2010 DOE Hydrogen Program and Vehicle Technologies Program AMR

HYDROGEN AND FUEL CELL EDUCATION AT CALIFORNIA STATE UNIVERSITY, LOS ANGELES

Dr. David Blekhman

California State University, Los Angeles

prepared April, 2010

Project ID
ED003

Overview

Timeline

- Start: 8/15/2008
- End: 9/15/2010
- ~75 % complete

Budget

- Total project funding
  - DOE $238,727
  - Contractor $90,423
- Funding received in full.

Barriers

Workforce Development
- Curriculum development
- Laboratory development

Education and Outreach
- Outreach to community colleges and schools
- Partnerships including OEMs
- Program development into research

Hydrogen Production

Partners

- California State University, Los Angeles— Project lead
- California Fuel Cell Partnership
- GM Corp, Honda
- Sothern California Edison
- More listed later

Project Objectives

- Implement a comprehensive set of curriculum development and training activities:
  - Developing and offering several courses in fuel cell technologies, hydrogen and alternative fuels production, alternative and renewable energy technologies as means of zero emissions hydrogen economy, and sustainable environment.
  - Establishing a zero emissions PEM fuel cell and hydrogen laboratory supporting curriculum and graduate students' teaching and research experiences.
  - Providing engaging capstone projects for multi-disciplinary teams of senior undergraduate students.
  - Fostering partnerships with automotive OEMs, energy providers, community colleges, government agencies and other stakeholders.

College Initiatives

- Redesigning the curriculum to implement an effective Alternative and Renewable Energy Technologies program including hydrogen economy and fuel cell applications.

- Building a hydrogen fueling station to serve the central Los Angeles area and become a focal point of research, educational and outreach activities. The station is being funded by several agencies and foundations.

- Establishing a research Center for Alternative and Renewable Energy and Sustainability. Funded by NSF programs and local partners.

Milestones for 2-year Project

- Develop and offer fuel cell and hydrogen courses (Task 1.0) in the 2008-2009 academic year.
- Purchase and install the majority of the equipment for the hydrogen laboratory in the 2008-2009 academic year and summer 2009.
- Install solar panels in the 2008-2009 academic year and summer 2009.
- Design and build “Hydrogen Safety” senior project in the 2008-2009 academic year.
- Suggest improvements and complete courses listed in Task 1.0 in the 2009-2010 academic year.
- Complete experiments setup in the hydrogen laboratory in the 2009-2010 academic year and summer 2010.
- Complete wiring of solar panels and connect to the electrolyzer in the 2009-2010 academic year and summer 2010.

Key Personnel and Functions

Dr. David Blekhman, PI — teaches courses, supervises research assistants and laboratory development, hydrogen station, and provides overall project coordination.

Dr. Crist Khachikian — integrates current grant into college grant initiatives and energy center.

Dr. Darrell Guillaume — organizes ME department and advisory board, grant execution experience.

Dr. Trinh Pham — teaches course.

Dr. Virgil Seaman — curates outreach efforts: government and community colleges, hydrogen station, TECH 250 coordination.

Dr. Chivey Wu — teaches graduate course and contributes to laboratory development.

Power, Energy and Transportation Emphasis Department of Technology

- TECH 100 Introduction to Automotive Mechanisms
- TECH 370 Power, Energy and Transportation
- TECH 405 Advanced Engine Design
- TECH 470 Electric, Hybrid and Alternatively Fueled Vehicles
- TECH 474 Power Generation, Distribution and Utilization (+Smart Grid)
- TECH 476 Electronic and Computer Control Systems
- TECH 478 Fuel Cells, Emerging Technologies
- TECH 478 Photovoltaics, Emerging Technologies
- TECH 488 Fluid Power

Course Development

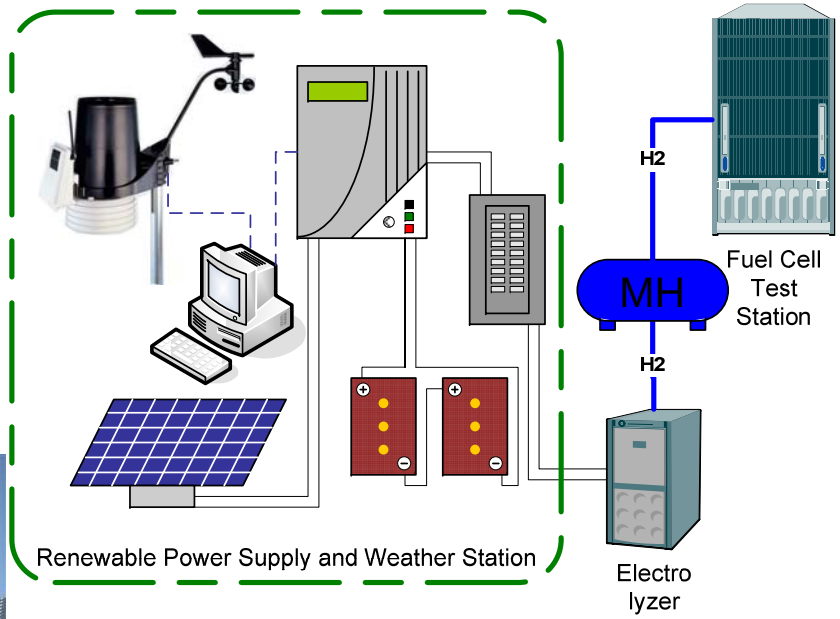
- TECH 474-Fuel Cell Applications—Dr. Blekhman, Spring'09 (10 Tech, 11 ME, 1 EE students), Spring'10 (8 Tech, 7 ME). Both offerings included laboratory and MCFC project. For final exam attended 2009 ASME Fuel Cell Conference in Huntington Beach, CA. Midterm exam: 2010 NHA Hydrogen Conference in Long Beach, CA.
- ME 554-Fuel Cell Systems—graduate, Dr. Wu, Spring'09 (16 students), Spring'10 (10 students). 2010 also includes laboratory. In addition, Dr. Wu is the PI for NASA Fuel Cell Powered UAV grant.
- ME 454-Renewable Energy and Sustainability—undergraduate, Dr. Pham, Spring'09 (26 students). Winter'10 (15 students). One week module and a project.
- TECH 470-Electric, Hybrid and Alt. Fueled Vehicles—Dr. Blekhman, Winter'09 (Bonus course)
- TECH 370-Power, Energy and Transportation —Dr. Blekhman, Fall'08, Spring'09, Fall'09, (Bonus course, one week module)

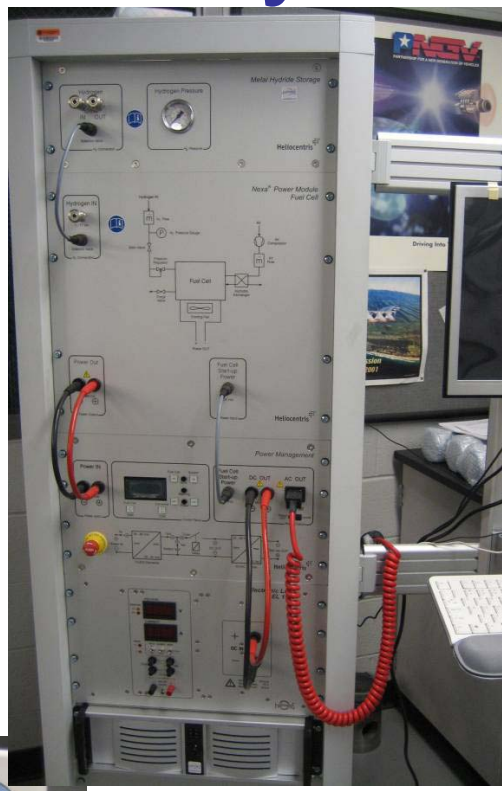
University Wide Course Lower Division

- TECH 250 The Impact of Technology on the Individual and Society is a general education required course. It is taught by the Technology Department faculty. It is open to all majors in the university and is selected to deliver our message to the university-wide student body. Faculty training complete. Added one week of HFCT material.
- Enrollment
  - Fall 2008 – 126 (4 sections were offered)
  - Winter 2009 – 35
  - Spring 2009 – 25
  - Fall 2009 – 150 (5 sections were offered)
  - Winter 2010 – 31
  - Spring 2010 – 25 TOTAL: 392

- PPT and video lectures provided.
  - 1. Title: Prof._Blekhman-Fuel Cells, Duration: 00:34:08, Link: http://ess-msite.calstatela.edu/Mediasite/Viewer/?peid=10b36466-a786-43a7-9bfc-142ebc51f5fb
  - 2. Title: Prof._Blekhman-Hydrogen Economy, Duration: 00:35:24 Link: http://ess-msite.calstatela.edu/Mediasite/Viewer/?peid=c39fd43a-c9c8-4e95-b799-48ebbfc5116f

Zero Emissions Laboratory





March 25, 2009 Hydrogen Station Permitting Workshop organized by NREL and hosted by CSULA

Fuel Cell GM and Toyota SUVs.

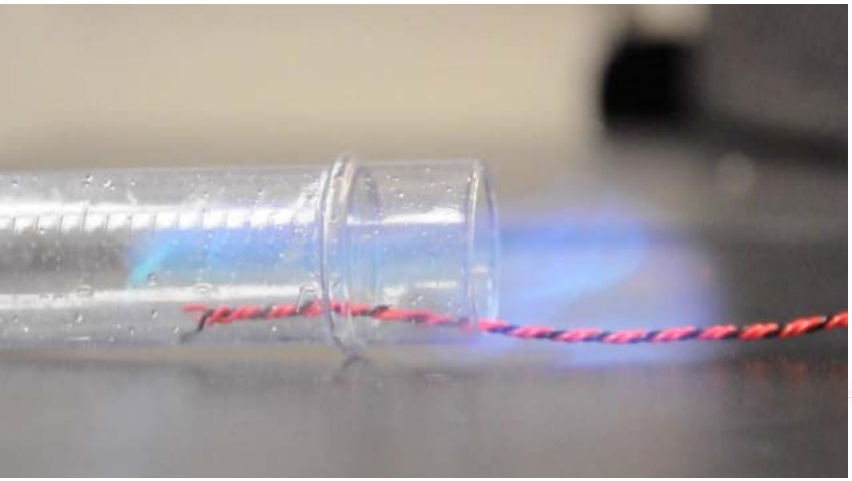
Heliocentris: Nexa Training System Complete, Proton-Hogen GC600 Electrolyzer

Solar Project
Senior Design 2008-2009

56 Sharp Modules 135W and 23 Solec Modules 90W
Total Power 9.9 kW
Solar panel team members Cesar Cardenas, Jesse Morales, Edgar Avalos, Jacob Dayneko, Jimmy Hoo and Jeovany Aguilar gauge the output of their panels on top of the Engineering and Technology building. From: CSULA Today Magazine Summer 2009
"Campus Sustainability Projects" spotlight:
http://www.calstatela.edu/univ/ppa/spotlight/archive/2009/campus_sustainability.php

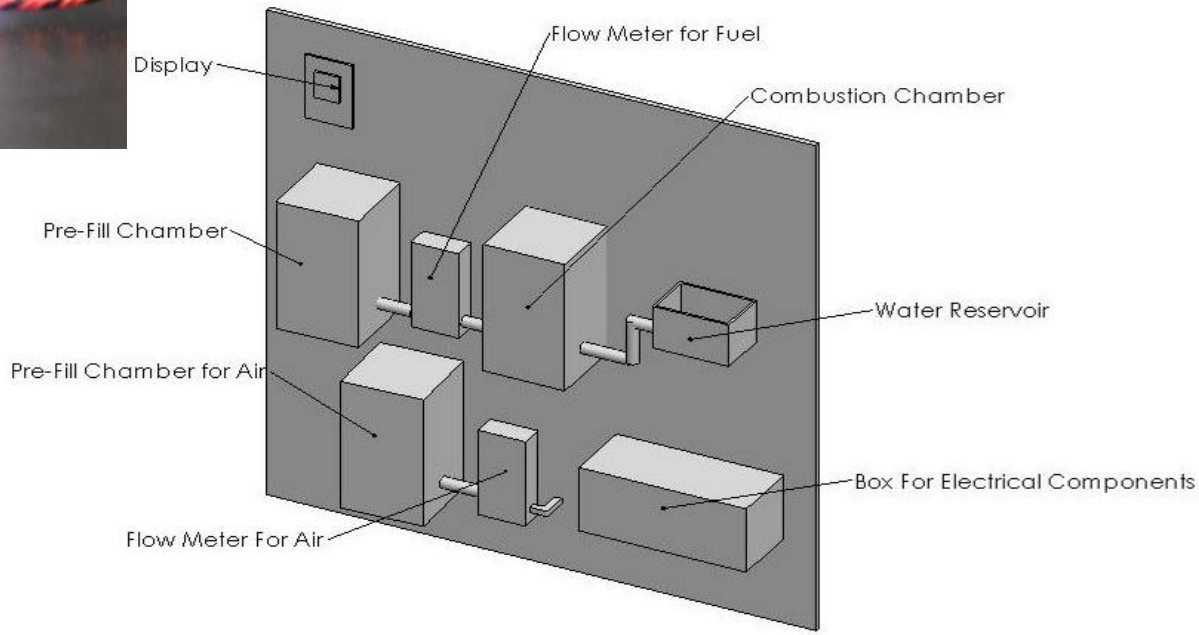
H2 Safety Experiment
Senior Design 2008-2009(last year)

Flammability limits of gasses



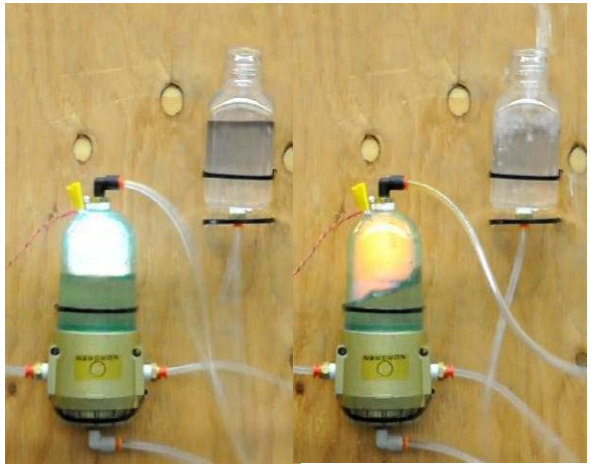
2 ME and 2 EE students

Over summer 2 students from ELAC

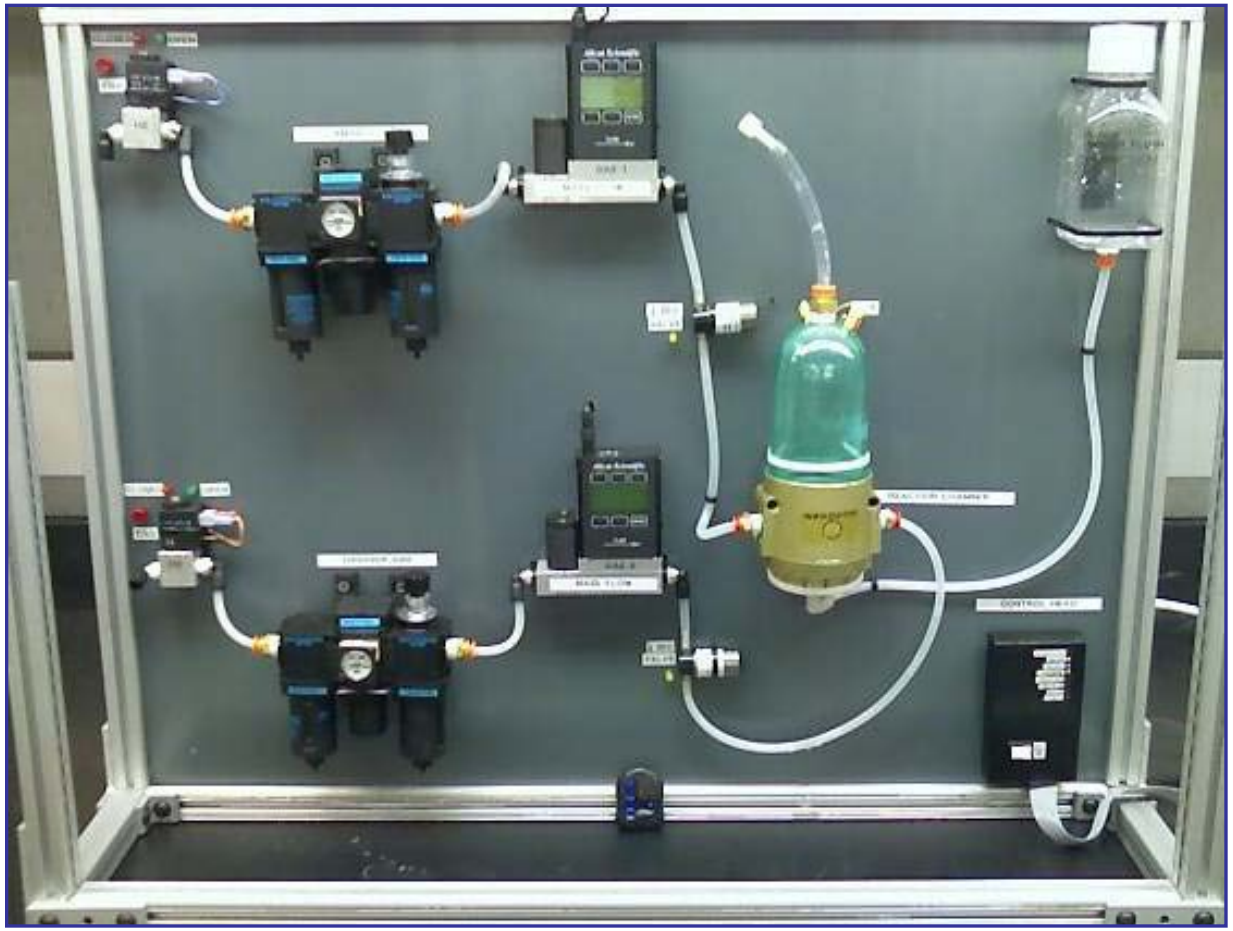


H2 Safety Experiment Senior Design 2008-2009

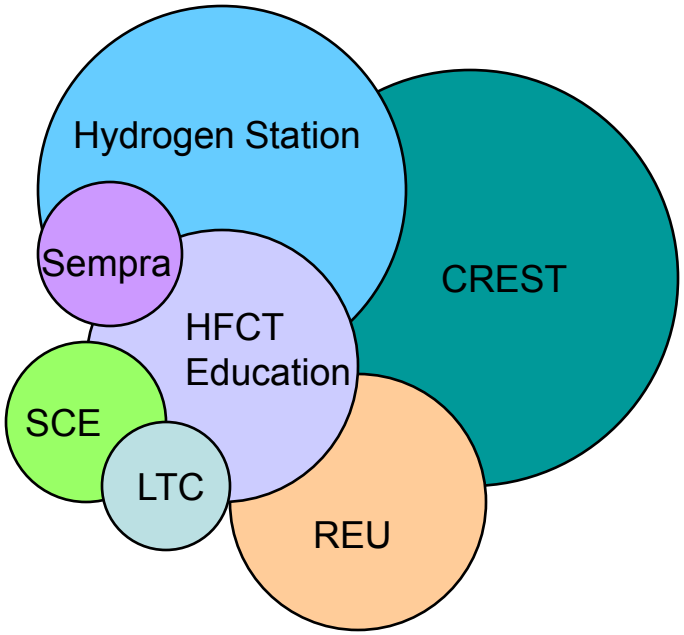
Proof-of-concept experiments:
Ignition in Air



Flammability limits of gasses



Synergistic Activities



- Hydrogen and fuel Cell Education at California State University Los Angeles
- Centers of Research Excellence in Science and Technology Center for Energy and Sustainability (CEaS)
- Research Experience for Undergraduates Site in Energy and Sustainability
- Establishing a Demonstration Hydrogen Fueling Station at Cal State L.A
- Sempra sponsored senior design
- Southern California Edison: $30,000 donation for Power, Energy and Transportation Program
- Leonard Transportation Center at Cal State San Bernardino: “Building Hydrogen Economy One Block at the Time,” $5,000, Assess the costs of H2 production using NREL’s H2A model.

CREST CEaS

- Centers of Research Excellence in Science and Technology
  Center for Energy and Sustainability (CEaS)
  - Award #0932421, NSF09-510
  - $5,000,000 / 5 years
  - Khachikian, Pham, Guillaume, Blekhman etc: 13 Faculty from 7 departments, 4 projects.

Direct Methanol Fuel Cells on a Microfluidic Platform

The Center has a 5-year research project to develop, optimize, and test a miniaturized methanol fuel cell that can be used to inexpensively and efficiently power portable electronic devices. Direct methanol fuel cells (DMFCs) are a promising sustainable application for power-hungry mobile technologies. Center researchers believe that methanol is currently the best fuel choice for portable electronic devices because it has greater energy densities than other energy alternatives. Fuel cells can potentially provide 5-10 times more energy per volume than rechargeable batteries.

REU-SHArK, 2010

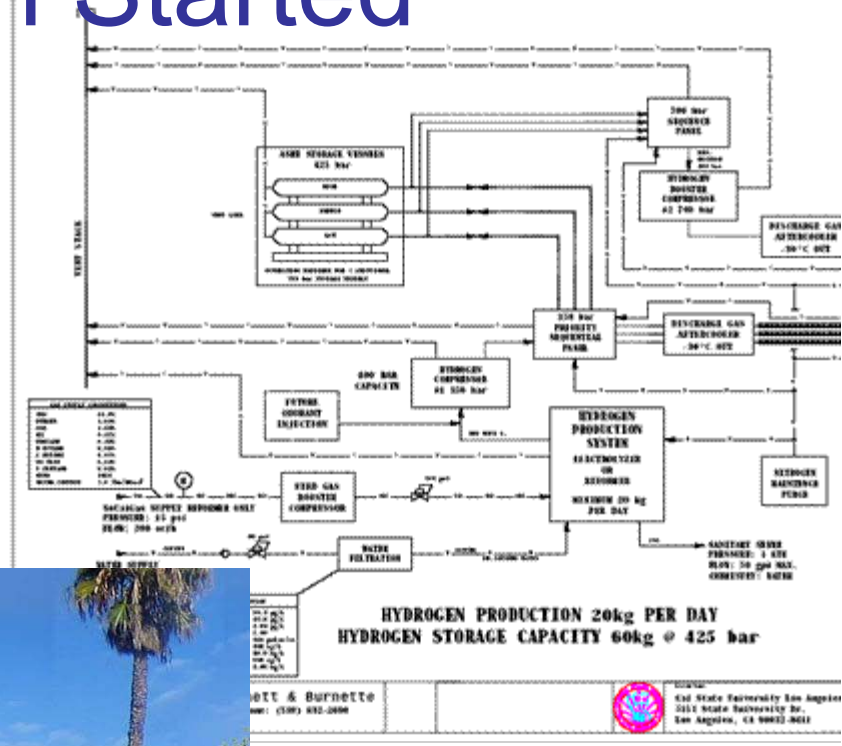
- Research Experience for Undergraduates Site in Energy and Sustainability
  - Award #0932421, NSF09-510, started 2009
  - $300,000 / 3 years
  - Khachikian, Guillaume, Pham, Blekhman etc

CSULA is joining the SHArK. The project goal of this project is to find a metal oxide semiconductor material that can split water into hydrogen and oxygen using sunlight. The project is run out of the **University of Wyoming** and is part of a **Cal Tech** NSF-funded project titled "Powering the Planet" that focuses on solar water splitting (www.ccisolar.caltech.edu)

CSULA students visiting Cal Tech researchers, Fall 2009

CSULA Hydrogen Station Construction Started

- Establishing a Demonstration Hydrogen Fueling Station at Cal State L.A
  - CARB No. 06-618 $2,700,000
  - DOE Award #DE-09EE0000443 $475,000
  - AQMD, MSRC, AAA and others
  - Seaman, Blekhman and many more



Electrolyzer, 60 kg/day, 350 bar—700 bar, publicly accessible.

Expected January 2011

Sempra Senior Project

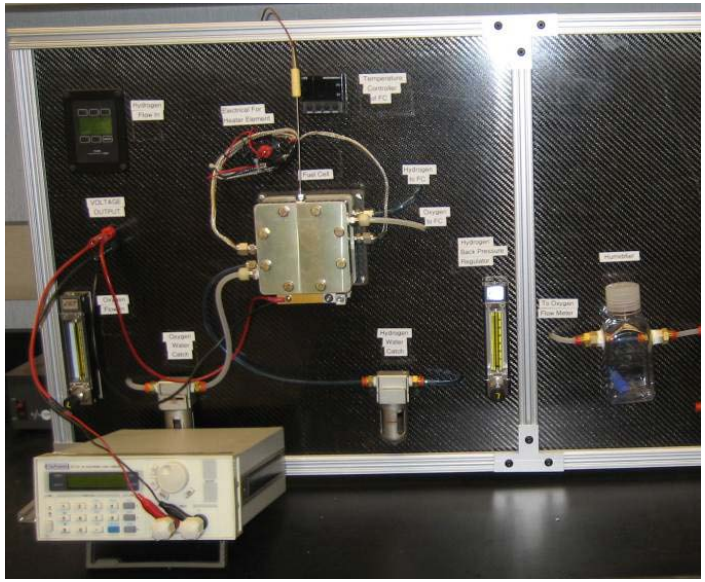
MOBILE DISPENSED HYDROGEN VERIFICATION LAB

California is the world leader in the number of H2 stations, 20+ are in operation

- ECST senior project: 3 ME and 1EE student.
- To create a device capable of measuring the amount of hydrogen dispensed by a hydrogen station to an accuracy of +/- 2% per mass and serve as the official verification standard approved by the California Department of Food and Agriculture, Measurement Standards Division.
- Currently California does not have a method to measure the amount of H2 dispensed from the stations and cannot verify the accuracy of the readings provided by the dispensers, +/- 8%.
- Needs a method analogues to conventional gasoline standards.

Graduate Student 1

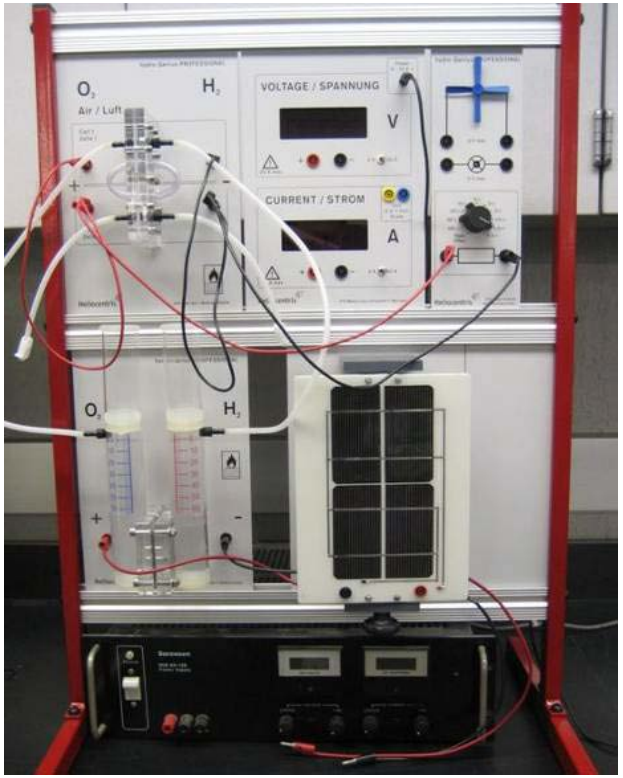
- The PI and the graduate student attended an intensive 3-day Fuel Cell course offered at Los Alamos Laboratory. The training benefited student's graduate research and PI's course materials.
- Established professional contacts with researchers at Los Alamos.



Fuel cell test stand

- Pursues teaching opportunities
- Applied to CSU Pre-doctoral program
- Student presentation "Root Cause Analysis of Low Fuel Cell Voltage Generation" was awarded the first place oral presentation in Engineering and Computer Science I at the California State University, Los Angeles 18th Annual Symposium on Research, Scholarship and Creative Activity. Among the winners from other disciplines, the student has been invited to the CSU statewide competition in San Jose.

Graduate Student 2



Heliocentris: Dr. Fuel Cell

- Laboratory development
  - Lab1 a-b, Characteristic Curve and Efficiency of the Electrolyser
  - Lab2 a-b, Characteristic Curve and Efficiency of the Fuel Cell
  - Lab3, Nexa Training System Complete : Fuel Cell Power Potential
- Operating manuals
  - Nexa Training System Complete
  - Hogen Electrolyzer
- Assists with teaching labs for undergraduate and graduate courses
- Provided leadership for the NHA “Hydrogen Community” project

2010 Hydrogen Design Contest: Designing a Hydrogen Community

Sponsored and supported by the **National Hydrogen Association's** Hydrogen Education Foundation, the U.S. Department of Energy, Chevron, FuelCellStore, and the California Fuel Cell Partnership. **5 Tech and 2 ME students on the team.**

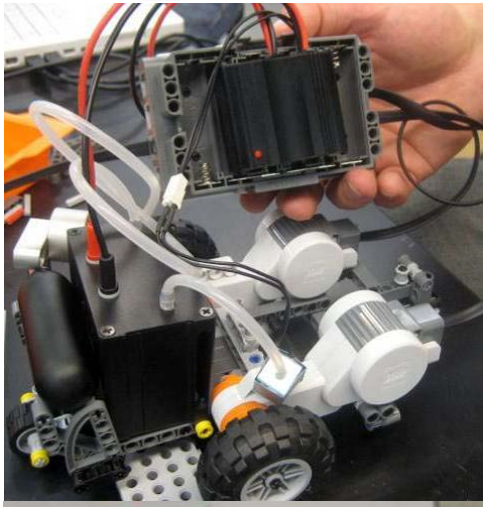
Soaring Eagle Hydrogen Community

Cal State LA

3/24/2010

Hector Nava
Jose Padilla
David Harbottle
Keith Bacosa
Taj Beaghler
Sharon Thomas
Andrew Huettner
Academic Advisor: Dr. Blekhman

Outreach: ELAC, LEGO and Horizon Fuel Cell Technologies



- Summer workshop for 14 students from East Los Angeles College.
- Theme: Fuel cells and robot programming.
- Built Lego Mindstorms robots for programming.
- Studied operation of fuel cells and hydrogen technologies.
- Utilized Horizon's H-20 fuel cell to power Lego Mindstorm robot. We believe that is the very first application of fuel cells for powering Lego Mindstorms.
- Horizon Fuel Cell Technologies was very interested in further promoting this effort. The company placed two videos of robot assembly and robot running on its website:

  http://www.horizonfuelcell.com/video04.htm
- CSULA publication: http://www.calstatela.edu/univ/ppa/spotlight/archive/2009/LEGO-fuelcellproject.php

Horizon H-20 fuel cell is being installed on to a Lego Mindstorm vehicle platform (upper) and completed robot (bottom).

Outreach

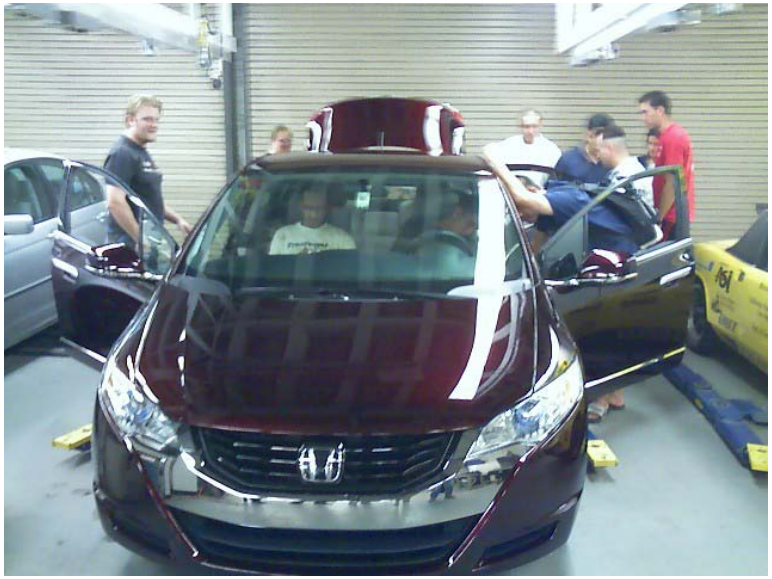
- August 2008 Hydrogen Road Tour Day at the California Science Center in Los Angeles
- September 2008 Santa Monica Alternative Car Show
- October 2009 Boeing Day on campus more then 150 middle and high school students
- May 2009 National Laboratory Day

- Fall'08, college hosted two open house events for middle and high-school students, about two hundred of whom toured the Zero-Emissions Fuel Cell laboratory
- February'09, participated in the Southern California Edison Black History Month event
- March 2009, Advanced Energy and Transportation Building Groundbreaking—Cerritos Community College
- April 2009 Looking Green Magazine Expo + publication in the magazine

Partnerships

GM—student tours

Honda—guest lecture



CA Fuel Cell Partnership

- Hydrogen Day Tour
- Invited to Multiple Hydrogen Operators Meetings (last Oct'09)
- Two Hydrogen Station Permitting workshops at CSULA (Aug'08 and Mar'09)
- Provided input to CAFCP Educational Activities

Partnerships and Collaborations

- Community Colleges
- Los Altos High School through H2-ICE
- Partners through hydrogen station
  - Hydrogenics
  - CARB
  - Southern California Edison
  - Sempra—Gas Company
  - AQMD
  - Mobile Source Air Pollution Reduction Committee
  - AAA California
  - OEMS vehicles using station : GM, Hyundai, Daimler, Toyota
- Five program collaboration in writing two 2010 ASEE papers addressing curriculum and laboratory development
  - CSULA, MTU, Humboldt, UNCC, UND
- Special Thanks
  - ASME
  - Dr. Jack Brouwer of National Fuel Cell Research Center at UC Irvine
- In Development
  - Horizon Fuel Cell Technologies
  - JPL for REU
  - Cal Tech & U. of Wyoming for SHArK
  - LA Metro

Future Work

- Review and propose improvements for future course offerings.
- Complete setup of experiments in the hydrogen laboratory and select additional equipment as needed.
- Complete Zero-Emissions Fuel Cell and Hydrogen Laboratory.
- Continue efforts for sustained presence of fuel cell and hydrogen topics in the college curriculum.
- Continue student development.
- Continue efforts in developing partnerships and research projects.
- Develop courses in Hydrogen Station design, operation and maintenance—seeking funding.

Summary

- Work is underway addressing all tasks and objectives: Hydrogen and Fuel Cell courses, lab development, research and outreach.
- The team demonstrated solid progress toward completing all tasks and developed new directions.
- Wide spectrum of multidisciplinary courses targeting lower, upper and graduate levels.
- Graduate students demonstrate maturity and make contributions.
- Grant accomplishments are a coherent effort among many collaborators and is a congruent element in college Alternative and Renewable Energy initiatives including the development of hydrogen station.
- Active development of partnerships, outreach to wide spectrum of audiences and public education.
- Two 2010 ASEE papers and multiple university publications.