NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Hydrogen & Fuel Cell Technology Status

Shaping the Future of Business on Long Island

Robert J. Remick

3/16/2011

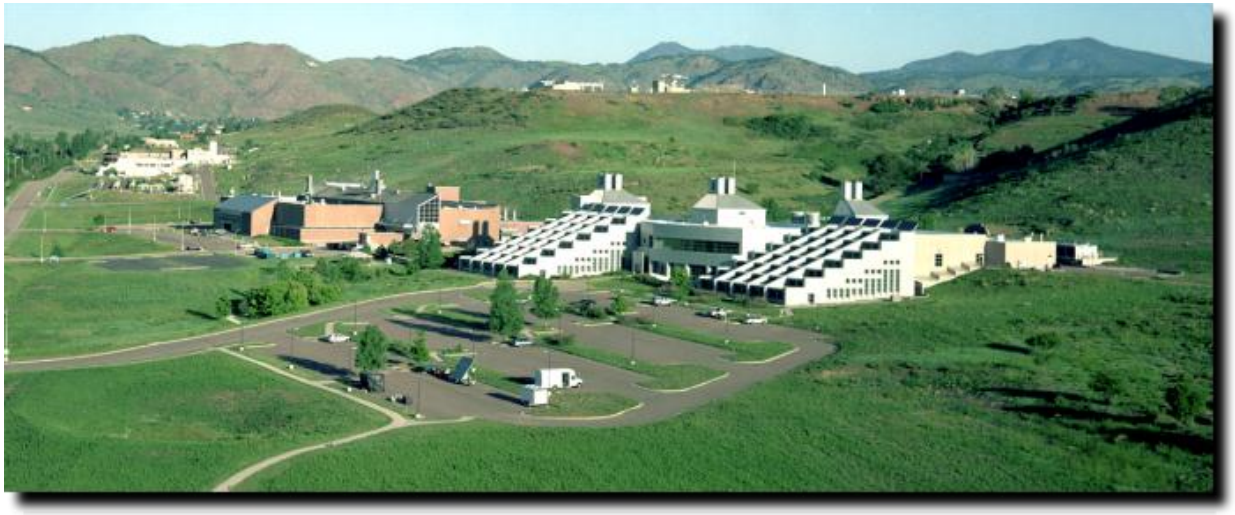
National Renewable Energy Laboratory

Only national laboratory ***dedicated*** to renewable energy and energy efficiency R&D

Research integrates range of solutions from fundamental ***science through technology deployment***

Collaboration with industry and university partners is a hallmark

Research is ***market relevant***



Primary Science & Technology Lines

Renewable Electricity





- Solar
- Wind
- Geothermal
- Electric Systems
- Building Systems

Strategic Energy Analysis

Foundational Science

Renewable Fuels



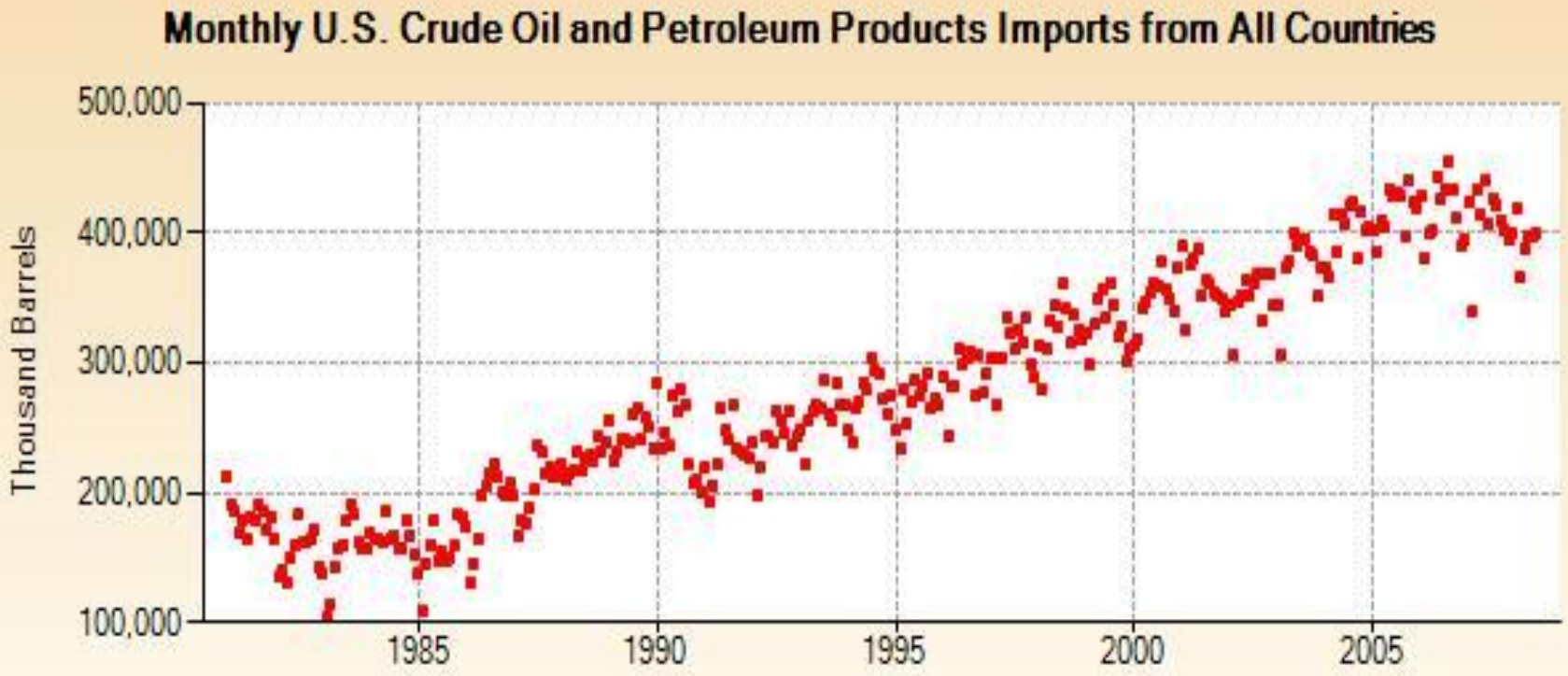


- Biofuels
- Hydrogen
- Vehicle Systems

- From Science to Systems -

Why Hydrogen?

U.S. Dependence on Imported Oil



Source: U.S. Energy Information Administration

- *Diverse Domestic Resources*
- *High Efficiency & Reliability*
- *Zero / Near-zero Emissions*

Renewable Sources:

- *Wind*
- *Biomass*
- *Solar*
- *Geothermal*
- *Hydro*
- *Ocean*

Non-Renewable Sources:

- *Nuclear*
- *Coal* (with carbon sequestration)
- *Natural Gas* (for transition period only)

H_2

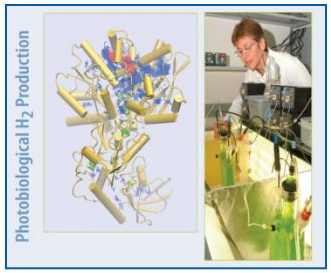
Stationary/ Backup Power

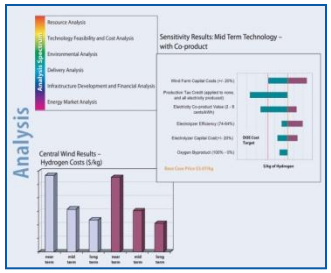
Transportation

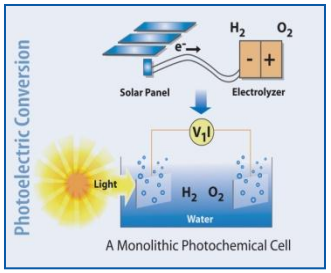
Specialty Markets

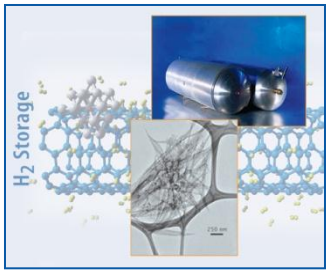
NREL Hydrogen Technology Thrusts

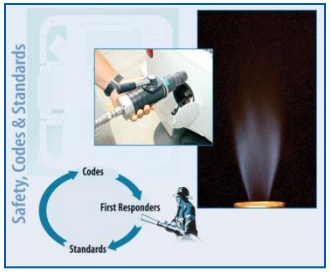
- Hydrogen production
- Hydrogen delivery
- Hydrogen storage
- Fuel cell manufacturing
- Fuel cells
- Technology validation
- Safety, codes, & standards
- Analysis







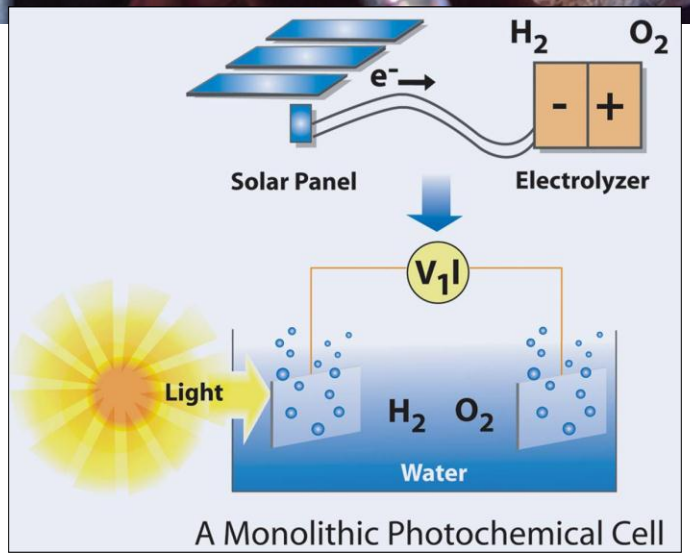




H_2 Production: Photoelectrochemical

Photoelectrochemical materials are specialized semiconductors that use energy from sunlight to dissociate water molecules into hydrogen and oxygen.

NREL's work involves identifying and developing durable and efficient photoelectrochemical materials, devices, and systems.

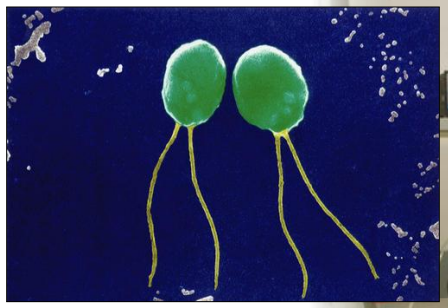


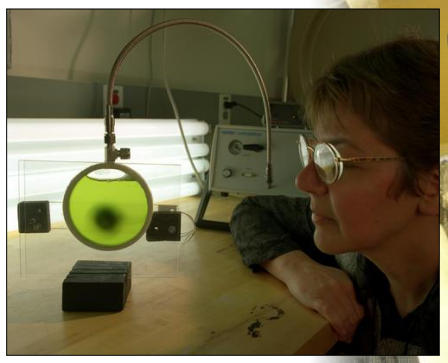
A Monolithic Photochemical Cell

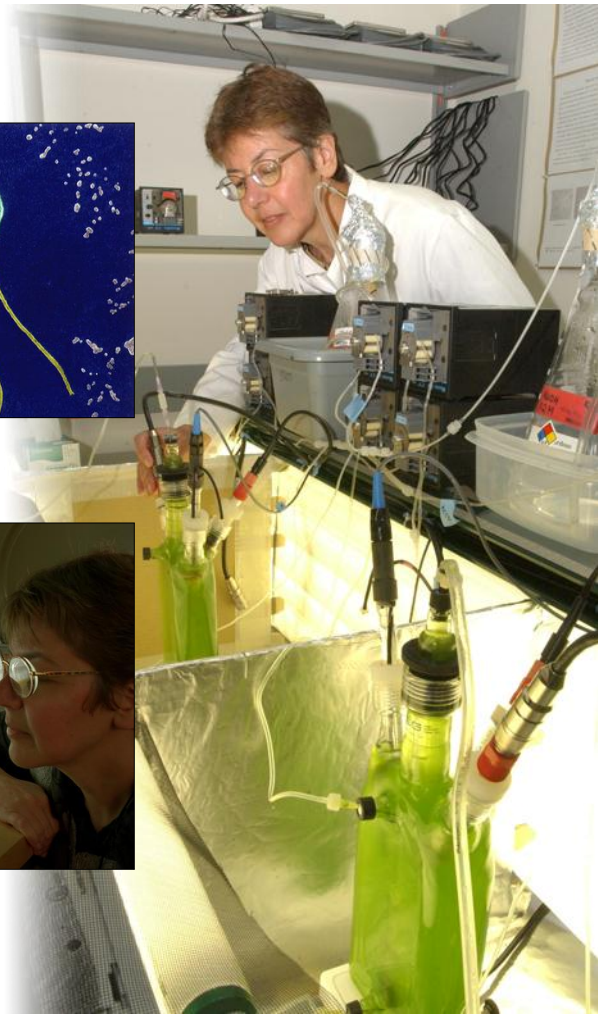
H_2 Production: Photobiological

Hydrogen is produced from water using sunlight and specialized microorganisms such as green algae and cyanobacteria. These microorganisms consume water and photoproduce hydrogen as a byproduct of their natural metabolic processes.

NREL is engineering organisms that can sustain hydrogen production in the presence of oxygen.







H_2 Production: Fermentation

Fermentation technologies are used to convert renewable biomass resources such as corn stover, sugarcane residue, and switch grass into hydrogen.

NREL is investigating direct fermentation of cellulose and hemicellulose as feedstock for hydrogen production.

H_2 Production: Biomass Pyrolysis

Biomass pyrolysis produces a liquid product—bio-oil—which contains a wide spectrum of components that can be efficiently produced, stored, and shipped to a site for renewable hydrogen production.

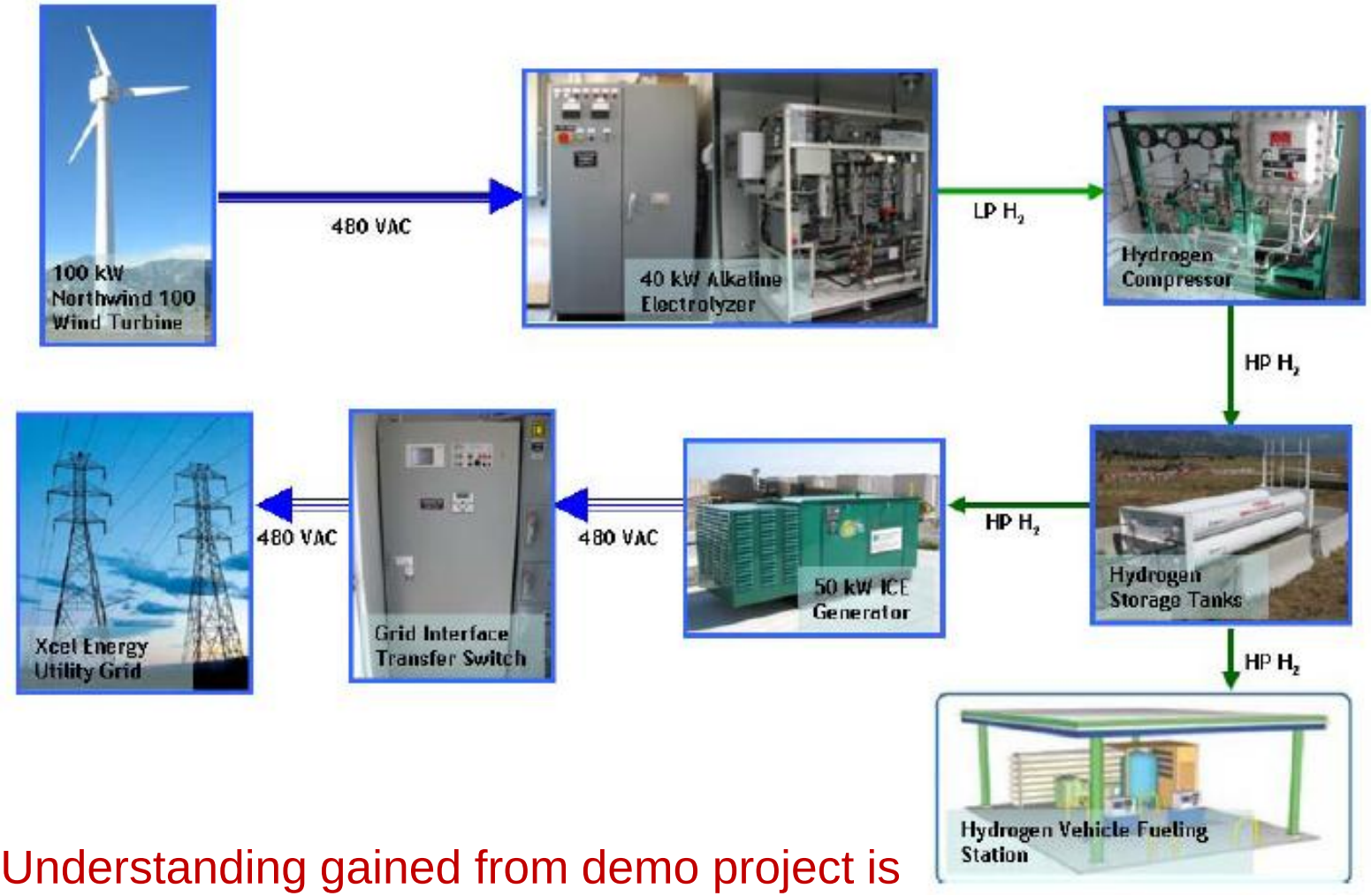
NREL is investigating the low-temperature, partial oxidation, and catalytic reforming of bio-oil to produce hydrogen.

H_2 Production: Biomass Gasification

Biomass is converted into syngas—a gaseous mixture of CO, hydrogen, and other compounds—by applying heat in the presence of steam and oxygen.

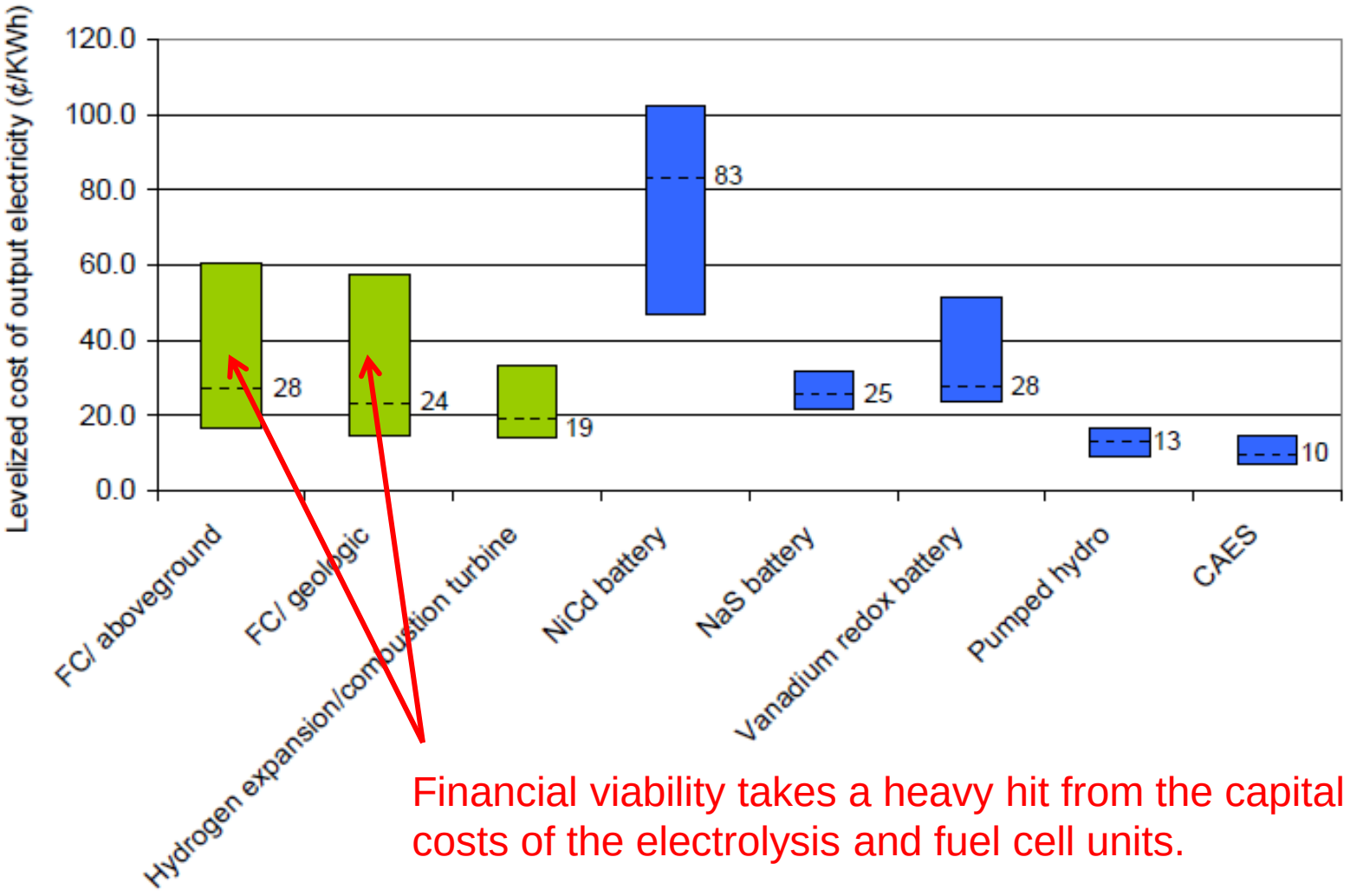
NREL is investigating gasification yields, gas compositions, and contaminant removal for centralized hydrogen production.

H_2 for Renewable Electric Storage



Understanding gained from demo project is being used to do financial analyses.

Cost of Hydrogen-based Electricity Storage (3.8¢ per kWh electricity input cost)

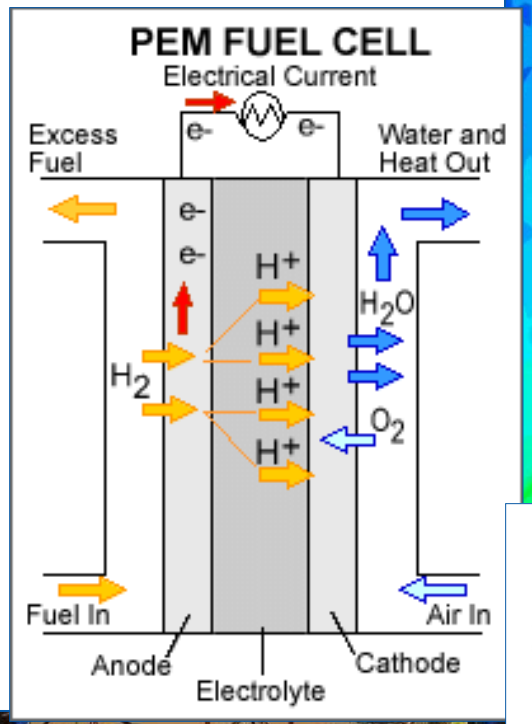


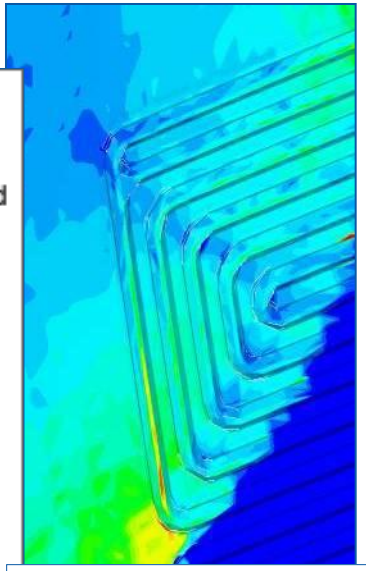
Financial viability takes a heavy hit from the capital costs of the electrolysis and fuel cell units.

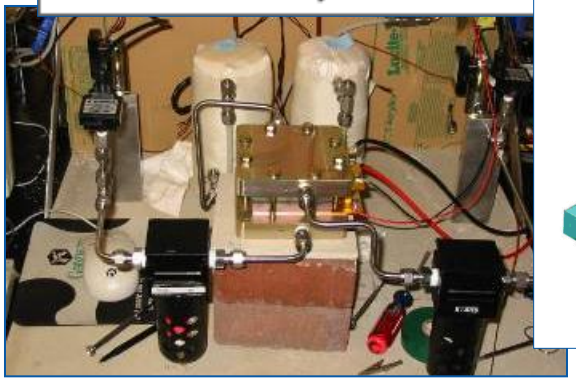
Best use of H_2 is in Fuel Cells

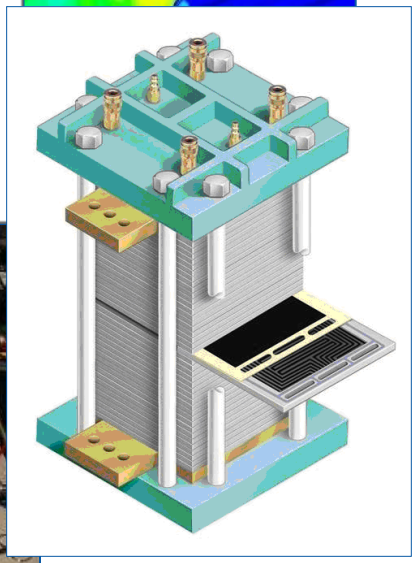
Fuel cells use hydrogen (or hydrogen-rich fuel) and oxygen or air to create electricity by an electrochemical process.

NREL's work involves improving the cost, performance, and durability of proton exchange membrane fuel cells, with a focus on low-cost catalyst development.









Learning Demonstration Project

Started in 2006 with four auto manufacturers and three energy companies.

Ford/BP and Chevron/Hyundai-Kia Concluded in 2009

Daimler, GM, and Air Products Continue to Demonstrate Vehicles/Stations within Project through 2011

Hydrogen Secure Data Center - Approach

Bundled data (operation & maintenance/safety) delivered to NREL quarterly

DDPs

Internal analysis completed quarterly

HSDC

NREL's Hydrogen Secure Data Center

CDPs

Detailed Data Products (DDPs)

•Individual data analyses

• Identify individual contribution to CDPs

• Only shared with partner who supplied data every 6 months[1]

Composite Data Products (CDPs)

•Aggregated data across multiple systems, sites, and teams

• Publish analysis results without revealing proprietary data every 6 months[2]

1) Data exchange may happen more frequently based on data, analysis, & collaboration

2) Results published via NREL Tech Val website, conferences, and reports

DOE Vehicle/Infrastructure Demonstrations

Verified performance in 152 fuel cell vehicles and 15 hydrogen filling stations:

- *EFFICIENCY: 53 – 58% (>2x higher than internal combustion gasoline engines)*
- *RANGE: 196 – 254 miles*
- *FUEL CELL SYSTEM DURABILITY: 2000 hours (~70,000 miles)*

Demonstrated Fuel Cost: $8.00/gge, from natural gas

NREL/SRNL Verify >400 mile range

Test Route

68 mile/kg (≈mpg)

DRAFT

Evaluation of Range Estimates for Toyota FCHV-adv Under Open Road Driving Conditions

Keith Wipke[1], Donald Anton[2], Sam Sprik[1]

ver. 2.1
July 10, 2009
PTS-05 of SRNS CRADA No. CR-04-003

SRNL

NREL National Renewable Energy Laboratory
Innovation for Our Energy Future

[1] National Renewable Energy Laboratory
[2] Savannah River National Laboratory

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Capabilities Developed Under Fuel Cell Vehicle Learning Demo Being Applied to Other/New Projects

FC Buses
(funded by DOE and DoT)

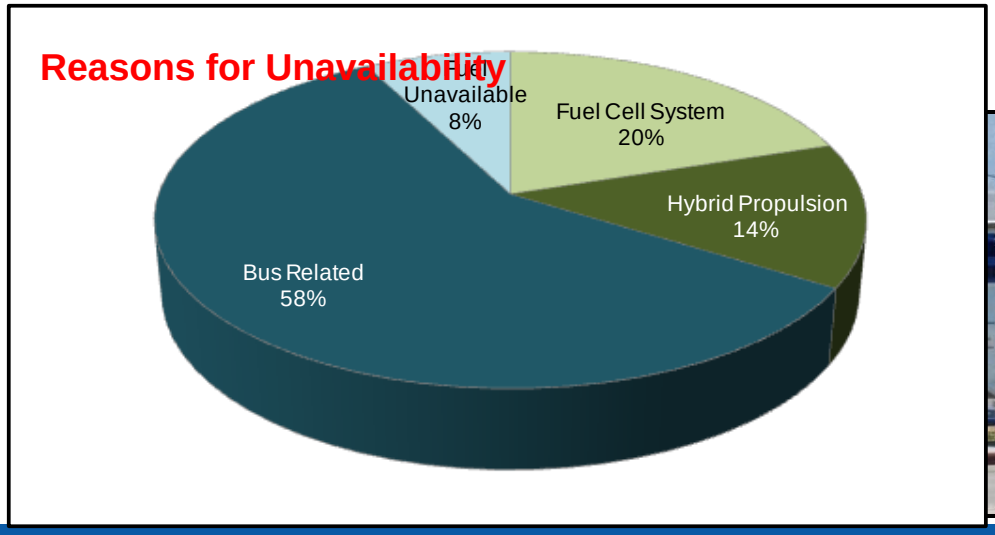
FC Forklifts
(funded by DoD and DOE)

FC Backup Power
(funded by DOE)

Data Summary: Next-Generation FCBs

SunLine — Palm Springs, California Status: in progress

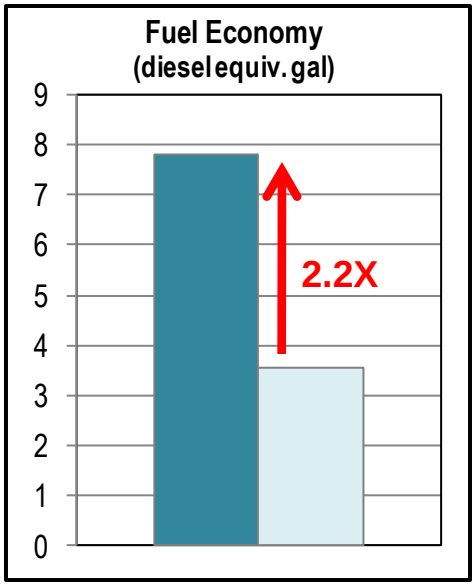
- New Flyer/Bluways bus with Ballard fuel cell system
- Bus went into service May 27th
- More than 9,600 miles accumulated, >800 fuel cell hours
- Average hours/day: 7.37
- Max hours in one day: 14.4
- 5.75 mi/kg, 6.5 mi/DGE: 2 times CNG baseline buses
- First report published in March 2011

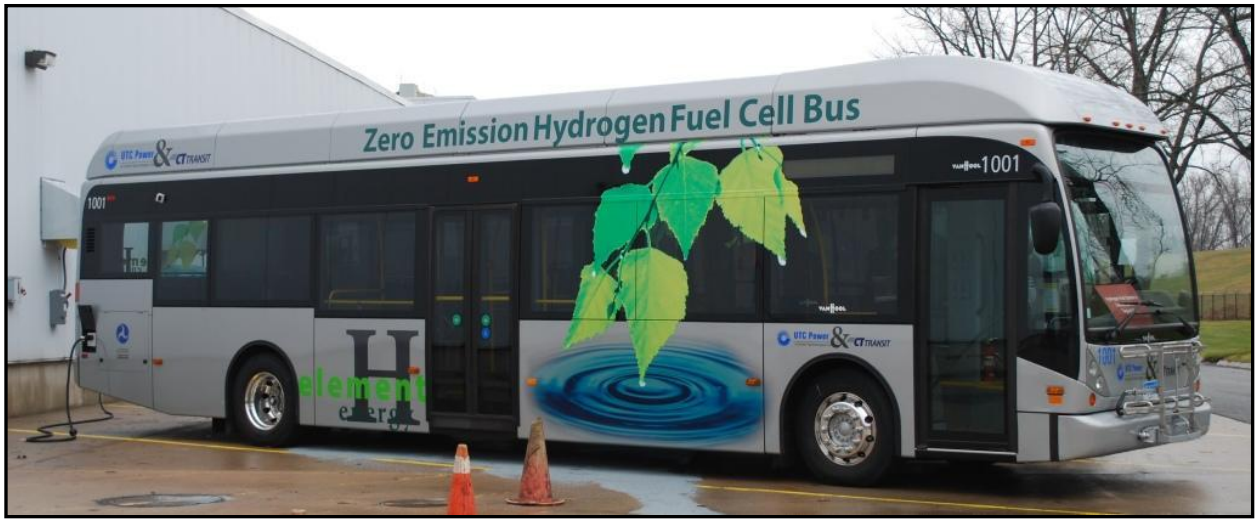


Data Summary: Next-Generation FCBs

CTTRANSIT — Hartford, Connecticut Status: in progress

- Next generation, 40-ft Van Hool/UTC Power
- Fuel cell dominant hybrid system
- Four buses delivered and in operation
- Buses have logged more than 11,000 miles
- 858 total FC hours
- 6.92 mi/kg; 7.82 mi/DGE at 13.7 mph average speed





National Fuel Cell Bus Program

Data Summary: Next Gen FCBs

AC Transit — Oakland, California

- Zero Emission Bay Area (ZEBA) demonstration led by AC Transit
- 40-ft Van Hool/UTC Power
- 7 of 12 buses delivered
- 3 first-generation buses retired. Two of those fuel cell power systems were transferred into new buses (one > 8,500 hrs.)

BurbankBus — Burbank, California

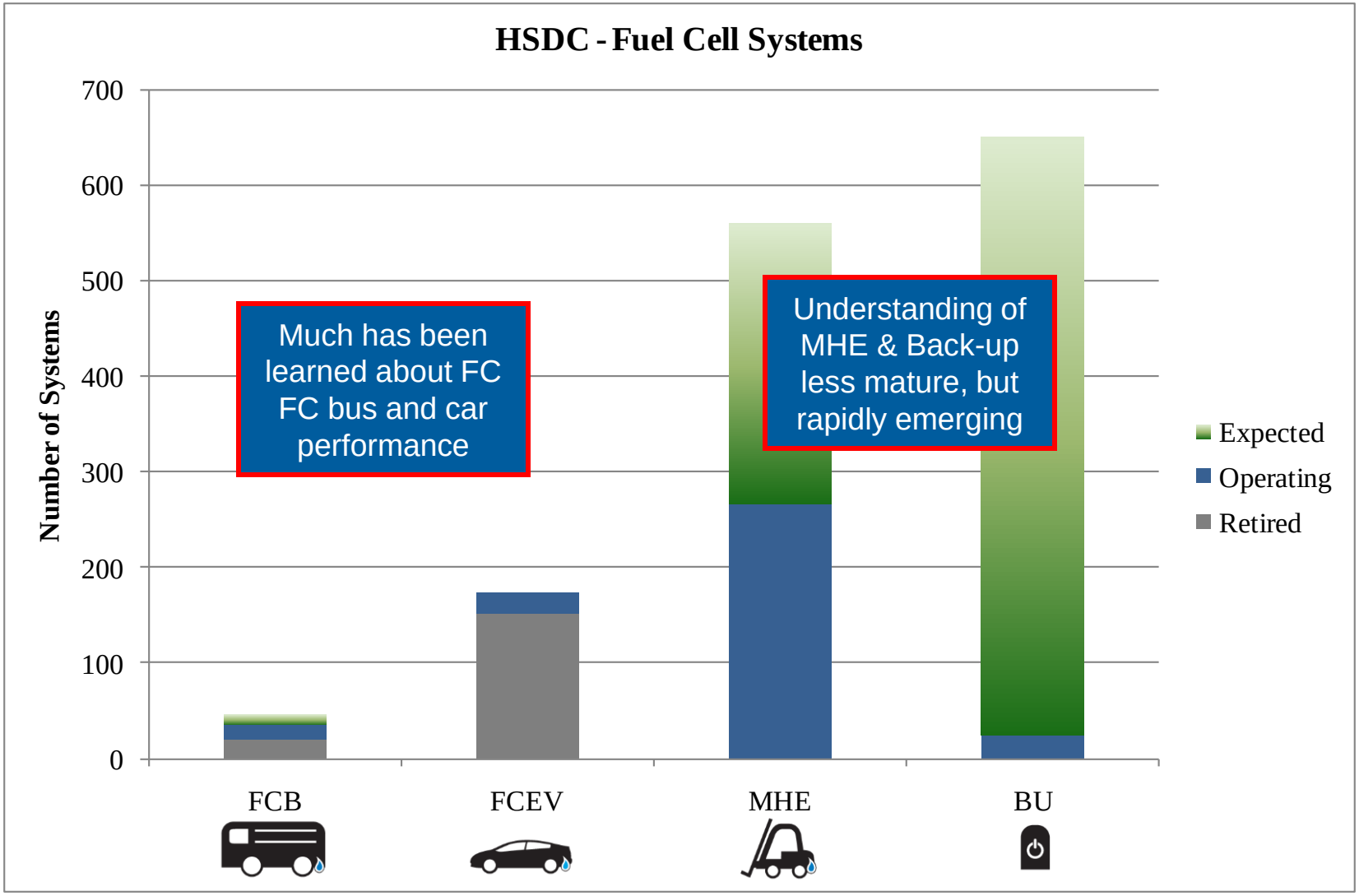
- CARB funded development and demonstration project
- Proterra FCB, battery dominant, plug-in hybrid
- Hydrogenics fuel cells and lithium titanate batteries

Fuel Cell-Powered Forklifts are Here Now

Hydrogen-powered fuel cells are a viable solution for material handling equipment

- Allow for rapid refueling
- Provide constant power during use
- Eliminate need for space for battery storage and chargers
- Fuel costs are a problem

Number of Fuel Cell Units Being Evaluated and Providing Data to NREL



Government Funded Early Fuel Cell Markets

- Funding sources include DOD Defense Logistics Agency, DOE American Recovery and Reinvestment Act (ARRA), and DOE Interagency Agreement (IAA)
- Diverse collection of early market fuel cell applications, project partners, and end users
- Expected fuel cell deployment: >1,000 units
- Fuel cell applications cover fuel cell forklifts, backup power, micro-CHP, APU, and portable power

Summary

- Hydrogen-fueled fuel cells are a good business case today for back up power supplies, for example for the telecommunications industry (cell towers) although fuel delivery to remote locations is a problem.
- Fuel cell-powered forklift trucks are approaching commercialization targets but fuel costs are high.
- Fuel cell transit buses are moving toward commercialization as well, but still need more durability.
- Fuel cell vehicles will be in the showrooms and available for purchase in 2015 from GM, Toyota, Honda, and possible Hyundai in the US and from Daimler in Europe. But where will they find fuel?

Recent Quotes

“Toyota says cost of fuel cells will plunge by 2015.”

Automotive News/March 7th, 2011.

“South Korea expects to add a half million new jobs working in fuel cells over the next few years.”

Motorweek/March 14th, 2011 Segment 3024

Information Resources

Start at www.nrel.gov


NREL has 1,800 talented staff, with a track record of accomplishment, who are passionate about delivering on the nation's energy efficiency and renewable energy objectives.