



2015 DOE Hydrogen Program and  
Vehicle Technologies Program  
AMR

# CSULA Hydrogen Refueling Facility Performance Evaluation and Optimization



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Project ID: TV024

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*This presentation does not contain any proprietary, confidential, or otherwise restricted information*



# Overview



## Timeline

- Start: 10/01/2012
- End: 12/31/2016

70% complete

## Budget

- Expenditure of Government Funds
  - FY13-14 \$180,000
  - FY15 ~\$80,000
- Total project funding
  - DOE \$400,000
  - Contractor \$400,000

## Partners

- California State University, Los Angeles— [Project lead](#)
- Hydrogenics Corp.

## Barriers

### Hydrogen Production and Delivery

- Reduce the cost of compression, storage, and dispensing at refueling stations
- Research and develop low-cost, highly efficient hydrogen production technologies

### Technology Validation

- Validate complete systems of integrated hydrogen and fuel cell technologies for transportation, infrastructure and electricity generation applications under real-world operating conditions.

### Education

- Educate key audiences to facilitate near-term demonstration, commercialization, and long-term market acceptance.



# Project Objectives

- The project objective is to test, collect data, and validate hydrogen refueling architecture deployed at CSULA and its individual components in a real-world operating environment. The performance evaluations data will be provided to the National Fuel Cell Technology Evaluation Center (NFCTEC) at NREL.
- Academic objectives
  - Contribute to the development of new industry standards
  - Develop and implement fueling station system performance optimization
  - Conduct outreach and training activities promoting the project and hydrogen and fuel cell technologies
  - Provide a living-lab environment for engineering and technology students pursuing interests in hydrogen and fuel cell technologies



# Tasks: Phase 1

Task 1. Develop data acquisition (DAQ) for station performance with existing capability

Task 2. Design and implement enhanced data acquisition (DAQ) for station performance evaluation

Task 3. Enable hydrogen purity testing and reporting

**COMPLETED**



# Tasks: Phases 2 and 3

Task 4. Regular data collection and reporting after completing Task 2 **COMPLETED**



Task 5. Conduct outreach and training activities for public and government and engage students in station related activities.

Task 6. Data reporting update and station performance optimization after completing Task 4

Task 7. Evaluate station utilization and assess the need for station upgrades and enhanced performance



# CSULA Hydrogen Station

Production: 60 kg/day

Storage: 60 kg

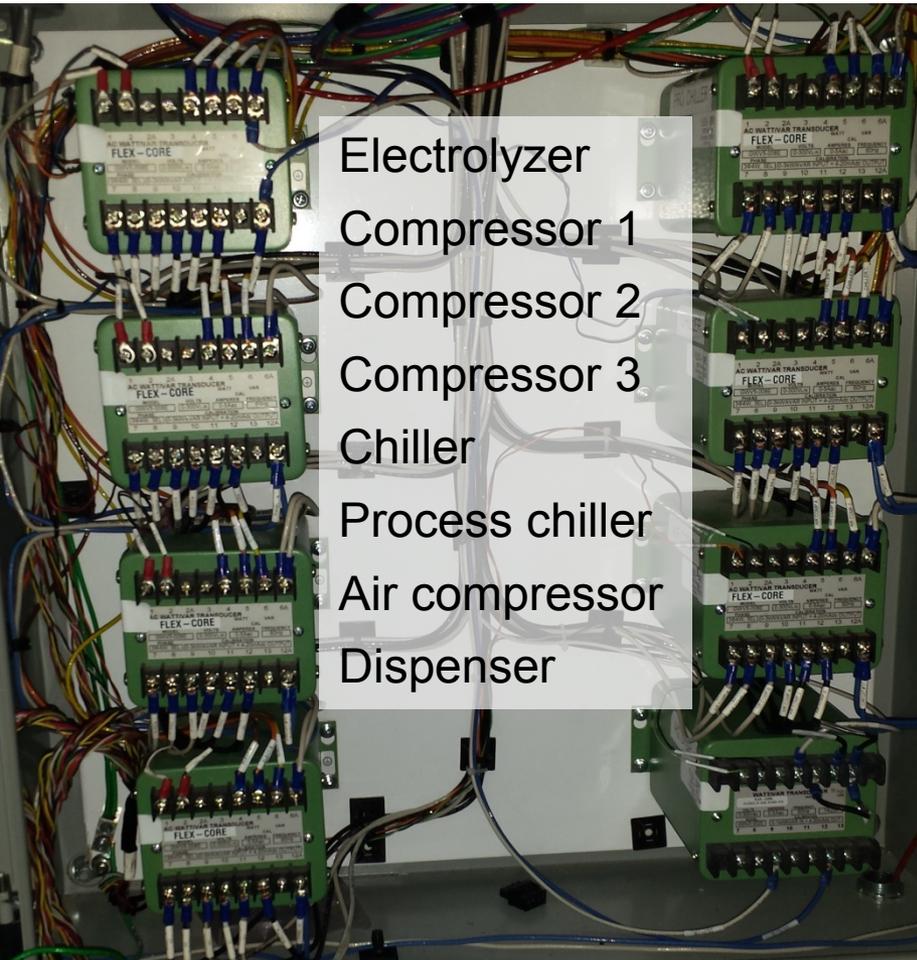
Pressure: 5,000 and 10,000 psi

Capacity: 15-20 fuel cell vehicles per day





# Approach/Strategy: Facility Power Meters



- Electrolyzer
- Compressor 1
- Compressor 2
- Compressor 3
- Chiller
- Process chiller
- Air compressor
- Dispenser

Facility Power Meters Junction Box

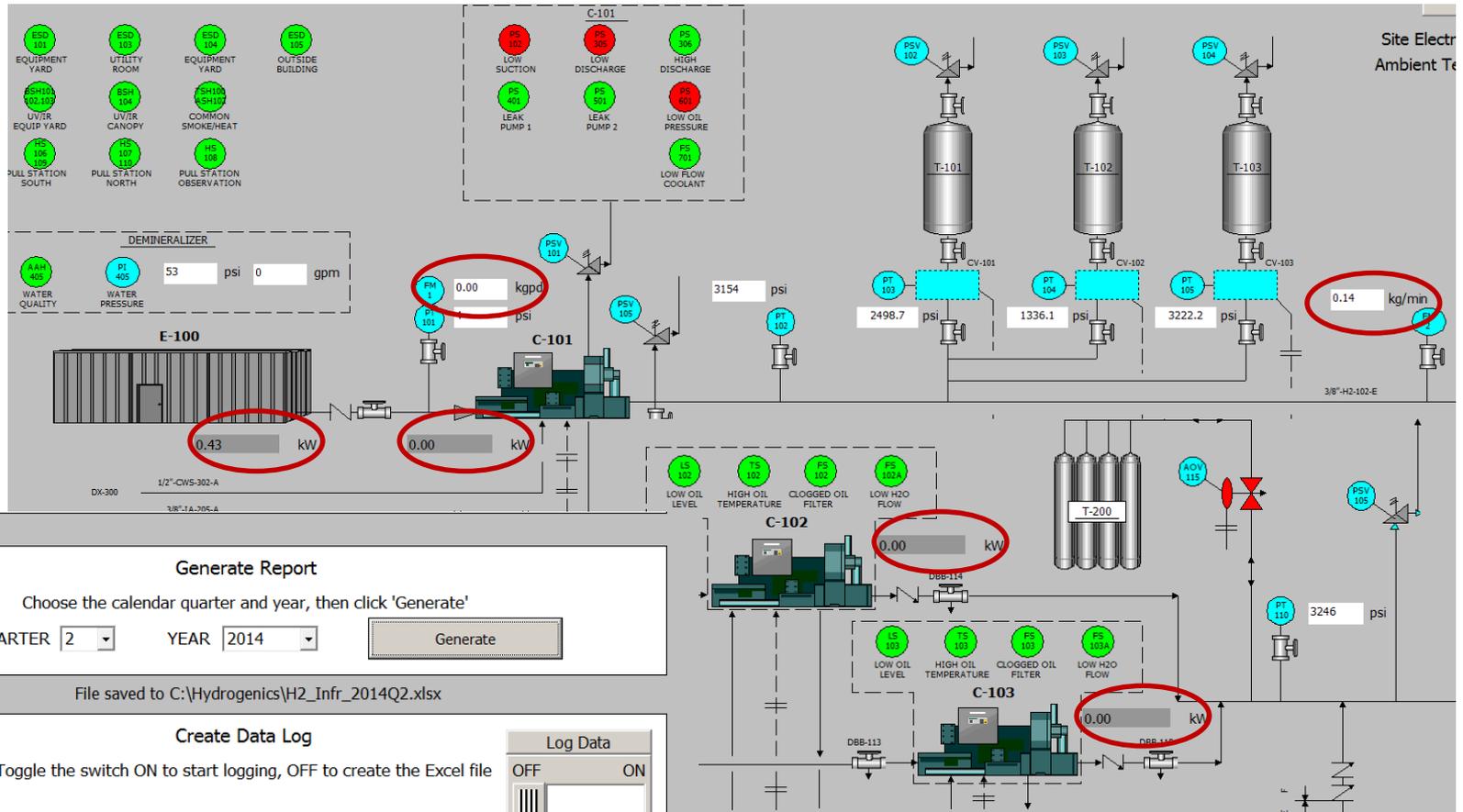


Facility Master Meter:  
Base load  
(above)  
Electrolyzer on  
(right)





# Accomplishments: Readings in the Interface





# Accomplishments: Reports Automatically Generated

H2\_Infr\_2015Q1.xlsx - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW ACROBAT

A20 : 700 Bar Dispensing

|    |                                              |                      |               |          |          |
|----|----------------------------------------------|----------------------|---------------|----------|----------|
| 4  | Calendar Quarter (ex. 2011Q2)                |                      | 2015Q1        |          |          |
| 5  | Site Name                                    |                      | CSULA         |          |          |
| 6  | Precooling Description                       |                      | Chiller       |          |          |
| 7  | Manufacturer/ Model                          |                      | Quantum/70MPa |          |          |
| 8  | Precooling Temperature                       |                      | -20           |          |          |
| 9  |                                              |                      |               |          |          |
| 10 | <b>Data should be from reporting quarter</b> |                      |               |          |          |
| 11 | Monthly Data Table                           |                      | Month         |          |          |
| 12 | Category                                     | Units                | Month1        | Month2   | Month3   |
| 13 | 250 or 350 Bar Dispensing                    |                      |               |          |          |
| 14 | Hydrogen Dispensed at 250 or 350 bar         | kg                   | 14.69         | 30.10    | 1.97     |
| 15 | 250 or 350 bar Energy Cost                   | dollars              | \$ 3.48       | \$ 9.95  | \$ 0.37  |
| 16 | Total Energy Consumed in Dispensing 350 bar  | MJ                   | 114.05        | 325.74   | 11.97    |
| 17 | Dispenser Electronics                        | MJ                   | 44.71         | 82.18    | 3.05     |
| 18 | 350 Precool Energy Consumed                  | MJ                   | 69.33         | 243.56   | 8.92     |
| 19 | Specific Energy Consumed                     | MJ/(kg H2 processed) | 7.76          | 10.82    | 6.09     |
| 20 | 700 Bar Dispensing                           |                      |               |          |          |
| 21 | Hydrogen Dispensed at 700 bar                | kg                   | 101.03        | 95.13    | 240.75   |
| 22 | 700 bar Energy Cost                          | dollars              | \$ 10.76      | \$ 10.45 | \$ 11.52 |
| 23 | Total Energy Consumed in Dispensing 700 bar  | MJ                   | 352.16        | 341.92   | 377.08   |

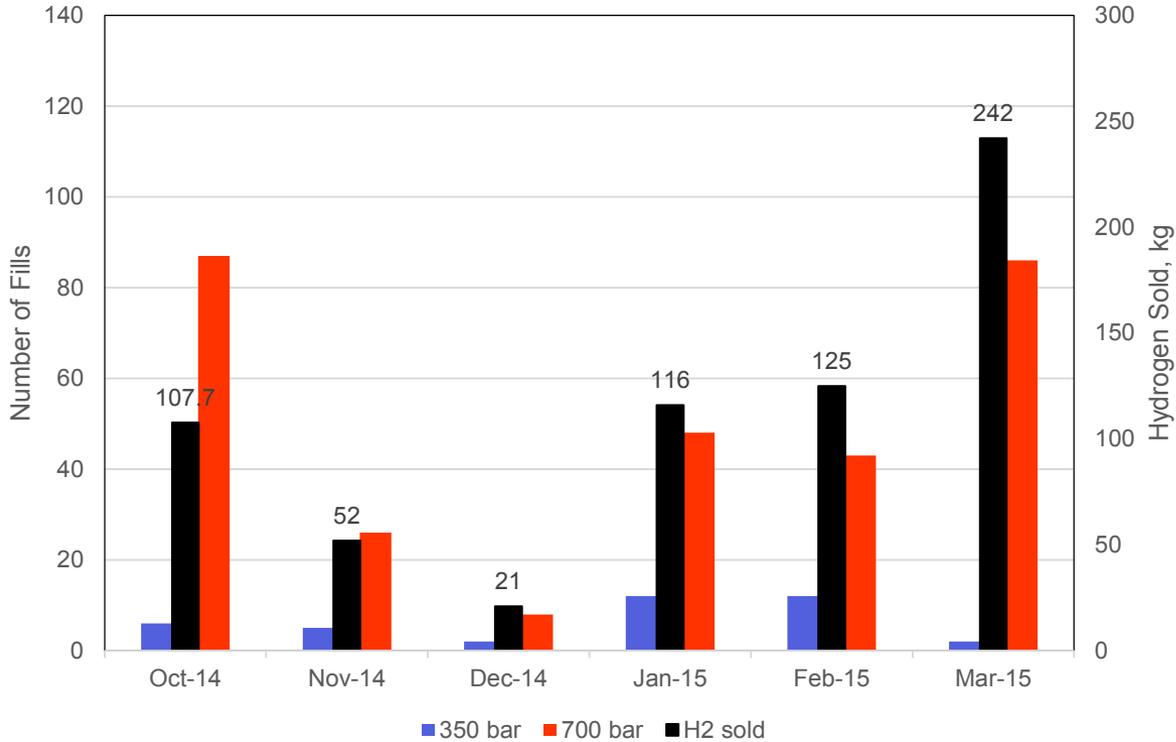
Navigation: Compression\_3\_700 | Dispensing | Fuel Log | Maintenance | H2 Cost | Safety | H2 Quality | Electrolyzer

2015 Q1 is displayed.

Data is collected in Microsoft SQL database  
Upon request performance reports are automatically generated



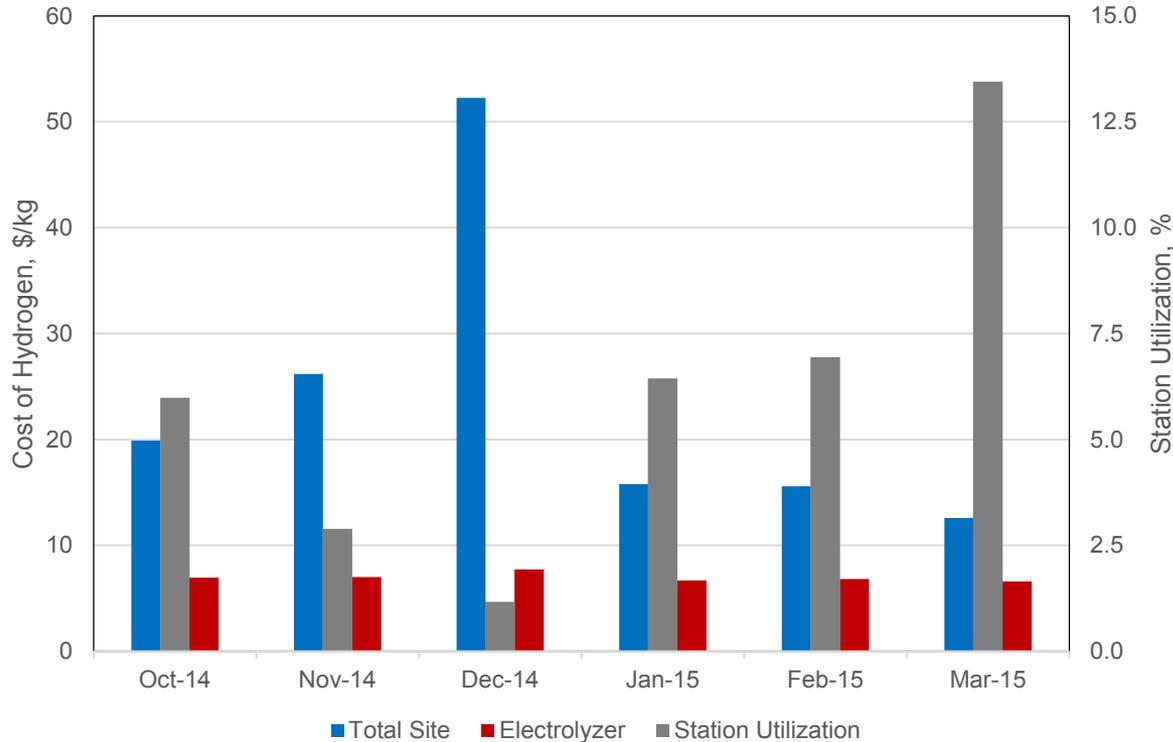
# Fueling Events



The chart demonstrates:  
 Fueling demand increases, maximum in March 2015 at 242 kg  
 700 bar fills are dominant



# Hydrogen Costs



The chart demonstrates:

Station utilization rose to 13% in March 2015, 100% corresponds to 30 day/month x 60 kg/day = 1800 kg/month

Cost of electricity used is 13 ¢/kWh. Cost of hydrogen from electrolysis is level at 6.60-6.90 \$/kg. However, with the balance of plant, the cost is highly dependent on utilization and fluctuated from 50 to 12 \$/kg with utilization of 3 and 13% respectively.



# Collaborations: Dispensing Meter Type Approval

CSULA is the first in U.S. to receive seal of approval for sale of hydrogen on per kg basis as of January 2015. Testing was conducted in collaboration with the California Department of Weights and Measures, CAFCP and CARB.



Testing equipment at CSULA Station  
Right, yellow sticker- seal of approval



# Collaborations: Enabling Special Activities



Mobile lighting system.

Right, mobile refueler for remote hydrogen-fuel cell installations.



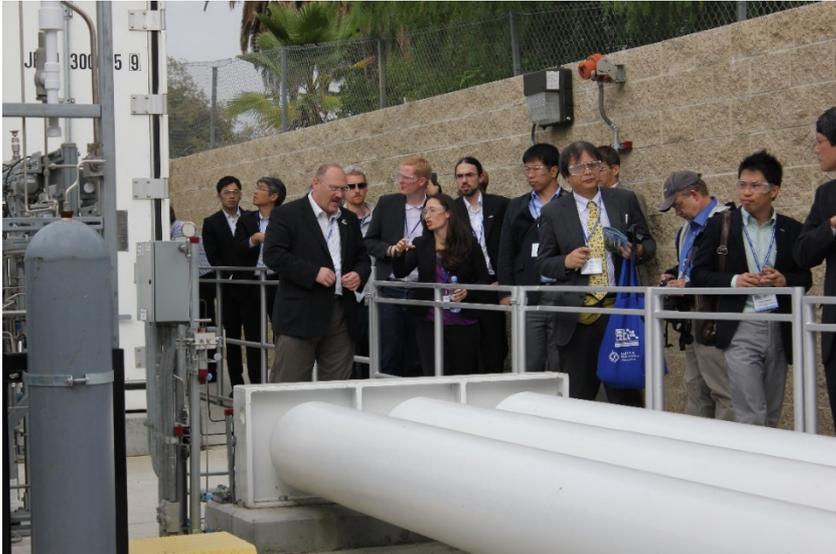
# Collaborations: Enabling Special Activities



The station is medium and heavy duty vehicle capable, E-bus fueling. Right, Audi demonstrates new fuel cell vehicles during 2014 LA Auto Show

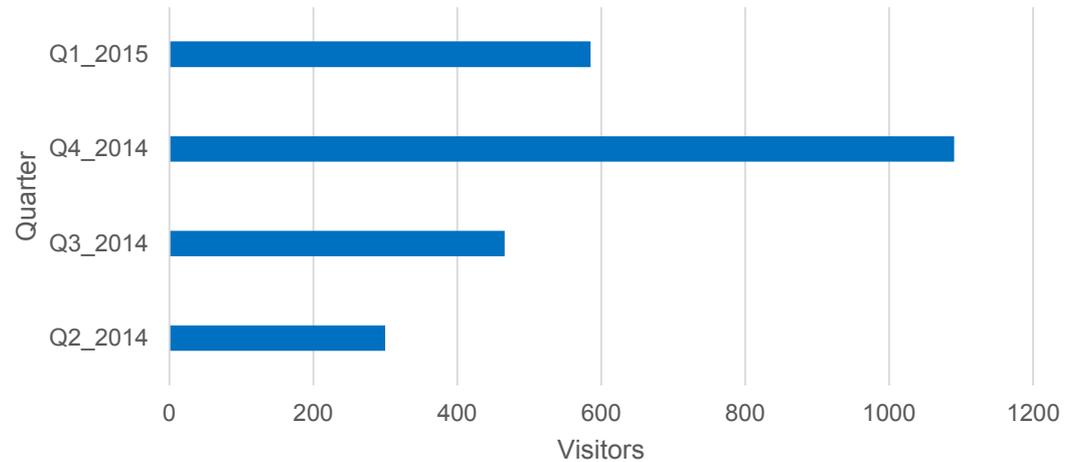


# Outreach



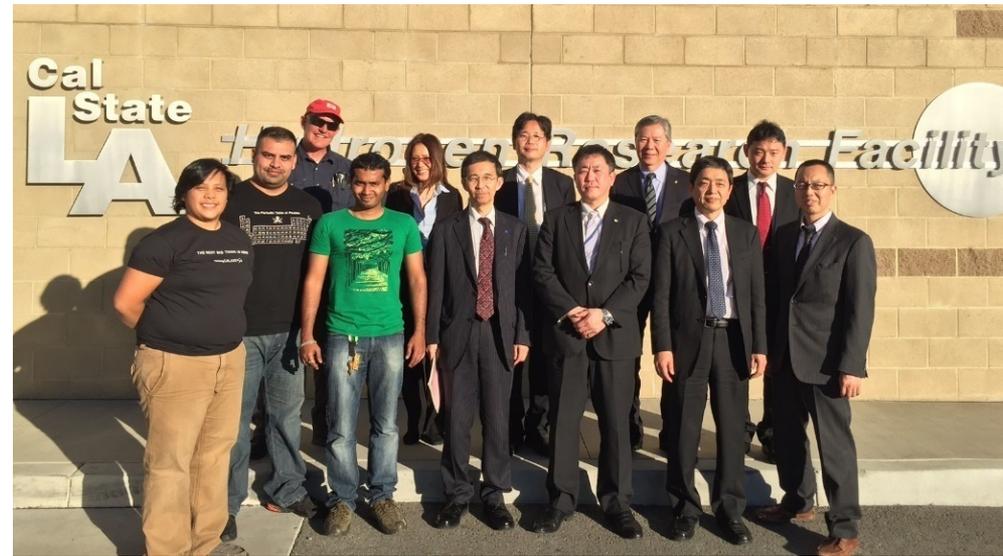
Professional meetings  
 Filming documentaries

Number of visitors (right) to  
 CSULA hydrogen station





# Outreach

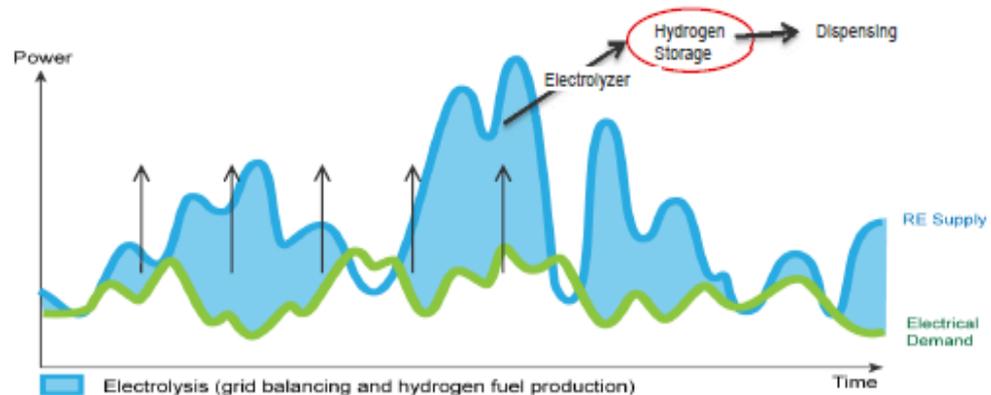


International visitors  
First responder training  
Scholars, students  
Local government



# Future Work: Research Opportunities

- Performance Optimization, Hydrogen Fleet and Infrastructure Analysis
  - Weekly patterns/storage
  - Availability via mobile app
  - Metering
- Smart Grid: Load Following with Renewable Power Generation
  - Off-peak load
  - Load shedding
- Workforce, Public and Professional Education



Intermittent wind exceeds load



# Summary

- **RELEVANCE.** Program demonstrates high relevance to the DOE Hydrogen and Fuel Cell program especially in light of rapid development of hydrogen infrastructure in CA and thousands of FCV expected in 2015-2016.
- **APPROACH.** Reviewed NREL reporting requirements and identified instrumentation needed. Developed pathways to improve station performance.
- **ACCOMPLISHMENTS.** Tasks 1, 2 and 3 completed. Transitioned into 4 and 5. Implemented installation of power and flow meters. Installed buffer tanks. Created Microsoft SQL database that generates quarterly reports. . Data is continuously collected and analysis has been enabled.
- **COLLABORATIONS and OUTREACH.** Rapid development of collaborations: CA DMS, CAFCP, H2FIRST. Funded member of the Southern CA Alternative Fuel Center. Conducted robust outreach activities.
- **FUTURE WORK.** Short term: collecting data, analyzing station and individual equipment performance. Long term: smart grid, infrastructure and expanded education opportunities.



# Publications and Presentations

- “Hydrogen Station Performance Evaluation Plan,” D. Blekhman, M. Dray and G. Sleiman. Fuel Cell Seminar and Exposition, Los Angeles, CA, 2014