

DEVELOPMENT OF A RENEWABLE HYDROGEN PRODUCTION AND FUEL CELL EDUCATION PROGRAM

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ED007

Overview

Timeline

- Start – August 2008
- Finish – September 2011
- 90% complete

Budget

- Total project funding
 - DOE – \$300,150
 - Contractor – \$74,966
- Funding for FY10
 - \$52,281
- Funding for FY11
 - \$0

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

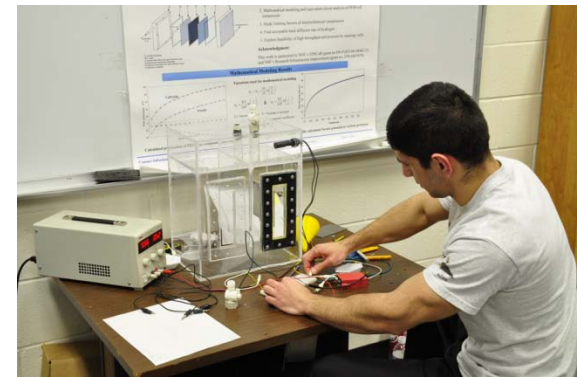
Concept: Imbed exposure to hydrogen technologies into many undergraduate courses

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: New traditional courses and the development of new modules in existing courses

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

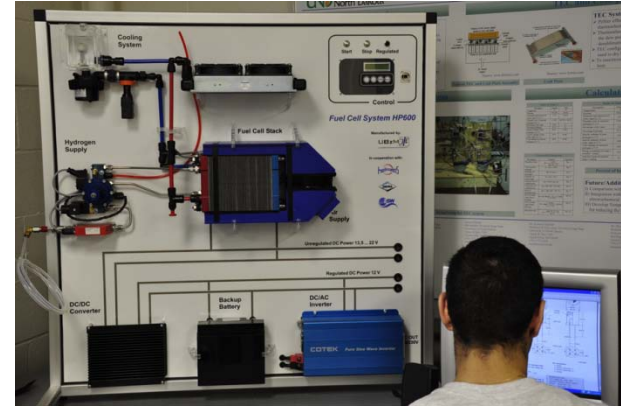
Concept: Provide experiential learning to undergraduate students

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 – FY11 Milestones

| Project Milestones | Task Completion Date | | | | Progress Notes |
|---|----------------------|-----------------|---------|------------------|----------------|
| | Original Planned | Revised Planned | Actual | Percent Complete | |
| Post new case studies on NSF sponsored web site | 06/30/11 | | | 0% | Not started. |
| Develop and teach 3 new undergraduate laboratory experiments | 05/15/10 | 5/15/11 | 3/15/11 | 100% | Completed |
| Identify and place two interns | 05/15/11 | | 3/1/11 | 100% | Completed |
| Presentation for hydrogen seminar | 3/15/11 | | 2/24/11 | 100% | Completed |
| <ul style="list-style-type: none"> • Implement certificate programs through new UND Institute for Energy Studies • Prepare article for Chemical Engineering Education • Deliver PowerOn! modules at summer camps | | | | | |

Approach - Evaluation

- **Student satisfaction with content and delivery**
- **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 – sustainable after program ends
- Currently under revision for publication summer 2011
- 54 students graduated in 2010 with exposure to case studies
- All future graduates from ChE and EE will graduate with exposure to hydrogen based case studies – 50 to 60 per year.
- Case studies presented for publication in NSF National Center for Case Study Teaching in Science

Technical Accomplishments

Task 2 – Development of new courses

- Hydrogen production and storage
 - New course develop and added as elective
 - Enrollment average 24 per offering, ChE, ME, EE
- EE 522-Renewable Energy Systems
 - Modified to highlight fuel cells and electrolysis
 - Enrollment ~20 students per offering, EE, ChE, ME
- Fuels Technology
 - Modified to highlight gasification and other hydrogen production technologies
 - Enrollment ~ 20 students, ChE, ME
- All courses taught simultaneously to undergraduate, graduate and distance students
- One ChE and three EE senior design project related to hydrogen

Technical Accomplishments

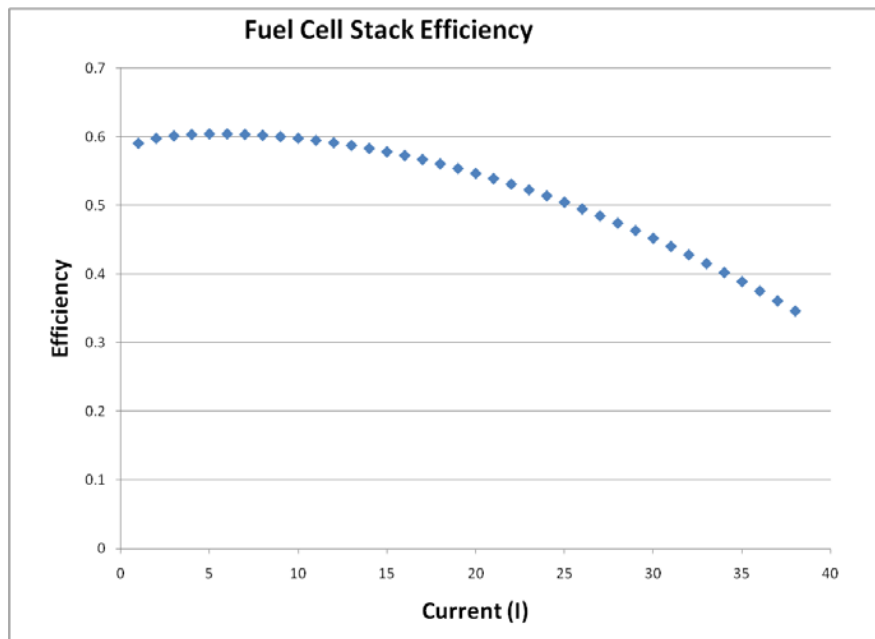
Task 3 – Laboratory Experiments in Hydrogen

- 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 for ChE 322
- 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 for ChE 322
- Fuel cell membrane
 - Demonstrates how membranes are made – ChE 322

HP600 Laboratory Experiments

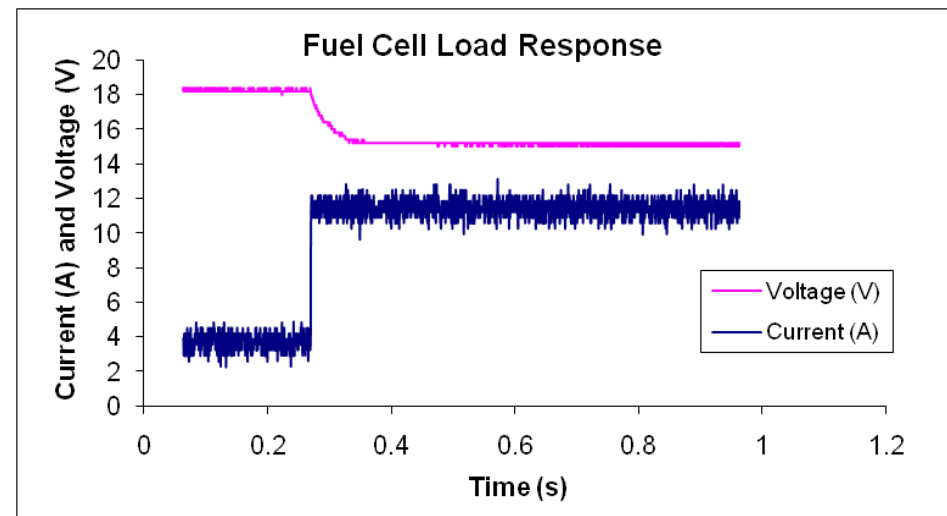
FC behavior knowledge

- Stack efficiency
- Characteristic curves



FC as a power supply

- Load response
- Regulated and unregulated voltage



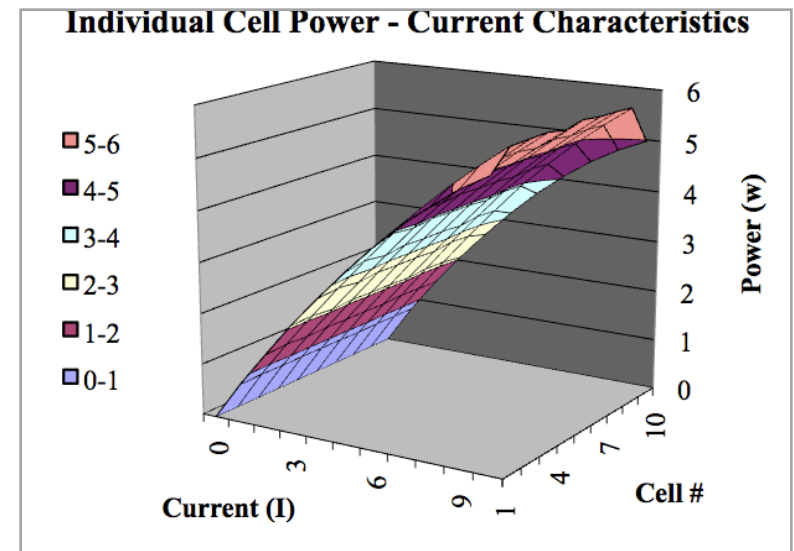
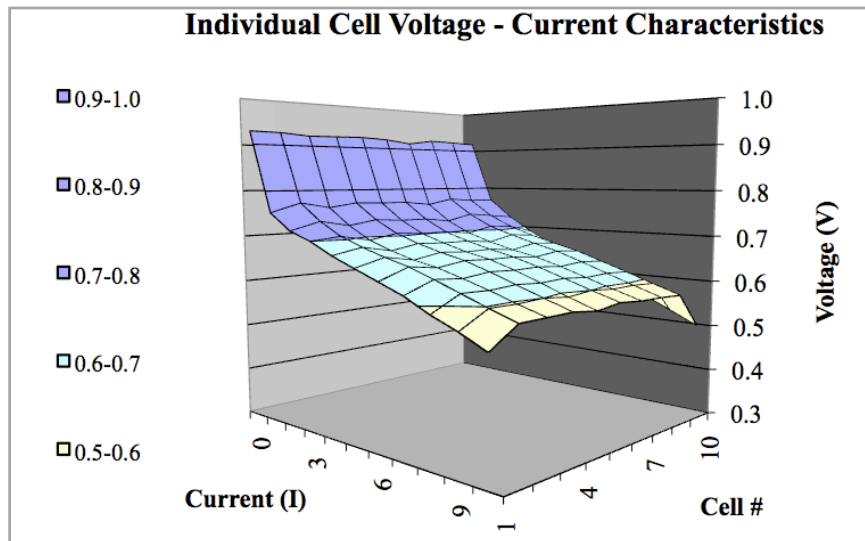
Heliocentric 50W Experiments

Basic FC knowledge

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

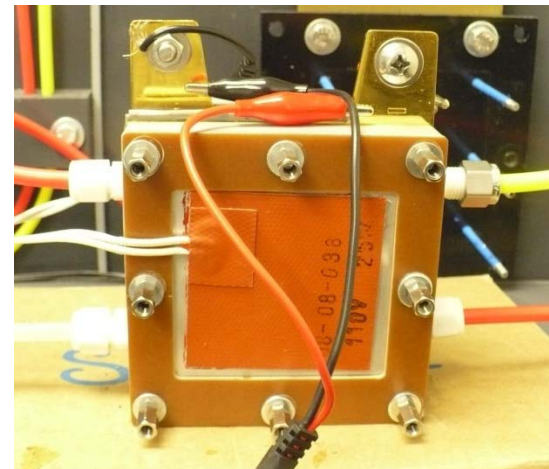
Fuel cell behavior

- Influencing parameters
 - Temperature
 - Air supply
 - Internal resistance



Membrane Experiments

- Demonstrates how membranes are made
- Students develop understanding of part and functions of membrane
- Demonstrates use of single cell test system
- Shows impact of loading and catalyst type on performance.



Technical Accomplishments

Task 4: MS/PhD Teaching Experience

- Jivan Thrakre, PhD candidate developed experiments for membrane production and testing
- Josh Goldade, MS, presented paper on lab experiments he developed or ASEE conference

Task 5: Summer Internship

- Two students placed at EERC in 2010, one at ORNL
- One 2010 intern now employed at EERC National Center for Hydrogen Technology
- Two students placed at EERC for 2011

Technical Accomplishments

Task 6: Hydrogen Seminary Series

- Catalyst Development for Fuel Cell Applications
- H₂ Production and CO₂ Capture via Gasification
- Students attended UND Energy & Environmental Research Center Hydrogen Summit

Task 7: Develop Modules for PowerOn!

- Modules developed in special topics class – 12 undergraduate students in AY 2011
- Six events sponsored during the past year
- Made contact with approximately 650 kids

Collaborations

- **Partners**

- NREL: technical review of course content
 - IEEE student tour of wind/H2 program
- Proton Energy Systems: technical input
- EERC: internships

- **Technical Transfer**

- Papers presented at ASEE conference
- Development of case studies in progress



Future Work – FY11

- Publish case studies
- New lecture course into course catalog
- Make new laboratory experiments permanent
- Implement certificate programs through new UND Institute for Energy Studies
- Prepare article for Chemical Engineering Education
- Place two new interns
- Deliver PowerOn! modules at summer camps

Summary

- **Over 200 students directly impacted by program**
 - Over 150 students exposed to case studies and laboratory experiments – all future graduates will be exposed
 - 27 students involved in senior design projects
 - 73 students have taken hydrogen related courses
 - 21 students involved with PowerOn / >650 youth
 - 2 PhD and 2 MS students developed material
 - 9 interns placed
 - 3 students chose hydrogen related project for MS research
- **2 undergraduates placed at EERC National Hydrogen Center, 1 at NREL, 2 PhD graduates placed with Nissan**
- **Results presented in 1 UND paper and 2 joint papers**