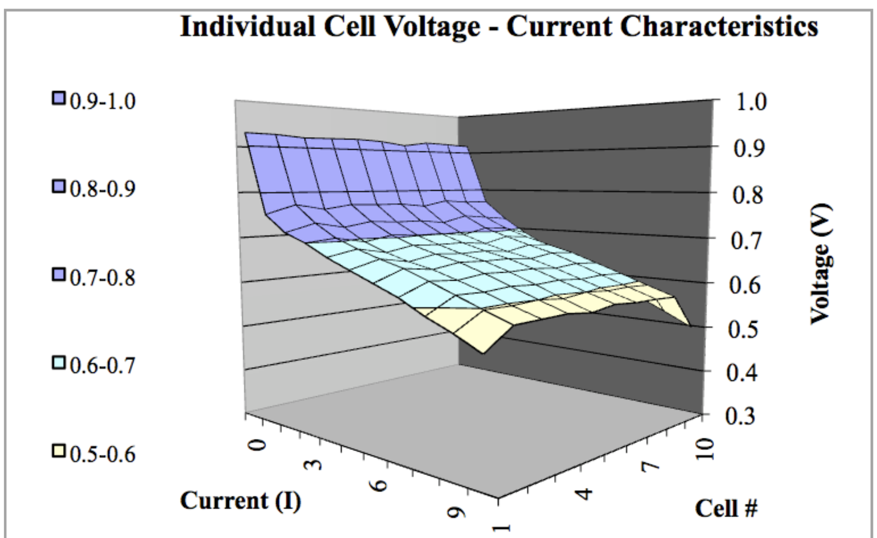
Technical Accomplishments Heliocentric 50W Experiments

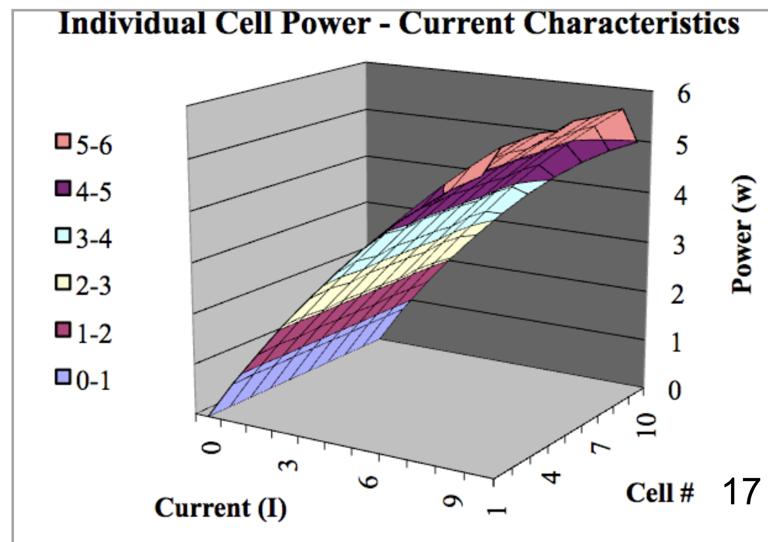
Basic FC knowledge

- Characteristic curve
- Hydrogen current curve
- Efficiency of a fuel cell power supply

Fuel cell behavior

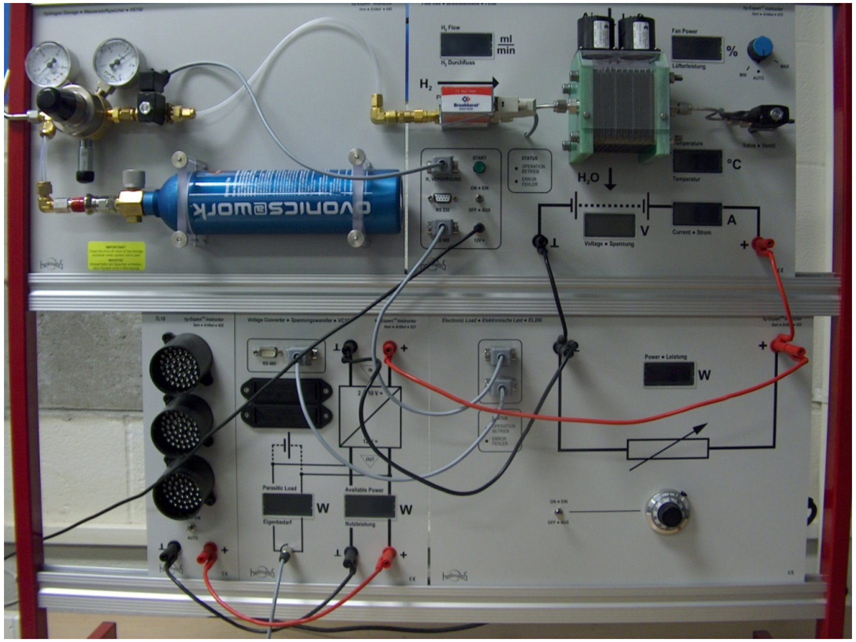
- Influencing parameters
  - Temperature
  - Air supply
  - Internal resistance





Technical Accomplishments Additional Experiments

- Fuel cell applications
  - Remote traffic light
  - Power inverter
- Fuel cell as a power supply
- Load response with incrementally increasing load
  - Increase load as a step function



Technical Accomplishments

Task 4: MS/PhD Teaching Experience

- Nilesh Dale, PhD candidate developed new case studies / input into hydrogen production, storage and transportation course
- Dr. Dale currently employed in Nissan's Fuel Cell program
- Josh Goldade (MS student) and Tessa Haagenson (Undergraduate) developed laboratory experiments / drafted paper for ASEE conference

Task 5: Summer Internship

- Two students placed at the EERC in 2009
- Two students placed at EERC in 2010, one at ORNL in 2009 and another one in 2010
- One 2009 intern now employed at EERC National Center for Hydrogen Technology

Task 6: Hydrogen Seminary Series

- Characterization of PEM Electrolyzer and PEM Fuel Cell Stacks using Electrochemical Impedance Spectroscopy
- Students attended UND Energy & Environmental Research Center Hydrogen Summit

Task 7: Develop Modules for PowerOn!

- Electrolysis and fuel cell car modules developed
- PowerOn public début April 2010 at Super Science Saturday
- Scheduled for summer camps 2010

Collaborations

- Partners
  - NREL: technical review of course content
    - IEEE student tour of wind/H2 program
  - Proton Energy Systems: technical input
  - EERC: internships
- Technical Transfer
  - Development of case studies in progress

Paper Submissions

- Blekhman, D., J. Keith, A. Sleiti, E. Cashman, P. Lehman, R. Engel, M. Mann, and H. Salehfar, 2010, "National Hydrogen and Fuel Cell Education Program Part I: Curriculum," ASEE Annual Conference & Exposition, Louisville, KY.
- Blekhman, D., J. Keith, A. Sleiti, E. Cashman, P. Lehman, R. Engel, M. Mann, and H. Salehfar, 2010, "National Hydrogen and Fuel Cell Education Program Part II: Laboratory Practicum," ASEE Annual Conference & Exposition, Louisville, KY.
- Goldade, J., T. Haagenson, H. Salehfar, and M. Mann, 2010, "Design of A Laboratory Experiment to Measure Fuel Cell Stack Efficiency and Load Response," ASEE Annual Conference & Exposition, Louisville, KY.
- Haagenson, T., J. Goldade, H. Salehfar, and M. Mann, 2010, "New Experiments Provide A Practical Analysis of A 50W Proton Exchange Membrane Fuel Cell," ASEE Annual Conference & Exposition, Louisville, KY.

Future Work – FY10/11

- Publish case studies
- Continue to teach new lecture courses
- Fully implement new laboratory experiments
- Place two new interns
- Sponsor two hydrogen seminars
- Deliver PowerOn! modules at summer camps

Summary

- Good progress has been made
- Program designed to maximize student exposure
- Case studies and lab experiments expose ChE, EE, and ME students in UND program
- New lecture courses provide in-depth technical training
- Sharing material makes impact world wide
- Involvement of NREL and Proton Energy provide added focus to program