



Hydrogen Energy in Engineering Education (H₂E³)

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ED004



Overview



Timeline

- Project start date: 09/15/2008
- Project end date: 09/15/2011
- Percent complete:
 - 60% completion projected by 6/11/2010

Budget

- Total project funding
 - DOE share: \$395,532
 - Contractor share: \$114,876
- Funding received in FY08: \$239,399
- Funding received in FY09: \$156,133

Barriers

- As identified in HFCIT MYPP, Section 3.9.5:
- Lack of educated trainers
 - Regional differences

Partners

- Project lead: Schatz Energy Research Center
- UC Berkeley/Institute of Transportation Studies
- Industry partners:
 - Jadoo Power Systems, Inc.
 - Protonex Technology Corp.
 - UTC Power
 - IdaTech LLC



Relevance:

Objectives over 3-year project (2008-2011)

- Deliver effective, hands-on hydrogen energy and fuel cell learning experiences to a large number of undergraduate engineering students at multiple campuses in the California State University (CSU) and University of California (UC)
- Provide follow-on internship opportunities for students at hydrogen and fuel cell companies
- Develop commercializable hydrogen teaching tools including a basic fuel cell test station and a fuel cell/electrolyzer experiment kit suitable for use in university engineering laboratory classes



Relevance

Project Objectives over the past year (06/2009-06/2010)

- Fabricate and deliver two fuel cell test stations and 24 bench-top electrolyzer/fuel cell kits for use in engineering laboratories at UC and CSU campuses
- Train engineering department technical support staff and faculty in the operation and maintenance of the fuel cell/electrolyzers kits and the test stations, and pilot their use with students at both campuses (HSU and UCB).
- Implement curricula and conduct assessment for specific engineering courses at UCB and HSU, including:
 - introductory courses (E10 at UCB, ERE115 at HSU)
 - engineering thermodynamics (ERE331 at HSU)
 - engineering data analysis (ERE322 at HSU)
 - energy and society (E100 at UCB)
 - upper division engineering labs (ME107B at UCB, ERE471 at HSU)
- Facilitate student internships at collaborating fuel cell companies



Relevance

Relevance to DOE Hydrogen Program

National Hydrogen Energy Roadmap (2002)

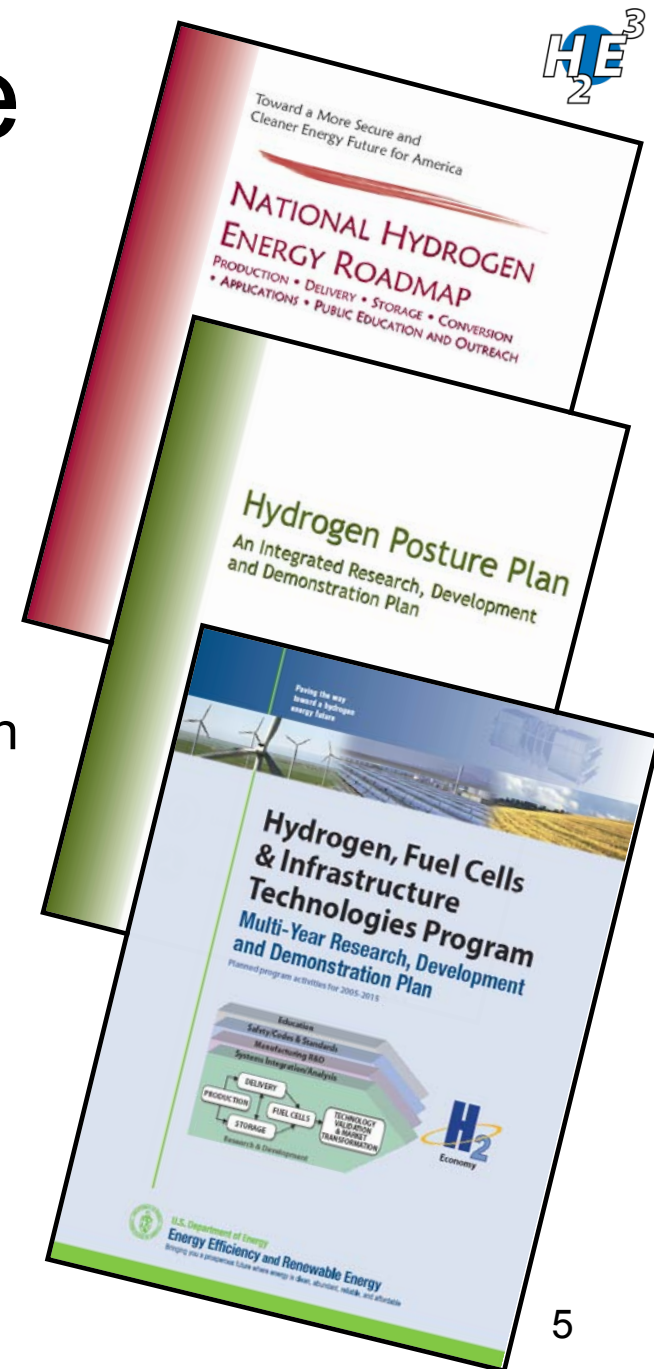
Notes that “hydrogen education programs are minimal” (still the case) and identifies college students and science teachers as target outreach audiences

Hydrogen Posture Plan (2006)

Education efforts need to “facilitate the expansion of hydrogen and fuel cell programs and learning modules at educational institutions, including... universities, for use in training a workforce of...engineers”

HFCIT Multi-Year RD&D Plan (2007)

“Work with university partners to develop and expand hydrogen technology course offerings and facilitate networking among schools with similar programs”





Relevance



Addressing Barriers

- **Lack of educated trainers.** Only a small number of universities in California offer hydrogen and fuel cell-specific learning opportunities for undergraduate engineering students. Even at these campuses, the number of engineering faculty with direct experience using fuel cells remains small, and fuel cell course content is underdeveloped.

- **Regional differences.** California has the advantages of being home to many hydrogen and fuel cell developers and on the leading edge of hydrogen energy infrastructure development. These features call for a special hydrogen energy education effort in California universities that makes use of these existing resources available in close proximity to many campuses.



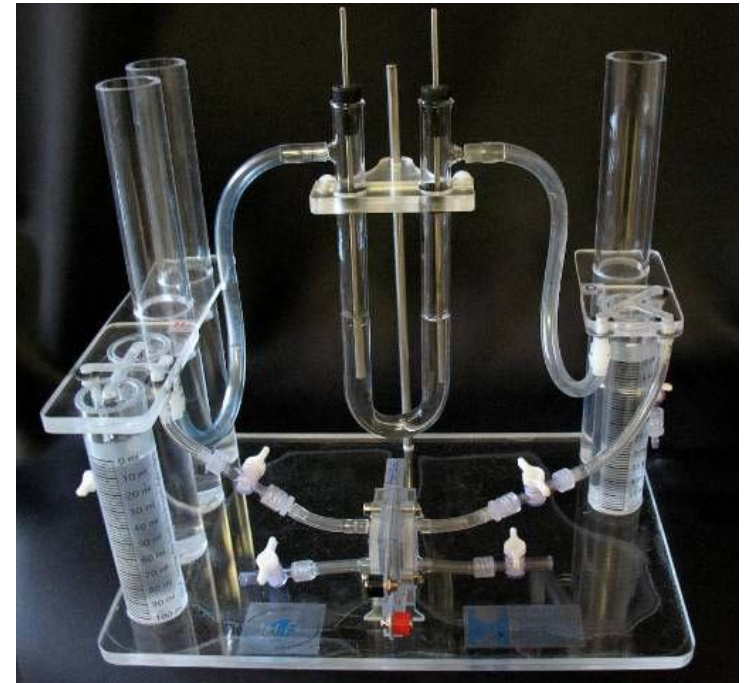
Approach

- Curriculum
 - Aimed specifically at undergraduate engineering students
 - Modules designed to replace portions of existing course curricula, not adding to total instructional burden for faculty
 - Initial use at UCB and HSU, later replication at other campuses
- Fuel Cell/Electrolyzer Kits
 - Alkaline electrolyzer and PEM fuel cell
 - More robust and higher power capacity than existing kits
- Fuel Cell Test Stations
 - Designed to work with any ~500W internally humidified stack
 - Emphasis on component visibility and pedagogical use in a research grade instrument
- Fueling Station Analysis
 - Study performance & efficiency of Hydrogen Highway fueling facilities
- Industry Internships
 - Follows directly on classroom experience, extends learning for students while grooming engineers for fuel cell industry partners



Previous Technical Accomplishments and Progress: FY09

- Identified two introductory engineering classes for initial use of curriculum: E10 (Energy Design & Analysis) at UCB and ERE115 (Intro to Environmental Resources Engineering) at HSU.
- Recruited interested faculty to review and pilot the curriculum modules in these courses at UCB and HSU
- Met with faculty to introduce H₂E³ project and solicit their input on module content and lab hardware needs
- Developed draft module outlines, worked with instructors to refine
- Designed and fabricated prototype Electrolyzer/Fuel cell kits
- Began design for fuel cell test station



Electrolyzer/Fuel Cell Kit designed and fabricated by SERC engineers



Technical Accomplishments and Progress: FY10

Electrolyzer/Fuel Cell Kits

- Fabricated and delivered 24 electrolyzer/fuel cell kits to UCB and HSU
- Developed curriculum for introductory material on fuel cells and hydrogen energy
- Developed curriculum for three lab modules incorporating electrolyzer/fuel cell kits
- Trained faculty (10), teaching assistants (10), and technical support staff (3) at UCB and HSU to operate and maintain kits
- Shot video of training session, which will be used to train faculty and TAs at other campuses



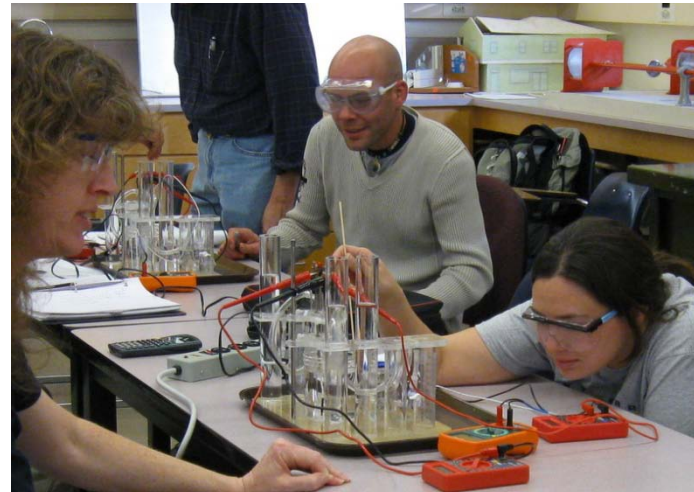
Lower division engineering students running efficiency experiments with electrolyzer/fuel cell kit



Technical Accomplishments and Progress: FY10

Electrolyzer/Fuel Cell Kits

- Implemented curriculum with the fuel cell kits in ERE115, ERE331 at HSU and E10 at UCB for a total of approximately 250 students at the two universities
- Conducted assessment and further refined curriculum and hardware



Upper division thermodynamics students running efficiency experiments with electrolyzer/fuel cell kit

Course Name	Total Enrollment
Introduction to Environmental Engineering (ERE115)	127
Thermodynamics and Energy Systems I (ERE331)	57
Energy Design and Analysis (E10)	67



Technical Accomplishments and Progress: FY10

Assessment of Pilot Curriculum for electrolyzer/fuel cell kits

The feedback given by the students was overwhelmingly positive. Many students commented that the lab was “fun”, “awesome”, and that they “liked”, “enjoyed” or “loved” this lab. 95% of the open-ended comments received began with a positive statement.

Pre and post-assessment results indicate that overall, students increased their understanding of the learning objectives.

“I loved learning how a fuel cell worked and seeing hydrogen created!”

“It was awesome and totally mind blowing to get to work with this device. I did not expect to have this chance until much later.”

“This lab has piqued my interest in the hydrogen fuel cell technology. I have browsed the internet and now realize the wide variety of products being made that use this technology.”

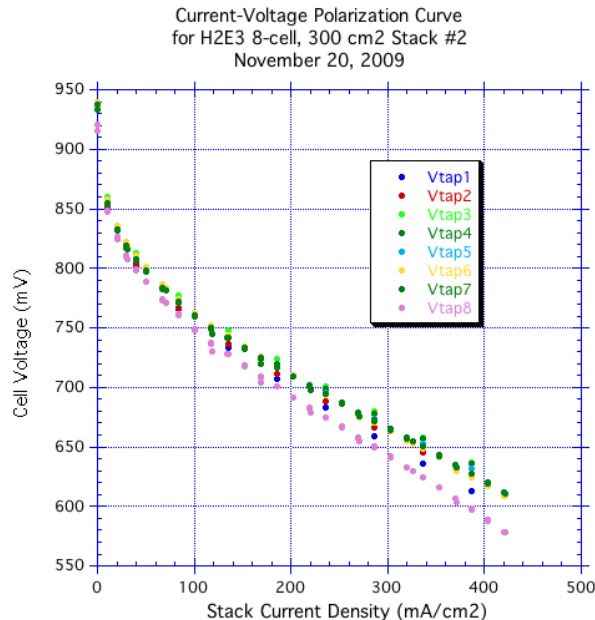
“The set-up wasn’t difficult at all – usually the hardest part of labs for me. It was fun!”



Technical Accomplishments and Progress: FY10

Fuel Cell Test Stations

- Completed two fuel cell test stations and delivered them to UCB and HSU
- Developed comprehensive operation and maintenance manual for test station



Current Voltage Polarization Curve for Fuel Stack #2



Hydrogen Fuel Cell Test Station



Technical Accomplishments and Progress: FY10

Fuel Cell Test Stations

- Developed and implemented curriculum and performed lab exercises using the test station in E100 and ME107B at UCB, and ERE471 at HSU, reaching approximately 290 students
- Trained faculty and support staff at HSU and UCB on operation and maintenance of the test station



Test Station delivered to UCB in Fall 2009

Course Name	Total Enrollment
Energy and Society (E100)	130
Thermodynamics and Energy Systems II (ERE471)	25
Mechanical Engr Lab (ME107B)	134



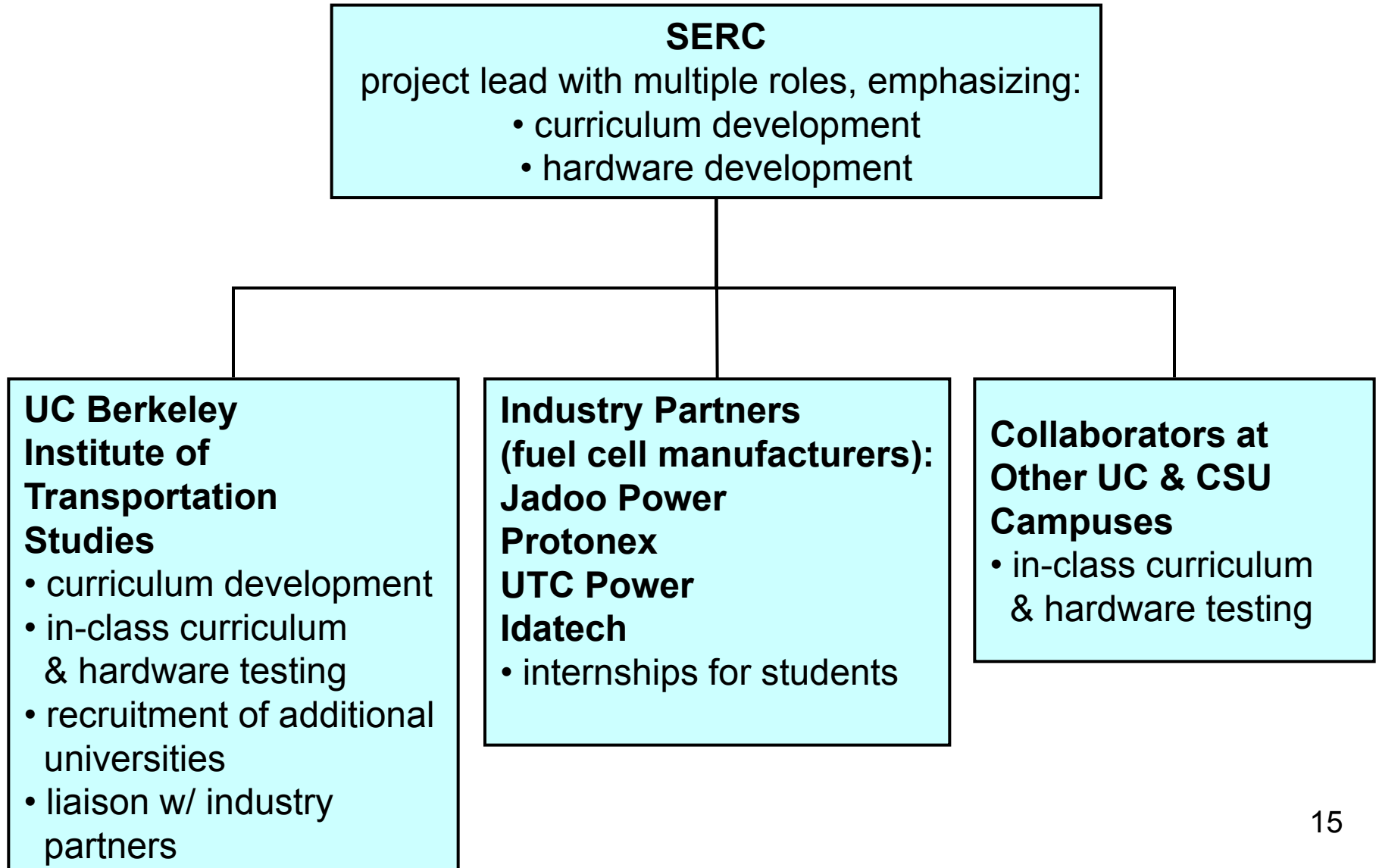
Technical Accomplishments and Progress: FY10



- Incorporated fueling station data into HSU ERE 322, Environmental Data Modeling and Analysis.
- Initiating student internships at Idatech and Protonex
- Three conference papers accepted for presentation at ASEE summer meeting and FIE October meeting
- Developing website to publish curricular material and users manuals for electrolyzer/fuel cell kits and test stations



Collaborations





Proposed Future Work



Remainder of FY 2010:

- Continue implementation and assessment of curriculum modules in classrooms and labs at UCB and HSU
- Recruit faculty at other UC and CSU campuses; preliminary contacts have been made
- Develop learning opportunities for campuses tied to Hydrogen Highway fueling stations (HSU, Bay Area and LA Area CSUs & UCs)
- Assess student internships with industry partners
- Disseminate curriculum at engineering education conferences
- Refine and extend web page

FY 2011

- Implement curriculum at other UC and CSU campuses
- Refine and conduct internships with industry partners
- Monitor and evaluate success of project
- Finalize web page to allow professors to easily obtain curricula
- Continue dissemination of program assessment



Summary



- Relevance
 - SERC's near-term and long-term project objectives are closely tied to DOE's Hydrogen Program objectives
- Approach
 - Curriculum modules
 - Fuel cell/electrolyzer kits
 - Fueling facility analysis
 - Fuel cell test stations
 - Industry internships
- Technical Accomplishments and Progress
 - Electrolyzer/Fuel cell kits completed and delivered
 - Curriculum implemented with fuel cell test kits, UCB E10, HSU ERE115 and ERE331
 - Assessment of pilot curriculum and laboratory hardware
 - Test stations completed and delivered
 - Trained faculty and support staff at HSU and UCB to operate the test stations
 - Implemented curriculum incorporating use of test station in E100 and ME107B at UCB, ERE471 at HSU
 - Incorporated fueling station data into HSU ERE322
- Collaborations
 - Partners: UCB, industry partners, other UC/CSU campuses
- Proposed Future Work
 - FY 2011: Recruit faculty at other campuses, conduct internships, analyze success of program, publish curricula and related materials on web page