

# Hydrogen Education Curriculum Path at Michigan Technological University

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***MichiganTech***

ED005

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# Overview

## Timeline

- Project Start Date: 09/01/2008
- Project End Date: 07/31/2011
- Percent Complete: 95%

## Budget

- Total Project Funding \$482,244
  - DOE \$375,000
  - MTU \$107,244
- Funding Received FY10 \$0
- Funding for FY11 N/A

## 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

# Broad Objectives of this Project

- **Task 1.0** *Develop and/or Refine Courses in Hydrogen Technology (100% completed)*
- **Task 2.0** *Develop Curriculum Programs in Hydrogen Technology (100% completed)*
- **Task 3.0** *Develop Modules for Core and Elective Engineering Courses (90% completed)*
- **Task 4.0** *Develop Modules to Supplement Commonly Used Chemical Engineering Texts (90% completed)*
- **Task 5.0** *Project Management and Reporting (75% completed)*

# Relevance to EERE Fuel Cell Technologies


## Program: Education Objectives

- Expand existing university programs in fuel cell and hydrogen technologies
  - **Past Year:** Developed hydrogen and fuel cell content and delivered it to a large number of UG & GR students in various engineering disciplines (Tasks 1, 3, 4). *Taught 3 lecture classes Fall 2010.*
  - **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.

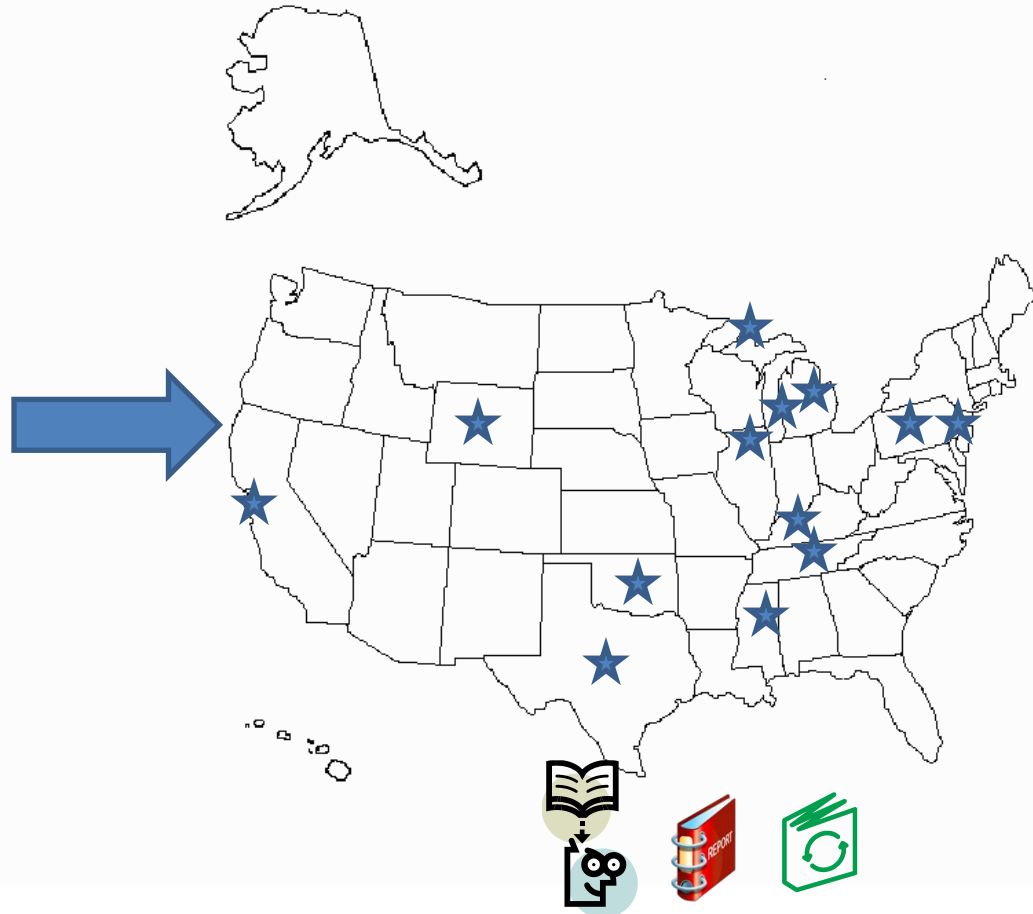
# Relevance to EERE Fuel Cell Technologies

## Program: Education Objectives

- Expand existing university programs in fuel cell and hydrogen technologies
  - **Past Year & Project:** *In Fall 2010 and Spring 2011* students worked on H<sub>2</sub> and fuel cell projects (Task 2). Our students learn best by doing real design and implementation projects in H<sub>2</sub> and fuel cell technology to motivate future career interests.
  - **Past Year:** Created and approved a Graduate Certificate in Hybrid and Electric Drive Vehicle Engineering (task 2) to attract tomorrow's energy leaders. The hydrogen / fuel cell courses are electives for this certificate.



Hydrogen Courses & Curriculum  
Modules   
Text Supplements 



# Approach: 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
- ★ Keisha Walters, Mississippi State University
- ★ Cindy Rice-York, Tennessee Technological University
- ★ David Silverstein, University of Kentucky
- ★ Kevin Dahm, Rowan University
- ★ Claire Komives, San Jose State University
- ★ Karen High, Oklahoma State University
- ★ Patrick Johnson, University of Wyoming
- ★ Tom Edgar, University of Texas at Austin

# Approach: Broad Impacts

## National Dissemination

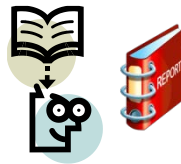
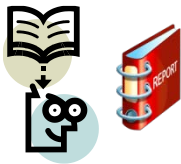
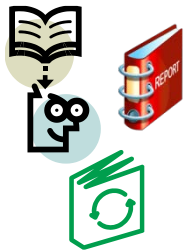
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Chem Eng

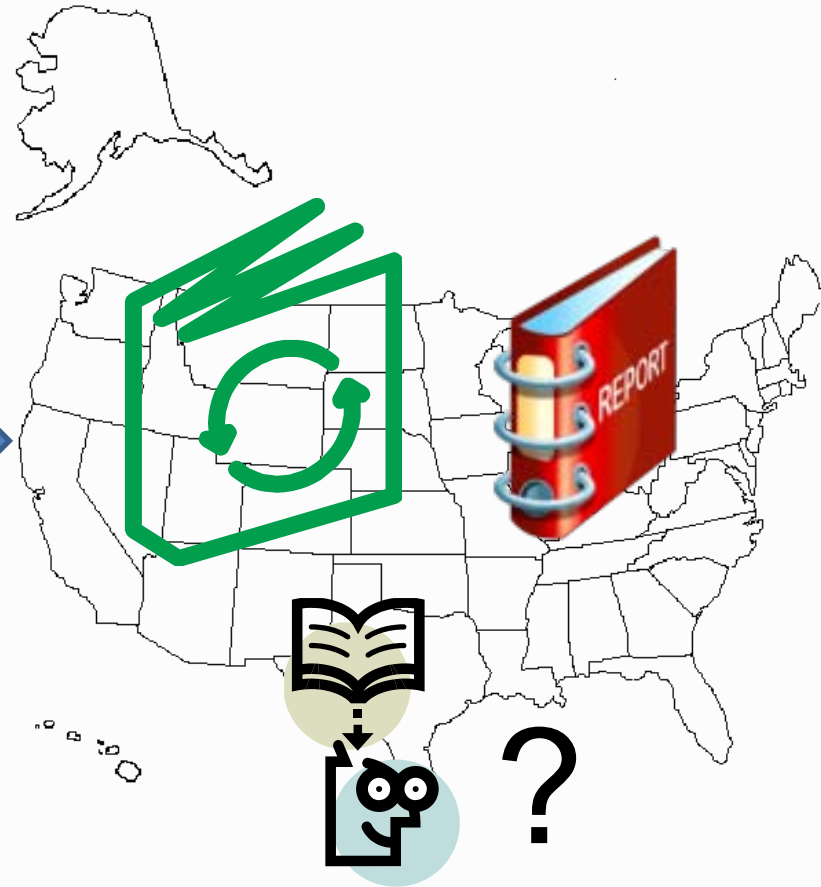
Mech Eng

Elec Eng



Hydrogen Courses & Curriculum  
Modules

Text Supplements



**Action for national dissemination: 8 conference presentations; 6 conference papers; module testing at a dozen institutions nationwide; industry review**



# Approach: 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)

# Milestones for FY10/FY11

Month/Yr	Milestone
Sept. 09 Jan. 10 Sept. 10 Jan. 11	Students in Alternative Fuels Group Enterprise work on hydrogen projects
Sept. 09 Jan. 10 Sept. 10 Jan. 11	Continue national testing of existing hydrogen and fuel cell modules in chemical, mechanical, and electrical engineering
Apr. 10	Approved proposal for graduate certificate

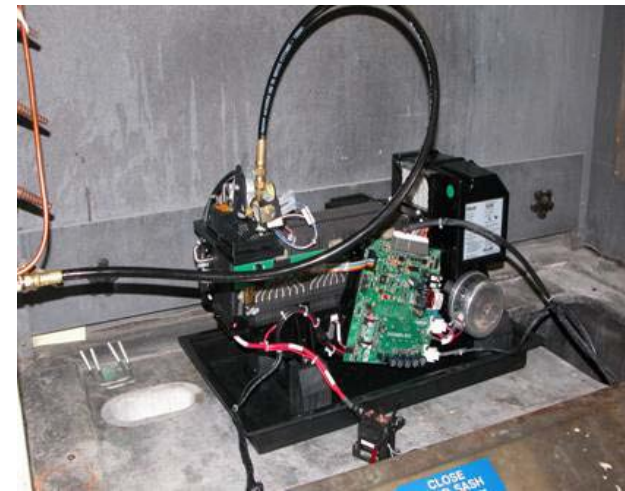
# Milestones for FY10/FY11

Month/Yr	Milestone
June 10	Complete development of modules for Felder & Rousseau text
July 10	Begin developing modules for Geankoplis text
Sept. 10 Sept. 11	Teach Fundamentals of Hydrogen as an Energy Carrier
Sept. 10 Sept. 11	Teach refined Fuel Cells courses
May 11	Complete development of modules for electrical and mechanical engineering courses

# Technical Accomplishments

- **Task 1** – *Develop and/or Refine Courses in H<sub>2</sub> Tech.*
- **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 and Fall 2010*
  - *2010 enrollment of 15 students*
    - *H<sub>2</sub> production from various energy sources*
    - *Class evaluations over 2 years: 4.7/5.0*
    - *Used problem modules from Task 3*

Ballard 1.2 kW Fuel Cell in the  
Hydrogen Measurements Laboratory



# Technical Accomplishments

- **Task 1** – *Develop and/or Refine Courses in H<sub>2</sub> Tech.*
- **Subtask 1.2** *Develop H<sub>2</sub> Measurements Laboratory*
  - *Task completed Dec. 2009 (Project year 2)*
  - *Taught Spring 2010 with 11 students*
  - *4 equipment stations from Heliocentris*
    - *Electrolysis, Faraday's law, Fuel Cell polarization, Fuel Cell car*
    - *Class evaluations 4.9/5.0*
- **Subtask 1.3** *Refine Existing Fuel Cell Courses*
  - *Task completed Dec. 2009 (Project year 2)*
  - *Two courses taught Fall 2009 and Fall 2010*
  - *2010 enrollment*
    - *CM/ENT 3974 (mostly undergraduates) had 23 students*
    - *Class evaluations 4.8/5.0, used problem modules from Task 3*
    - *MEEM 4260/5990 (mostly grad students) had 25 students*

# Technical Accomplishments

- **Task 2** – *Develop Curriculum in Hydrogen Technology*
- **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 approved by MTU administration*
    - *Enterprise Project work average semester enrollment 25-30 students*
    - *Enterprise Project work course evaluations: 4.7/5.0*
    - *Students are signing up for Minor*
    - *Some loss in interest due to increased DOE emphasis on hybrid and electric vehicles*

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



# Technical Accomplishments

- **Task 2** – *Develop Curriculum in Hydrogen Technology*
- **Subtask 2.2** *Develop Certificates*
  - *Task completed Apr. 2010 (Project year 2)*
  - *15 credit Graduate Certificate in Hybrid and Electric Drive Vehicle Engineering approved by MTU administration*
    - *End-of-term surveys suggest that grad students are highly interested in certificate*
    - *Courses developed in task 1 are part of the certificate*

# Technical Accomplishments

- **Task 3** – *Develop Modules for Core and Elective Engineering Courses*
- **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 40 modules covering introductory material, material and energy balances, thermodynamics, fluid mechanics, heat and mass transport, kinetics and reaction engineering, separations, process safety and process design, and materials science and engineering*
    - *Testing at MTU to >200 students per year*
    - *Tested at 12 external institutions, engaging hundreds of students*
    - *Very highly positive reviews from students and instructors testing these modules; content excites students to learn fundamentals to apply to new energy problems*



# Technical Accomplishments

- **Task 3** – *Develop Modules for Core and Elective Engineering Courses*
- **Subtask 3.2** *Develop Modules for Mechanical Eng.*
  - *Task underway (Expected completion July 2011)*
  - *Completed over 20 modules in fluid mechanics, heat transfer fuel cell technology, internal combustion engines, 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 July 2011)*
  - *Completed 6 modules in introduction to power and energy and power and energy laboratory*
- *Positive feedback from students, additional testing to occur after modules are complete*

# Technical Accomplishments

- **Task 4** – *Develop Modules to Supplement Commonly Used Chemical Engineering Texts*
- **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 (used by about 3000+ students at 100+ schools each year)*
  - *Task completed June 2010 (Project year 2)*
  - *90 problem modules for chapters 2-9 and 11*
  - *Materials published online*
  - *Additional problems will be published in 4<sup>th</sup> edition of book*

# 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 (book used by about 1500+ students at 50+ schools each year)*
  - *Task underway (to be completed March 2011)*
  - *Over 70 problem modules developed for chapters 1-7, 9, and 11*
  - *Material published online*
  - *No planned revision of book to date*

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
  - ASME International Fuel Cell Science, Engineering, and Technology Conference, June 2011, Brooklyn, NY
  - American Society for Engineering Education, June 2010, Louisville, KY
  - American Institute of Chemical Engineers, Nov. 2011, Salt Lake City, UT
  - American Society for Engineering Education, June 2011, Vancouver, BC, Canada

# Remaining Work on Grant, Complete this Year

- Module development: Mechanical Engineering and Electrical Engineering courses
- Continue student projects in Alternative Fuels Group Enterprise
- Teach courses (Fuel Cells, Hydrogen as an Energy Carrier)
- 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

# Acknowledgment

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- Thank you for your attention!