



2011 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 March, 2011*

Project ID  
ED003



# Overview

## Timeline

- Start: 8/15/2008
- End: 9/15/2010
- Extended 06/30/2011
- ~95 % 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
- Southern California Edison
- More listed later



# Project Objectives Relevance

- 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 Relevance

- 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.



# Approach for 2-year Project

- Develop and offer fuel cell and hydrogen courses in the 2008-2009 academic year.
- Purchase and install 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.



# Approach for 3<sup>rd</sup> Year

- Offer additional courses with fuel cell and hydrogen infrastructure topics.
- Continue curriculum sharing: publications and on-line.
- Identify and purchase additional equipment for the hydrogen laboratory.
- Organize/complete student teams for hydrogen related projects: Sempra, National Hydrogen Association, Hydrogen Super Eagle.
- Apply for grants/funding for program continuance.
- Guide graduate student thesis work and graduation.
- Strengthen outreach and collaborations.
- Complete CSULA Hydrogen Fueling Facility.
- Complete solar installation.



# 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.



# Hydrogen and Fuel Cell Curriculum Offerings

- TECH 474-Fuel Cell Applications— Spring'09, Spring'10
- ME 554-Fuel Cell Systems—graduate, Spring'09, Spring'10
- ME 454-Renewable Energy and Sustainability—Spring'09, Winter'10, one week module and a project.
- TECH 470-Electric, Hybrid and Alt. Fueled Vehicles— Winter'09, Winter'11, two weeks
- TECH 476 Electronic and Computer Control Systems— Fall'10, special project
- TECH 370-Power, Energy and Transportation—Fall'08, Spring'09, Fall'09, Fall'10, Spring'11, one week module
- TECH 250 The Impact of Technology on the Individual and Society—Fall'08, Spring'09, Fall'09, Winter'10, Fall'10, Winter'11, Spring'11, one week module, all lower division students in college  $\geq 600$





# 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



# Curriculum Online

Blekhman\_Fue\_Cells - Windows Internet Explorer

file:///C:/Documents%20and%20Settings/facuser/My%20Documents/CSU\_... Google

File Edit View Favorites Tools Help

Favorites Blekhman\_Fue\_Cells

mediasite  
by sonicfoundry

www.sonicfoundry.com

% Polls Ask Slide 6 of 14 Options ? Help powered by mediasite

**Proton Exchange Membrane Fuel Cell**

Cathode Oxid. & Pr. Anode Fuel

CBP CDL M ADL ABP

Schematic of an Individual Fuel Cell

The fuel cell is composed of an anode (a negative electrode that repels electrons), an electrolyte membrane in the center, and a cathode (a positive electrode that attracts electrons).

Paused 11:21/34:08

Blekhman\_Fue\_Cells

Date: 05/19/2008

Time: 8:53 AM

Length: 34 Minutes 8 Seconds

Info Details

file:///C:/Documents%20and%20Settings/facuser/My%20Documents/CSU\_LA/TECH\_478\_FI Internet 100%

PPT and video lectures.

- 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-b799-48ebbf5116f>

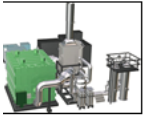


# MCFC Project Online

Firstname Lastname - Windows Internet Explorer  
 www.calstatela.edu/faculty/blekhman/MCFC\_Project.html

LA Faculty: Firstname Lastname

## Fuel Cell Applications Course Project



**Molten Carbonate Fuel Cell Performance with Alternative Fuels**

[Return to Power, Energy and Transportation](#)

- [Authors](#)
- [Introduction](#)
- [Assignment](#)
- [Download Files](#)
- [Publications](#)
- [Copyright](#)

**Authors**  
[Dr. David Blekhman](#)  
 California State University Los Angeles  
 Department of Technology  
[blekhman@calstatela.edu](mailto:blekhman@calstatela.edu)  
 phone: 323-343-4569

[Dr. Stephen McClain](#)  
 Baylor University  
[Stephen\\_McClain@baylor.edu](mailto:Stephen_McClain@baylor.edu)

[TOP](#) ↑

**Introduction**  
 Green technologies are ever so popular nowadays. Fuel cell technology holds the promise of high-efficiency utilization of fossil and alternative fuels. The purpose of the project is to provide a capstone experience to students in the Fuel Cell course. It ties together the complexity of the chemistry and electro-chemistry processes encountered in fuel cells. While PEM fuel cells are destined for vehicles and other mobile applications, Molten-Carbonate Fuel Cell (the backbone of the project) is being developed by Fuel Cell Energy (fce.com) for stationary applications. The simulations are run with various alternative fuels like digester, landfill and pyrolysis gas. Students are required to complete significant research of alternative fuels, utilize modern modeling tool, and read scientific and popular-scientific literature.

[TOP](#) ↑

**Assignment**  
 The final team report (one per team) will consist of two sections:  
 MCFC Operation Summary-50%  
 Simulation Results-50%

Internet

Firstname Lastname - Windows Internet Explorer  
 www.calstatela.edu/faculty/blekhman/MCFC\_Project.html

ULA Faculty: Firstname Lastname

The final team report (one per team) will consist of two sections:  
 MCFC Operation Summary-50%  
 Simulation Results-50%

Topics to address in the Summary:

1. Fuel reforming in MCFC
2. Operating conditions inside of the cell and main chemical reactions
3. Operational diagram (draw your own)
4. Variety of MCFC types produced by Fuel Cell Energy
5. Other manufacturers (1-2) and their product
6. Describe the details of Sierra-Nevada brewery installation
7. CA economic stimulus to MCFC installations

Simulation results:

1. Simulate all of the gases given in the paper, carefully review all of the steps
2. Compare Nernst voltages produced
3. Provide your inputs and results
4. Find a gas composition of a landfill gas, water treatment (digester gas) and biomass pyrolysis
5. Feed those in the program—compare results to the initial set of gasses
6. Write conclusions section for your simulations.

[TOP](#) ↑

**Download Files**  
 The simulation main file is FuelCellEx.xmcd. The file IGASProps\_CH4.xmcd is the database with constants. The database file needs to be linked inside of the simulation file at the line which starts as Reference. Use the right click and change properties by browsing to IGASProps\_CH4.xmcd on your computer. Valid MathCAD License is required to run the program.

[Download Project Zip File](#)

[Project Narrated Overview](#)

[TOP](#) ↑

**Publications**

Internet



# Curriculum Sharing and Collaboration

Blekhman, D., J. Keith, A. Sleiti, E. Cashman, P. Lehman, R. Engel, M. Mann, and H. Salehfar "National Hydrogen and Fuel Cell Education Program Part I: Curriculum," *2010 ASEE Annual Conference & Exposition*, Louisville, KY.

\*2<sup>nd</sup> Best paper award in the Energy Conversion and Conservation Division

Blekhman, D., J. Keith, A. Sleiti, E. Cashman, P. Lehman, R. Engel, M. Mann, and H. Salehfar "National Hydrogen and Fuel Cell Education Program Part II: Laboratory Practicum," *2010 ASEE Annual Conference & Exposition*, Louisville, KY.

**Outcome:** Heliocentris is sponsoring Energy Conversion and Conservation Division at 2011 ASEE and offering facility tour in Vancouver





# Presentations/Communications

- Presented “CSULA Hydrogen Station and Power, Energy and Transportation Program,” 4th Annual Jack R. Widmeyer Transportation Research Conference, 2010 at CSU San Bernardino Leonard Transportation Center, November, 2010. The presentation included report on the student project “Building Hydrogen Economy One Block at the Time” funded by the Leonard Transportation Center.
- Provided feedback to DE-FOA-0000429 RFI Renewable Hydrogen, Area of Interest 2: Turnkey Project Management for Hydrogen Energy Storage to Support Renewable Power Generation.
- Provided feedback to the 2011 Department of Energy Hydrogen and Fuel Cells Program Plan, titled “Insufficient Funding for Education in Market Transformation.”
- Presented “State-of-The-Art CSULA Hydrogen Station,” 2011 Fuel Cell & Hydrogen Energy Conference and Expo, Washington DC, February 2011.



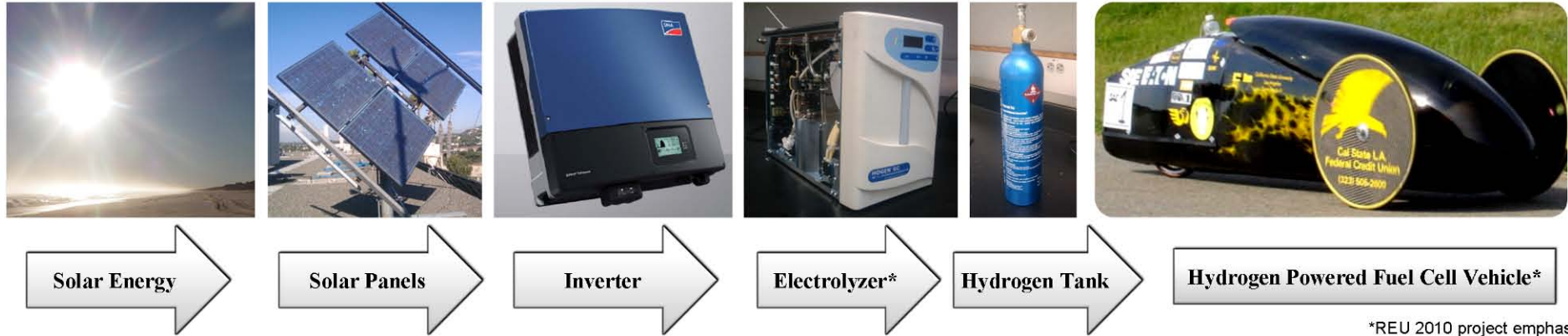
# Grant Activity

- Fulbright (awarded)
  - Fuel Cell Technologies and Hydrogen Infrastructure
- NSF-MRI (applied)
  - Acquisition of a Multifunctional Gas Analyzer for the Center for Energy and Sustainability
- CARB (applied)
  - REFLEX: Fuel Cell Plug-In Hybrid Electric Vehicle: California Edition
  - Transportation Hydrogen Energy Storage to Support Renewable Power Generation in California
- DOE (in development)
  - Graduate Automotive Technology Program
- ECO CAR (applied)
  - REFLEX: Fuel Cell Plug-In Hybrid Electric Vehicle: California Edition
    - Mayor of Los Angeles Mr. Antonio Villaraigosa, California Air Resources Board, US Hybrid, Hy-Gen Industries, ZT-Plus Thermoelectric Materials, Hydrogen Education Foundation, California Fuel Cell Partnership, Southern California SAE chapter and Clean Energy (engineering).



# FCV: Hydrogen Super Eagle

System Energy Flow Diagram for a Zero Emission System

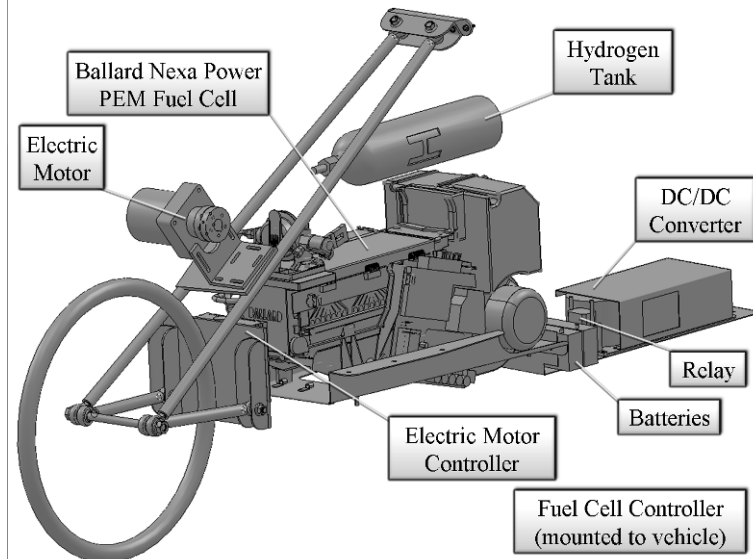


\*REU 2010 project emphasis

Summer REU program with support by CSULA Center for Energy and Sustainability (4 students)



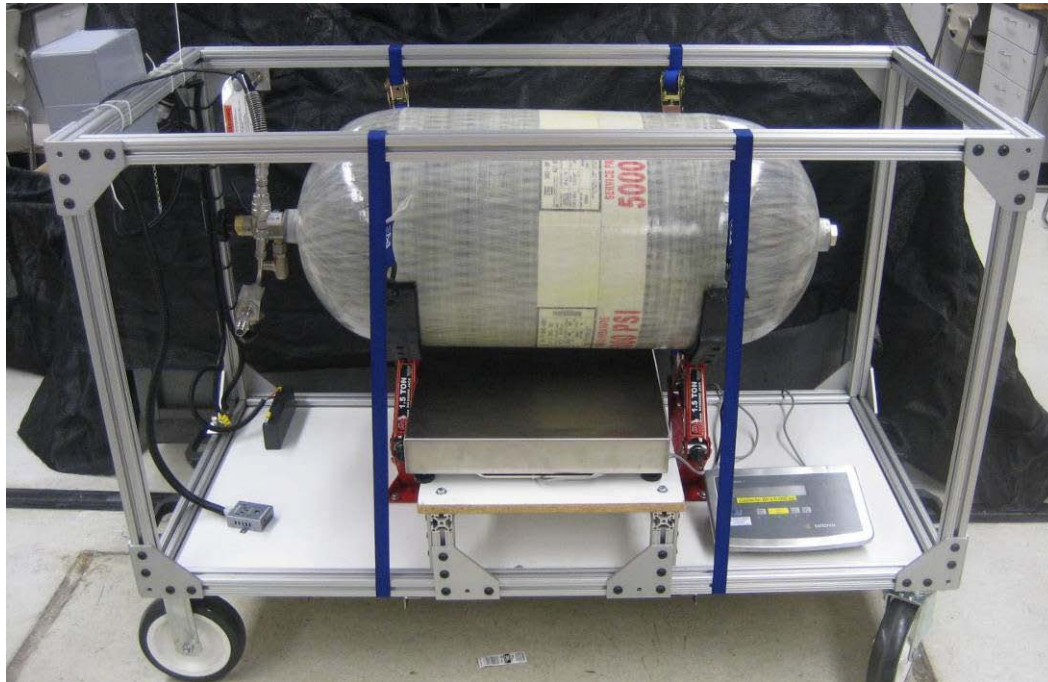
Vehicle Setup





# Sempra Senior Project

## MOBILE DISPENSED HYDROGEN CALIBRATION



- ECST senior project: 3 ME and 1EE student.
- To create a calibration device for measuring the amount of H<sub>2</sub> dispensed by a hydrogen station to an accuracy of +/- 2% per mass and serve as the official verification standard approved by the CA Dept. of Food and Agriculture, Measurement Standards Division.
- Needs a method analogues to conventional gasoline standards.



# Student Design Contest



## Home Hydrogen Refueling

Number of teams: **54**

Number of Countries: **19**

Number of Submissions **17**

Placed **7**

**Collaboration: 2 students from  
East Los Angeles College**

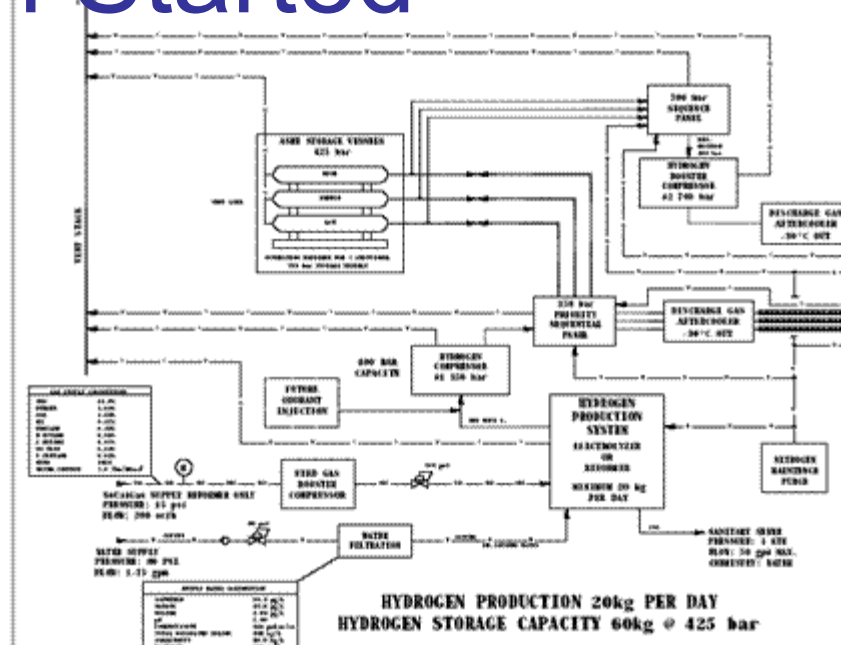
Hector Nava  
Jose Padilla  
Dennis Chinn  
Mark Anthony Aguilar  
Pamela Green  
Fakhru Shawaludin  
Keith Bacosa  
Annette Barrasza  
Mike Strada  
Julio Cesar Cardenas  
Christino Castro  
Advisor : Dr David Blekman



# 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 \$475,750
- AQMD, MSRC, AAA and others
- Seaman, Blehman and many more



Robb & Burnette  
Phone: (310) 832-0886

California State University San Angeles  
San Angeles, CA 90832-0811

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

Expected January 2011



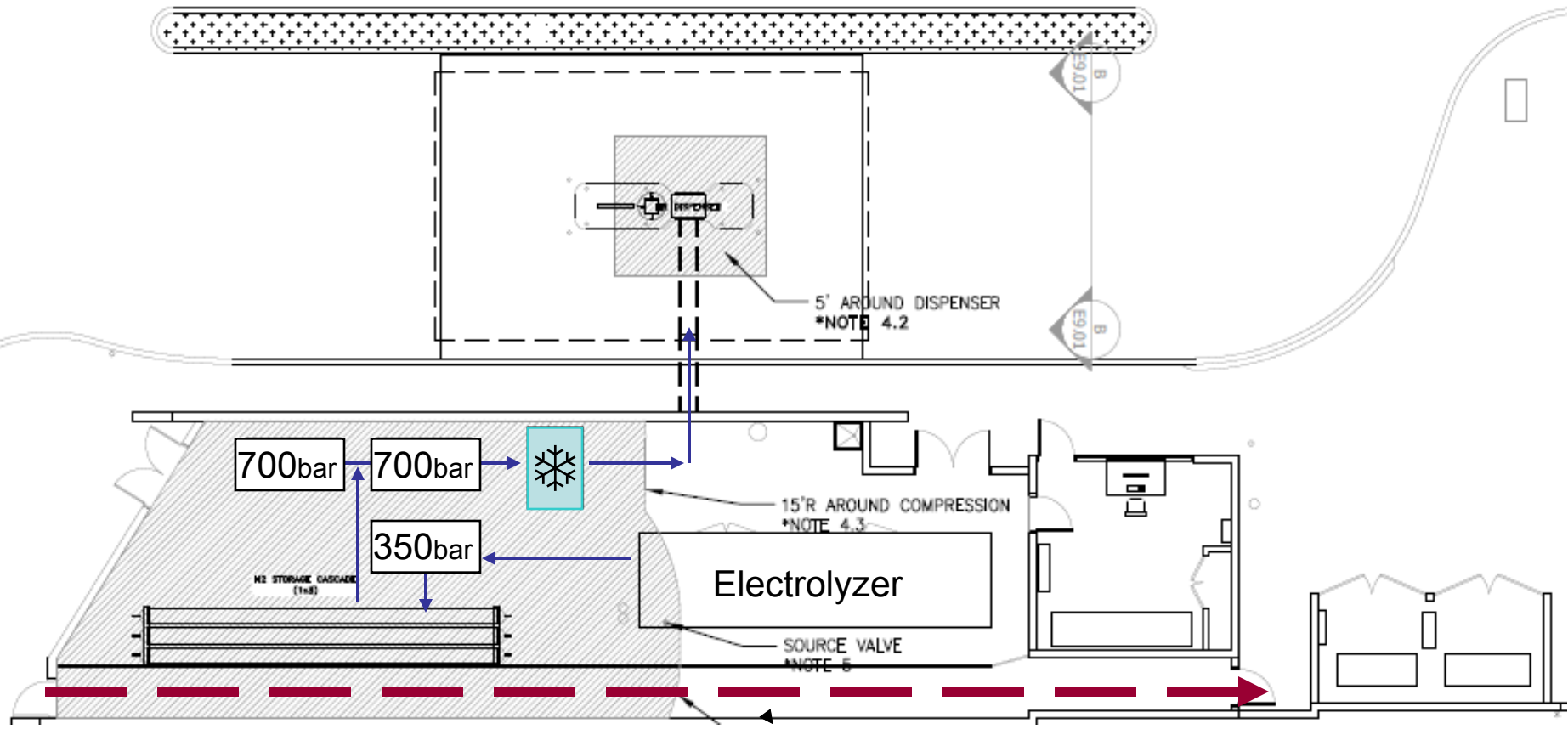
# Construction and Equipment

[http://www.calstatela.edu/faculty/vseaman/Hydrogen\\_Station.php](http://www.calstatela.edu/faculty/vseaman/Hydrogen_Station.php)





# Equipment Layout and Hydrogen Flow

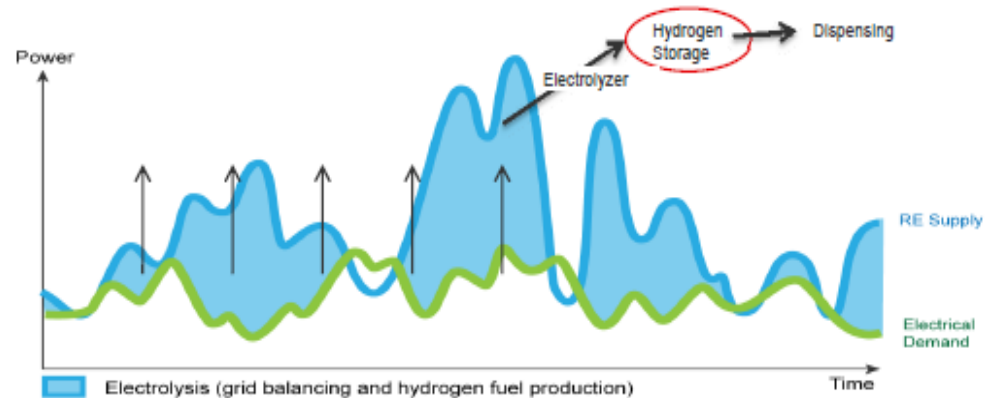


**Walking tours**

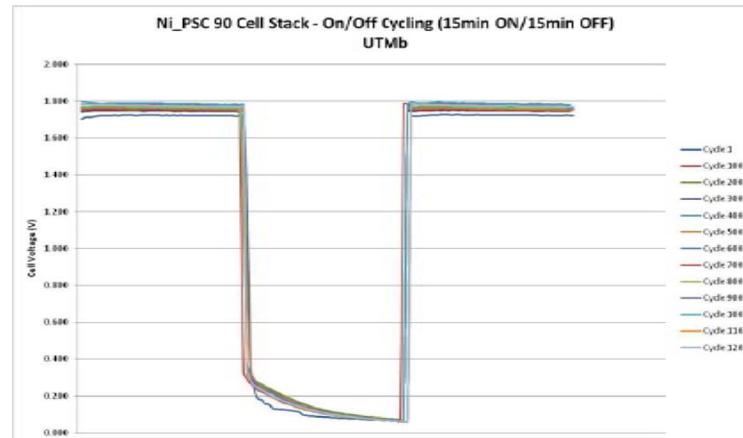


# Research Opportunities

- Performance Optimization, Hydrogen Fleet and Infrastructure Analysis
- Smart Grid: Load Following with Renewable Power Generation
  - Off-peak load
  - Load shedding
- Workforce, Public and Professional Education



## Intermittent wind exceeds load



Electrolyzers demonstrate quick start-stop without degradation



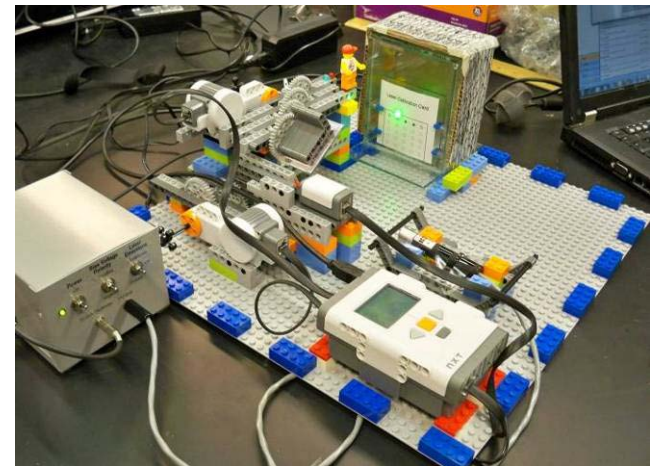
# Outreach



Los Altos Engineering Academy 2010 graduation day; the Hydrogen Internal Combustion Engine (HICE) team, Ed Richter (the instructor, left).

Taiwan Automotive International Forum & Expo, Long Beach, CA, June 2010.

**Multiple events on campus**



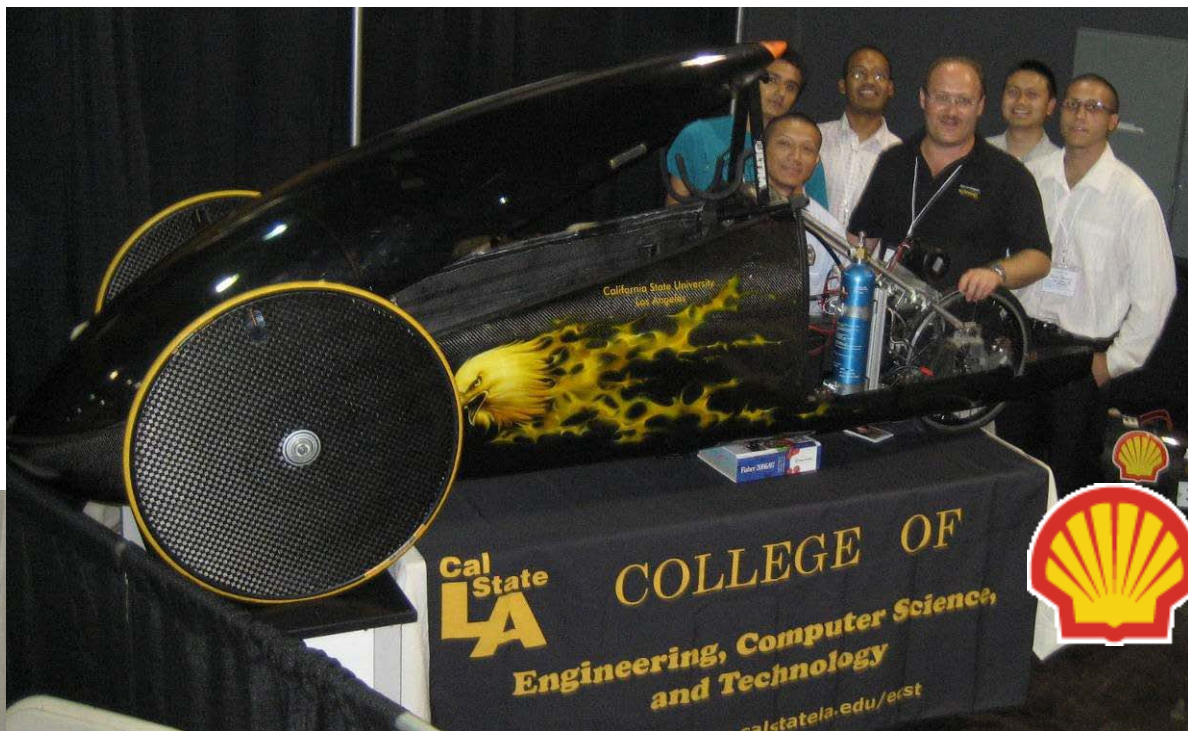
Lego based SHARK project in collaboration with the University of Wyoming and Cal Tech. The picture shows laser calibration.

Marengo Elementary School, Science Night, January 2010





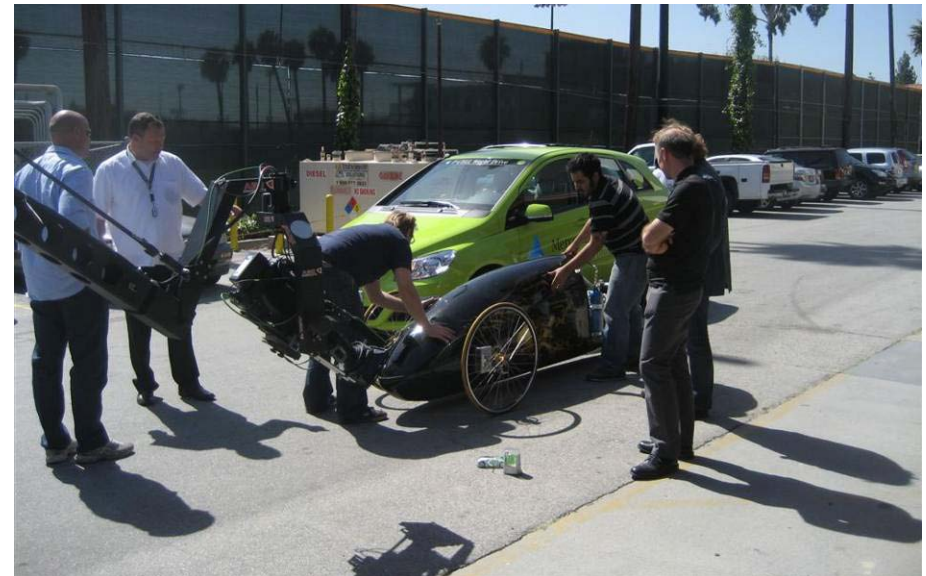
# 2010 Santa Monica Alt Car Expo & LA Auto Show



Hydrogen Super Eagle on display and Cal State LA students at 2010 Santa Monica Alt Car Expo, October 2010; left, Los Angeles Auto Show, November 2010.



# Mercedes Benz F-Cell World Drive



CSULA hosted Mercedes Benz F-Cell World Drive with Cristian Maier, March 8, 2011





# Partnerships and Collaborations

- Community Colleges
- Los Altos High School through H2-ICE
- UCLA-response to funding
- 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, HSU, UNCC, UND
- Special Thanks
  - California Fuel Cell Partnership (first responder training)
- Through grants
  - Mayor of Los Angeles Mr. Antonio Villaraigosa
  - US Hybrid
  - Hy-Gen Industries
  - ZT-Plus Thermoelectric Materials
  - Hydrogen Education Foundation
  - Southern California SAE
  - Clean Energy
  - Cal Tech & U. of Wyoming for SHARk
  - LA Metro



# Future Work: Program Completes – Work Continues

- Assure sustained presence of fuel cell and hydrogen topics in the college curriculum.
- Operate/research Hydrogen Fueling Facility.
- Develop courses in Hydrogen Station design, operation and maintenance.
- Grow Zero-Emissions Fuel Cell and Hydrogen Laboratory.
- Continue student development.
- Continue developing partnerships and research projects.
- Pursue funding opportunities to support our work



# Summary

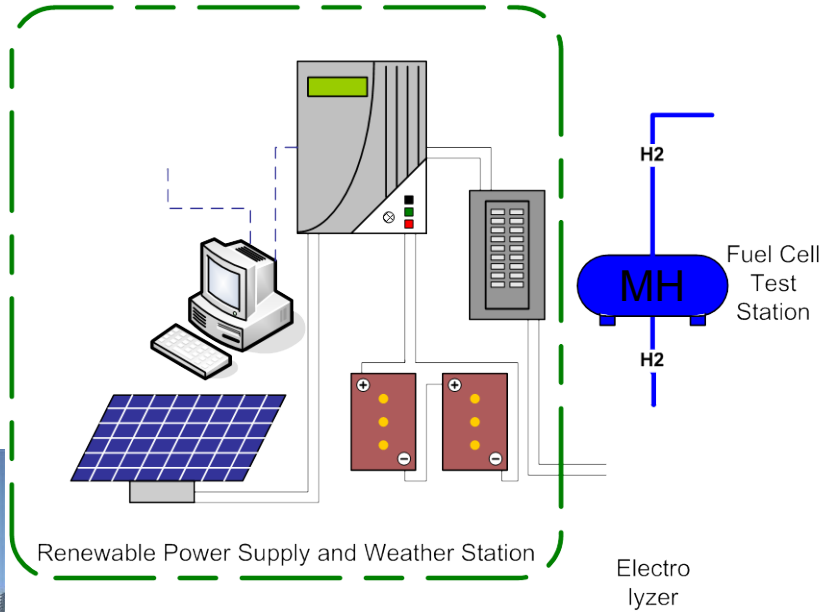
- Program demonstrates high relevance to DOE Hydrogen and Fuel Cell program as requested in grant opportunity with diverse approaches to completing tasks and integration in college.
- Completed all tasks proposed by the grant: Hydrogen and Fuel Cell courses, lab development, research and outreach.
- Developed new directions and plan for program sustainability beyond current funding.
- Developed and started dissemination of wide spectrum of multidisciplinary courses targeting lower, upper and graduate levels.
- Graduate students demonstrate maturity, make contributions and prepare to graduate.
- 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.



# Technical Back-Up Slides



# Zero Emissions Laboratory



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

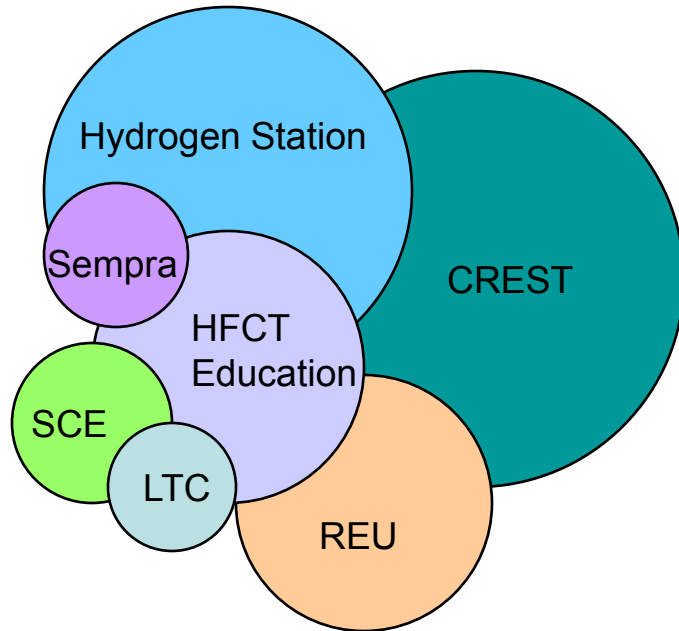
Fuel Cell GM and Toyota SUVs.



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



# 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 H<sub>2</sub> production using NREL's H<sub>2</sub>A 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, Gomez, etc: 20 (13)  
Faculty from 7 departments, 6 (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.



# 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 Beaghtler

Sharon Thomas

Andrew Huettnner

Academic Advisor: Dr. Blekhman

