Hydrogen Education Curriculum Path at Michigan Technological University

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Overview

Timeline

- Project Start Date: 09/01/2008
- Project End Date: 07/31/2011
- Percent Complete: 56%

Budget

- Total Project Funding $482,244
  - DOE $375,000
  - MTU $107,244
- Funding Received FY09 $208,792
- Funding for FY10 $0

Education Barriers Addressed

- Lack of information (A)
- Mixed messages (B)
- Disconnect between information and dissemination (C)

Partners

Michigan Technological University

- Chemical Eng., Mechanical Eng., Electrical Eng., Social Sciences, Keweenaw Research Center

Informal Collaboration with Other National Institutions & Industry

DOE Field Office & Headquarters

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Broad Objectives of this Project

- **Task 1.0** *Develop and/or Refine Courses in Hydrogen Technology*
- **Task 2.0** *Develop Curriculum Programs in Hydrogen Technology*
- **Task 3.0** *Develop Modules for Core and Elective Engineering Courses*
- **Task 4.0** *Develop Modules to Supplement Commonly Used Chemical Engineering Texts*
- **Task 5.0** *Project Management and Reporting*

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Relevance to DOE Hydrogen Program: Education Objectives

- Expand existing university programs in fuel cell and hydrogen technologies
  - **Past Year**: Developed new courses / content and delivered it to a large number of UG & GR students in various engineering disciplines (Tasks 1, 3, 4).
  - **Project:** Annual dissemination / websites (task 5) make content available for use at other institutions. There is potential for a large impact as many engineering departments do not offer courses or even problems within the core courses in hydrogen and fuel cell technology.

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Relevance to DOE Hydrogen Program: Education Objectives

- Expand existing university programs in fuel cell and hydrogen technologies
  - **Past Year & Project**: We continue to develop H_2 and fuel cell student projects (Task 2). Our students learn best by doing real design and implementation projects in H_2 and fuel cell technology which motivates students for future careers in H_2 energy.
  - **Past Year**: Created and approved an Interdisciplinary Minor in Hydrogen Technology (task 2) to attract tomorrow's energy leaders.

Approach: Project

Unique Curriculum Development

Module and Supplement Testing

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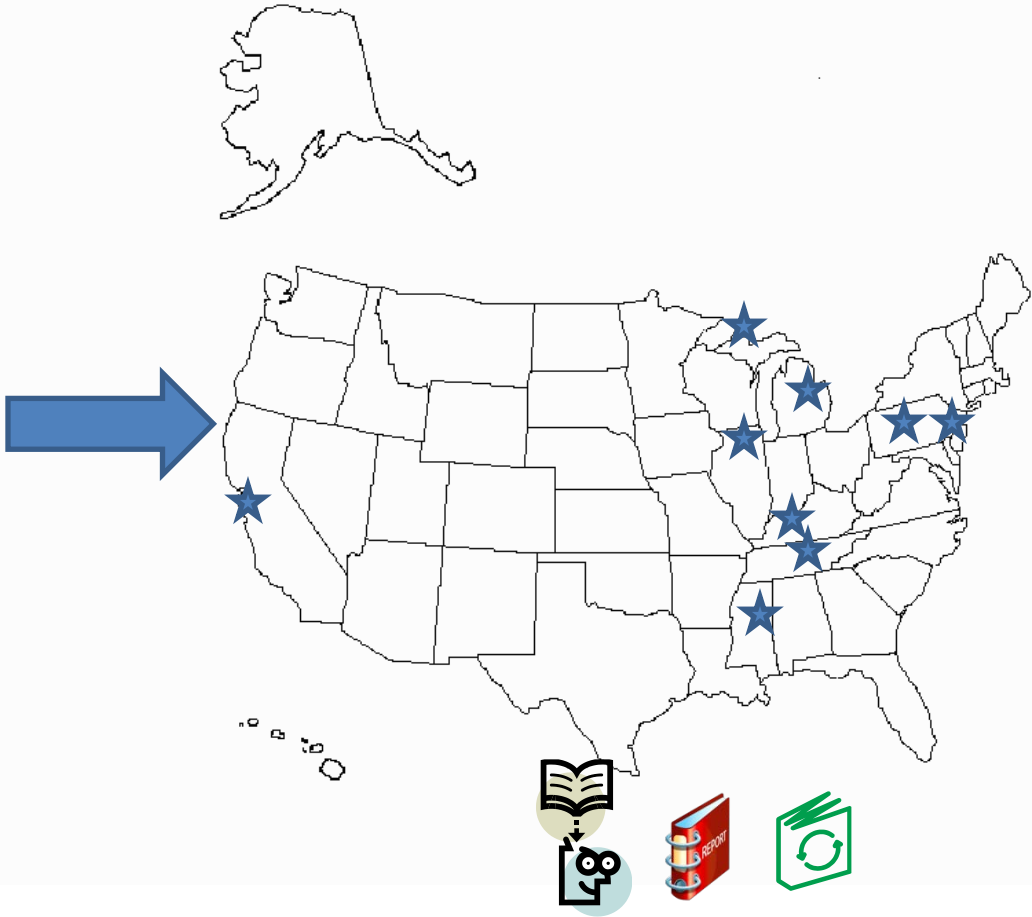
Michigan Technological University

Chem Eng Mech Eng Elec Eng

Hydrogen Courses & Curriculum
Modules
Text Supplements



Approach: Broad Impacts

National Dissemination

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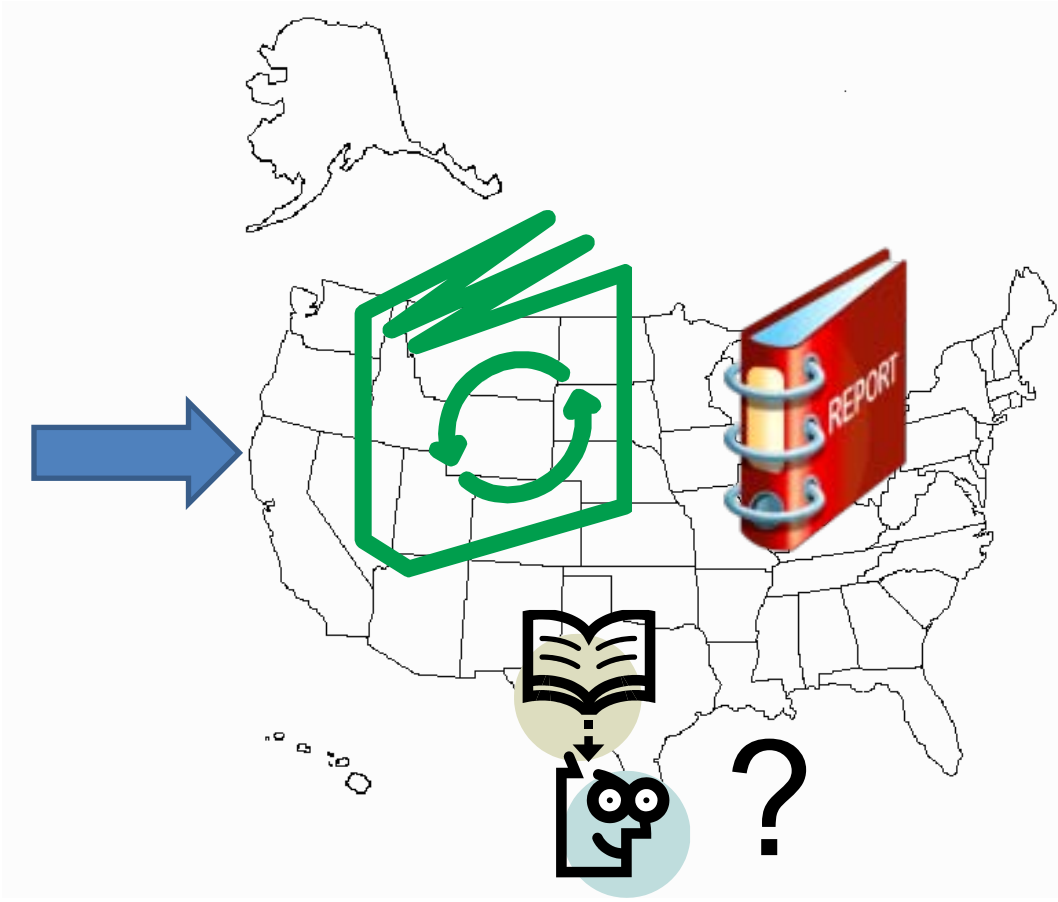
Chem Eng Mech Eng Elec Eng

Hydrogen Courses & Curriculum
Modules
Text Supplements



Milestones for FY09/FY10

Month/Yr	Milestone
Sept. 08 Jan. 09 Sept. 09 Jan. 10	Students in Alternative Fuels Group Enterprise work on hydrogen projects
Sept. 08	Begin development of modules for chemical engineering courses
Jan. 09	Submit proposal for undergraduate minor
Jan. 09	Begin national testing of existing chemical engineering modules

Milestones for FY09/FY10

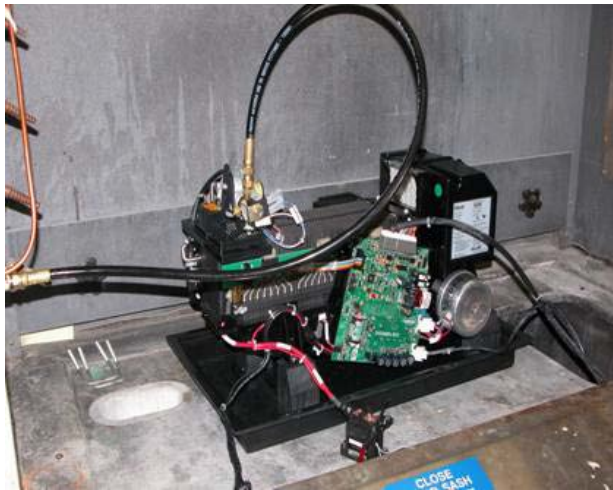
Month/Yr	Milestone
Jan. 09	Begin development of modules for Felder & Rousseau text
May 09	Begin development of modules for electrical and mechanical engineering courses
May 09	Begin development of new course material
July 09	Refine existing fuel cell courses
Sept. 09 Sept. 10	Teach Fundamentals of Hydrogen as an Energy Carrier
Sept. 09 Sept. 10	Teach refined Fuel Cells courses

Milestones for FY09/FY10

Month/Yr	Milestone
Dec. 09	Finish development of modules for chemical engineering courses
Jan. 10 Jan. 11	Teach Hydrogen Measurements Laboratory
Jan. 10	National testing of course modules
Apr. 10	Graduate certificate proposal
May 10	Continue module development for core courses
Jul. 10	Begin development of modules for Geankoplis text

Technical Accomplishments

- **Task 1 –** *Develop and/or Refine Courses in H_2 Tech.*
- ***Barriers Addressed* –** ABC
- ***Relevance* –** Provide accurate technical information on hydrogen and fuel cells to students, provide hands-on experience in a laboratory environment
- **Subtask 1.1** *Develop Fundamentals of Hydrogen as an Energy Carrier Course*
  - *Task completed Dec. 2009 (Project year 2)*
  - *Taught Fall 2009 with 27 students*



Ballard 1.2 kW Fuel Cell in the Hydrogen Measurements Laboratory

Technical Accomplishments

- **Task 1 –** *Develop and/or Refine Courses in H_2 Tech.*
- **Subtask 1.2** *Develop H_2 Measurements Laboratory*
  - *Task completed Dec. 2009 (Project year 2)*
  - *Taught Spring 2010 with 11 students*
  - *4 equipment stations from Heliocentris*
- **Subtask 1.3** *Refine Existing Fuel Cell Courses*
  - *Task completed Dec. 2009 (Project year 2)*
  - *Two courses taught Fall 2009*
  - *CM/ENT 3974 (mostly undergraduates) had 41 students*
  - *MEEM 4260/5990 (mostly grad students) had 20 students*

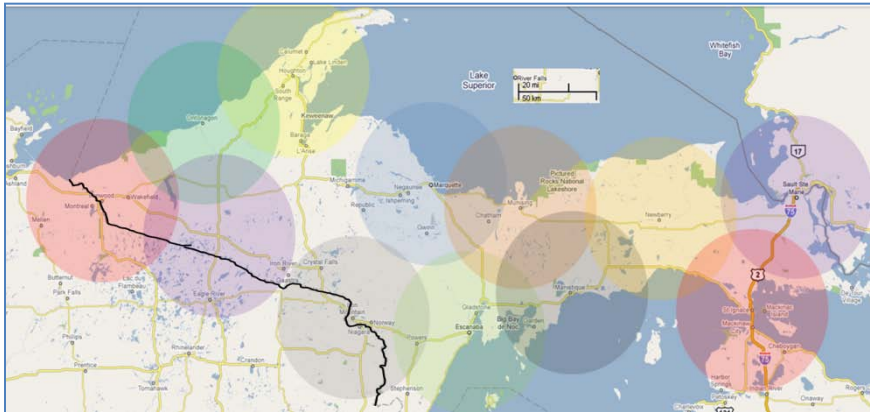
Technical Accomplishments

- **Task 2 –** *Develop Curriculum in Hydrogen Technology*
- ***Barriers Addressed*** **–** ABC
- ***Relevance*** **–** Provide hydrogen / fuel cell experience
- **Subtask 2.1** *Develop Minor in Hydrogen Technology*
  - *Task completed May 2009 (Project year 1)*
  - *16 credit Interdisciplinary Minor in Hydrogen Technology*
- **Subtask 2.2** *Develop Certificates*
  - *Task underway (Expected completion Fall 2010)*

Two Ballard 1.2 kW Fuel Cells on the John Deere e-Gator as part of an Alternative Fuels Group Enterprise project

Technical Accomplishments

- **Task 3 –** *Develop Modules for Core and Elective Engineering Courses*
- ***Barriers Addressed* –** ABC
- ***Relevance* –** Ease of use by faculty at other institutions
- **Subtask 3.1** *Develop Modules for Chemical Engineering*
  - *Task completed March 2010 (Project year 2)*
  - *Over 28 modules covering introductory material, material and energy balances, thermodynamics, fluid mechanics, heat and mass transport, kinetics and reaction engineering, and separations*



Vision of a hydrogen economy in 2025 for Michigan's Upper Peninsula as part of an Alternative Fuels Group Enterprise project

Technical Accomplishments

- **Task 3 –** *Develop Modules for Core and Elective Engineering Courses*
- **Subtask 3.2** *Develop Modules for Mechanical Eng.*
  - *Task underway (Expected completion March 2011)*
  - *Completed heat transfer modules, drafts under revision in fluid mechanics, energy conversion, combustion and air pollution, nonlinear systems analysis and control, failure of material in mechanics, and metal forming*
- **Subtask 3.3** *Develop Modules for Electrical Eng.*
  - *Task underway (Expected completion March 2011)*
  - *Completed for power and energy laboratory, under revision for introduction to power and energy*

Technical Accomplishments

- **Task 4 –** *Develop Modules to Supplement Commonly Used Chemical Engineering Texts*
- ***Barriers Addressed*** **–** ABC
- ***Relevance*** **–** Ease of use by faculty at other institutions
- **Subtask 4.1** *Develop Modules for Felder and Rousseau text*
  - *Introductory chemical engineering course on mass and energy balances*
  - *Progress underway (Expected completion June 2010)*
  - *Modules for chapters 2-8 completed, chapters 9 and 11 remaining*

Technical Accomplishments

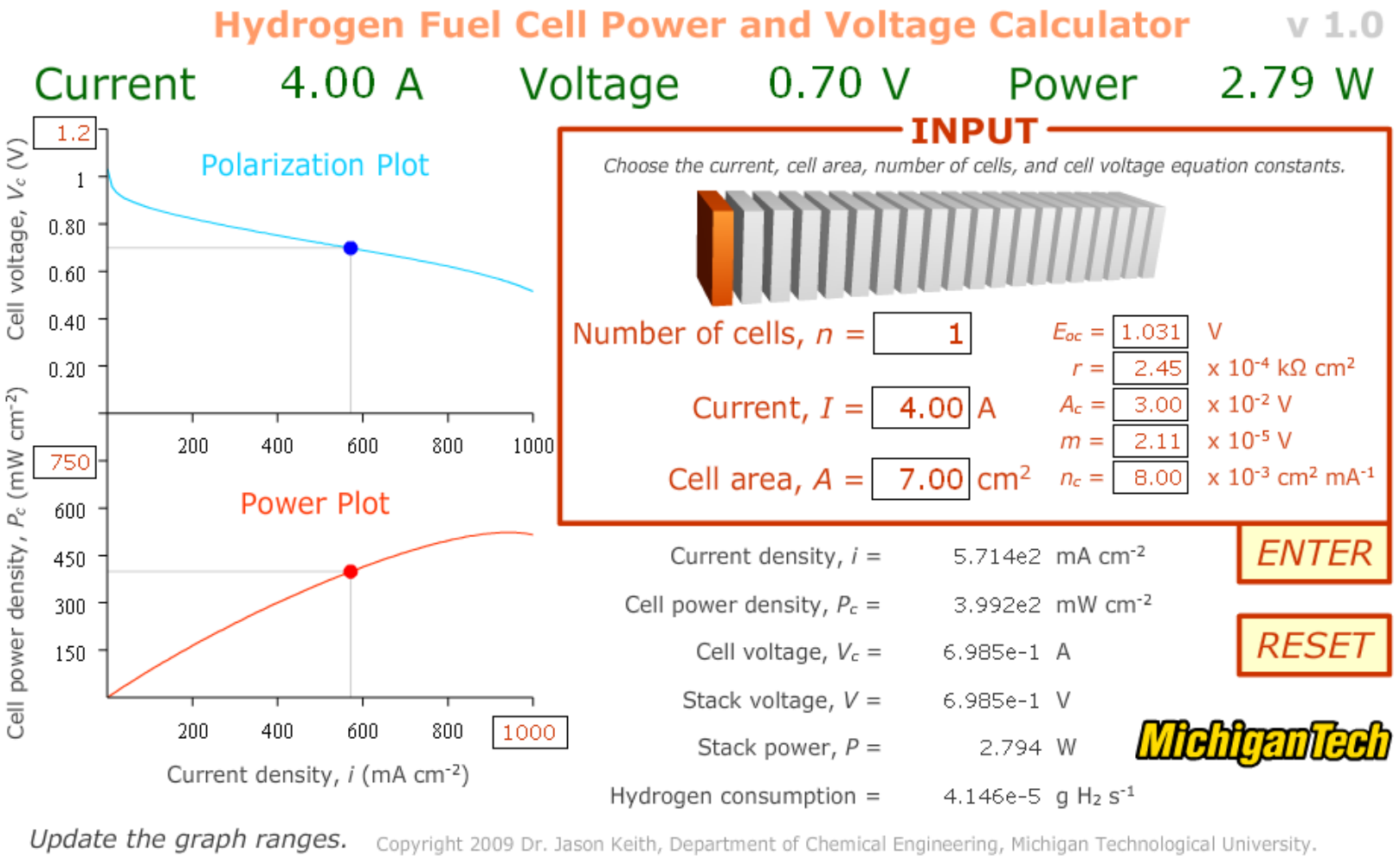
- **Task 4 –** *Develop Modules to Supplement Commonly Used Chemical Engineering Texts*
- **Subtask 4.2** *Develop Modules for Geankoplis text*
  - *Junior-level course on fluid mechanics and heat and mass transfer*
  - *Task to begin after completion of Subtask 4.1*

Heliocentris 50 W Fuel Cell in the Hydrogen Measurements Laboratory

Technical Accomplishments

- **Task 5 –** *Project Management and Reporting*
- Quarterly reports all submitted on time
- Oral presentations delivered at national meetings in Chemical Engineering, Mechanical Engineering, and Engineering Education

Technical Accomplishments



Input boxes: number of cells, stack current, and fuel cell cross-sectional area
Adjust parameters to move a point along a polarization plot and power density plot
Calculated parameters include voltage, power, and hydrogen consumption rate
Online at http://tinyurl.com/FCabacus

Listing of External Reviewers

H. Scott Fogler, University of Michigan

Michael Gross, Bucknell University

Don Chmielewski, Illinois Institute of Technology

Pat Walton, Michigan State University

Adrienne Minerick, Mississippi State University

Don Visco, Tennessee Technological University

David Silverstein, University of Kentucky

Kevin Dahm, Rowan University

Claire Komives, San Jose State University

Listing of External Reviewers

- Fan Liang Chan, UltraCell
- Chau-Chyun Chen, Aspen Technology
- Gavin Towler, UOP LLC

Discussions on project goals and accomplishments with industrial stakeholders:

- General Motors
- United States Army
- National Hydrogen Association
- 3M
- United Technologies
- American Chemical Society
- Rolls Royce
- Great Lakes Fuel Cell Education Partnership (joined 2009)

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Future Work: Rest of FY10

- Module development: Mechanical Engineering and Electrical Engineering courses
- Finish module development for Felder & Rousseau supplement
- Begin module development for Geankoplis supplement

Future Work: FY11

- Continue student projects in Alternative Fuels Group Enterprise
- Teach courses (Fuel Cells, Hydrogen as an Energy Carrier, Hydrogen Measurements Lab)
- Continue to test modules
  - Chemical, Mechanical, and Electrical Engineering courses
  - Textbook supplements
- National dissemination

Summary

- This work will help educate students on the advantages, disadvantages, challenges, and opportunities of hydrogen and hydrogen fuel cells within the nation's energy economy
  - Hydrogen Technology Course Development
  - Hands-on Project Work Through Alternative Fuels Group Enterprise
  - Modules developed for chemical engineering courses
  - Modules developed to supplement introductory chemical engineering text
  - National dissemination : American Institute of Chemical Engineers, American Society for Mechanical Engineering, American Society for Engineering Education

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- Thank you for your attention!

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