Proton ENERGY SYSTEMS | The Leader in On-site Hydrogen Generation

Development of Reversible Fuel Cell Systems at Proton Energy

Everett Anderson

NREL/DOE Reversible Fuel Cell Workshop

19 April 2011

PROTON
THE LEADER IN ON SITE GAS GENERATION.

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Proton Energy ⇨ Proton OnSite

- Reflects developing business model & expansion into other markets
- Leader in on-site generation of nitrogen, oxygen & zero air to compliment hydrogen
- Remains dedicated to the H_2 energy market

"We bring the gas solution to our client - be it hydrogen gas to a power plant, nitrogen gas to a laboratory or oxygen to a submarine. Proton OnSite is now the leader in on-site gas generation, everywhere."

- Rob Friedland, CEO and president of Proton OnSite

Outline

- Company Intro
- Regenerative Fuel Cell Configurations
- Technology Development/Demonstrations
- Unitized vs. Discrete Trade-off
- Renewable Energy Storage Application
- Development Needs
- Current Progress / Future Work

Proton OnSite

- **Manufacturer of Proton Exchange Membrane (PEM) hydrogen generation products using electrolysis**
- **Founded in 1996**
- **Headquarters in Wallingford, Connecticut.**
- **ISO 9001:2008 registered**
- **Over 1,400 systems operating in 60 different countries.**

ANAB ACCREDITED

Certified to
ISO 9001:2008

TÜV Rheinland
Precisely Right.

Proton Capabilities


PEM Cell Stacks

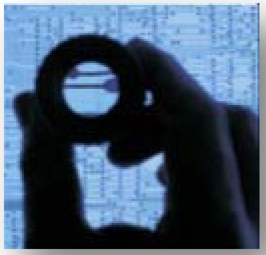

Complete Systems


Storage Solutions

- Complete product manufacturing & testing
- Containerization and on-site gas storage solutions
- Integration of electrolysis into RFC systems
- Turnkey product installation
- World-wide sales and service


Power Plants


Heat Treating


Semiconductors


Laboratories


Government

Hydrogen Products

Commercial Products

HOGEN™ Hydrogen Generators

S Series

H Series

C Series

HPEM
High Pressure
Generators

Lab Gas Generators

GC

StableFlow™

Hydrogen Control Systems

Future Products

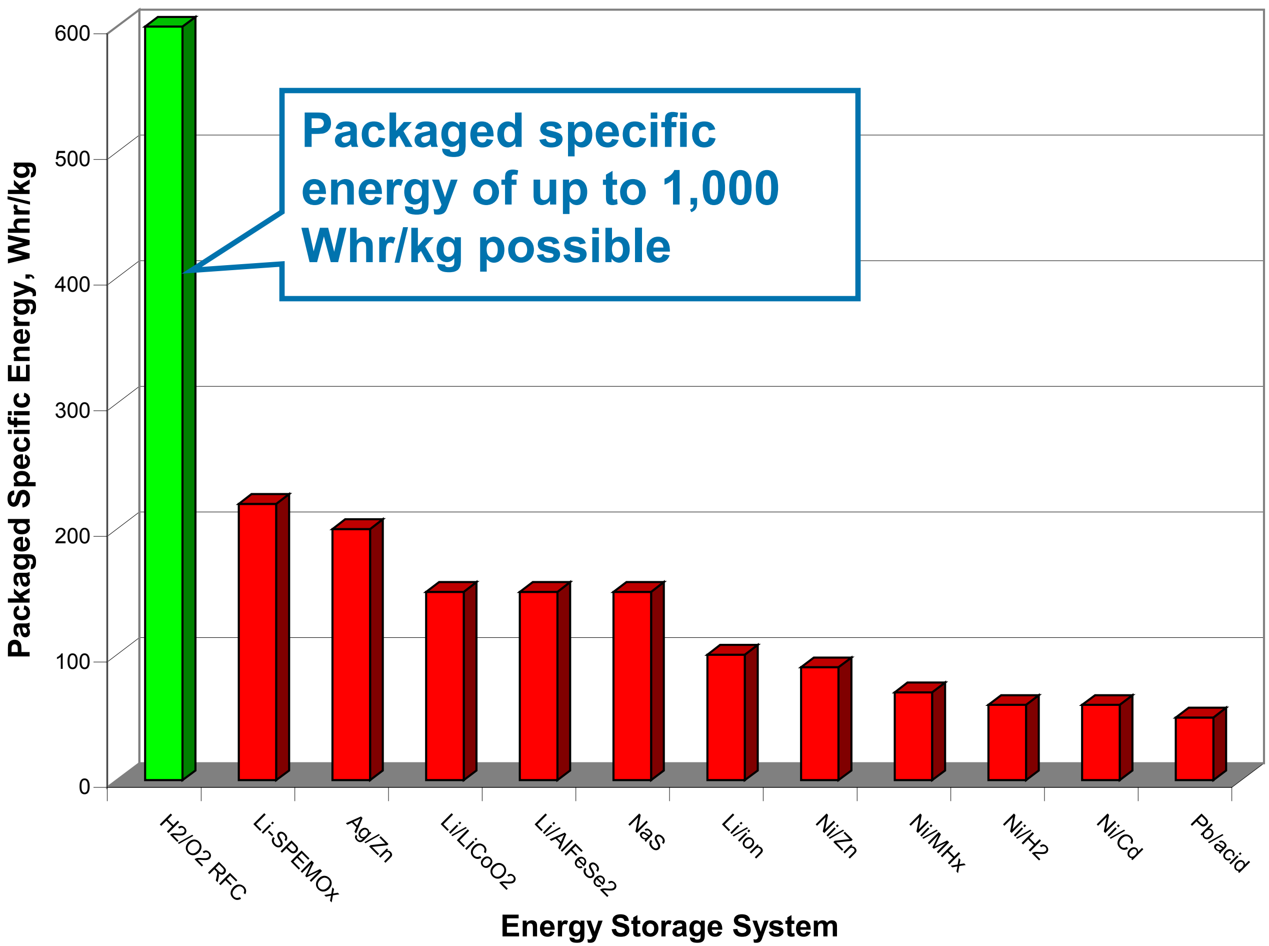
Fueling

Backup Power

Renewable Energy Storage

Regenerative Fuel Cells

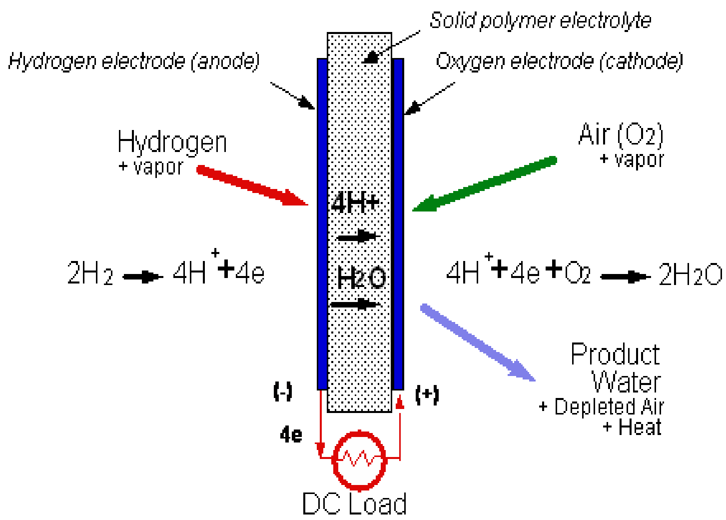
Comparison of specific energy to batteries



Source: Mitlitsky, et al, "Regenerative Fuel Cells", Energy and Fuels, 1998.

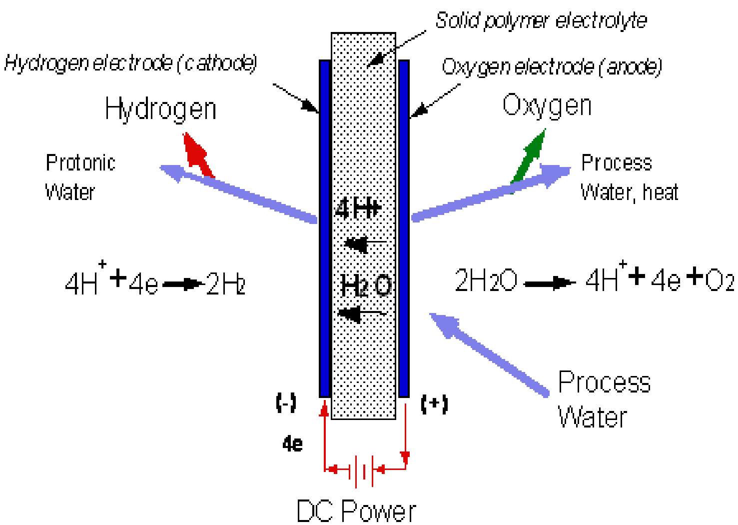
PEM Fuel Cell & Electrolysis

PEM Fuel Cell



Power Generation Mode

PEM Electrolysis

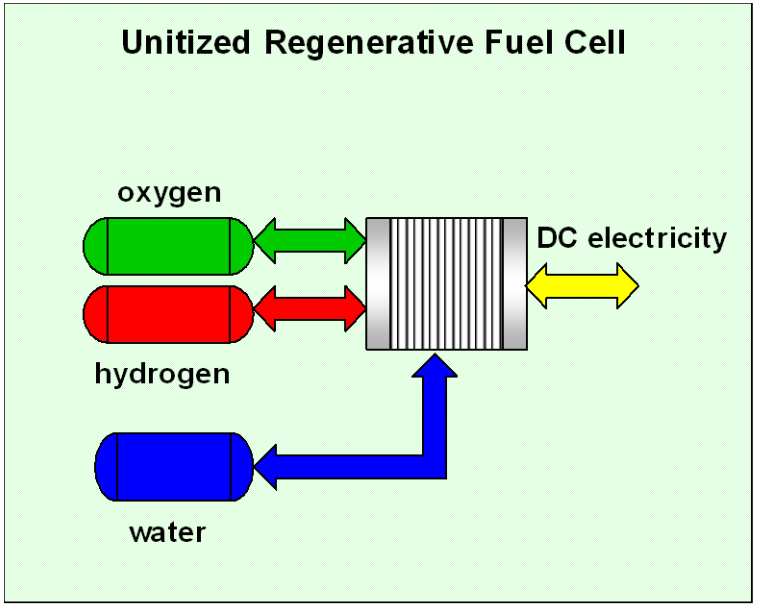


Hydrogen Generation Mode

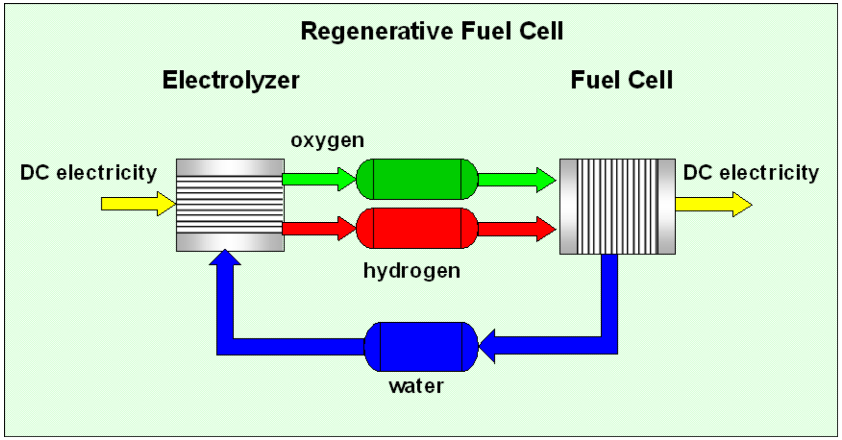
- Humidified gas streams vs. liquid water in contact with membrane
- Both need to consider 2-phase flow optimization in flow fields
- High potential material compatibility (~1V or less versus up to ~2V or more)
- Different pressure differentials (20 to >2400 psi) and high sealing loads
- Long lifetime expectations (5,000 vs. > 50,000 hours)

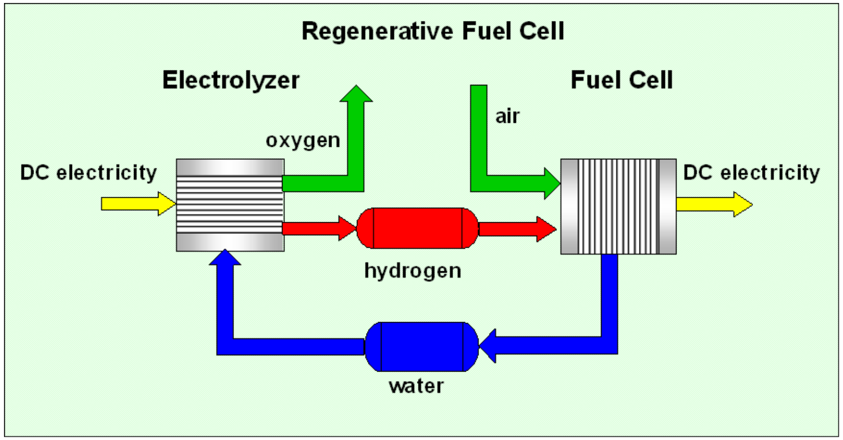
Regenerative Fuel Cells Options

- URFC – Unitized RFC
  - A cell stack that operates as both fuel cell and electrolyzer

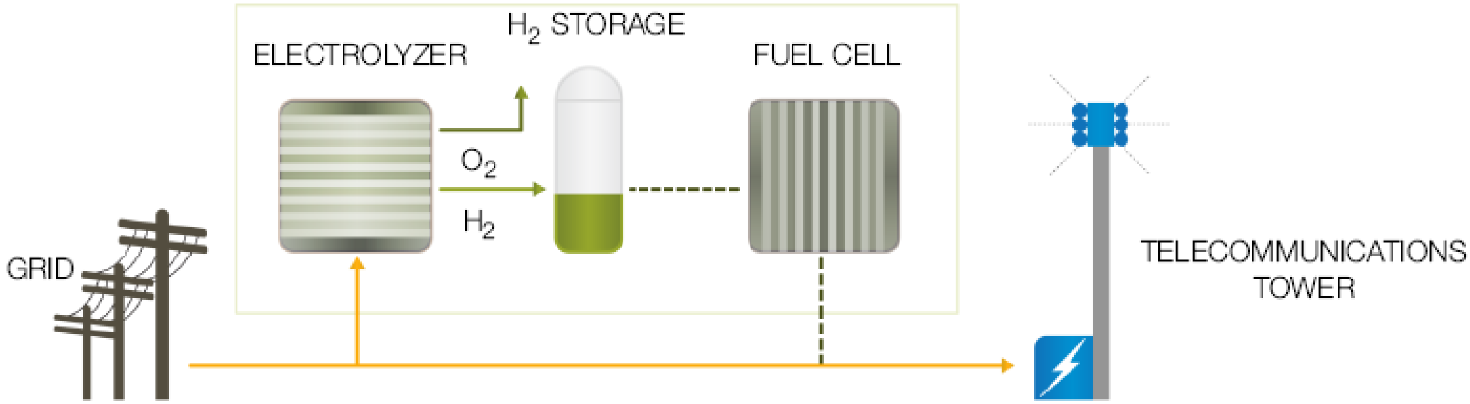


- DRFC – Discrete RFC
  - Separate fuel cell and electrolyzer stacks

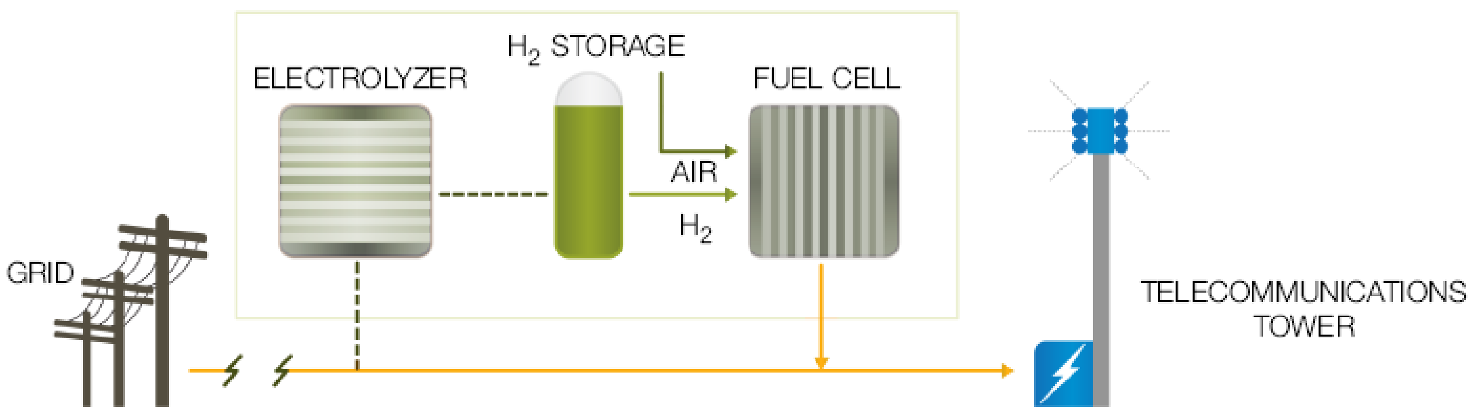




Backup Power System Concept
Using RFC & High Pressure Electrolyzer



When grid power is available, the HOGEN HP recharges the hydrogen storage.



When grid power is lost, the stored hydrogen is directed to a fuel cell, which provides backup power to the load.

Backup Power

Major Telecom Backup Power

- 3.5kW (net) of backup
- High-pressure hydrogen electrolyzer
- Enables function during a prolonged power outage

Wallingford Electric Substation

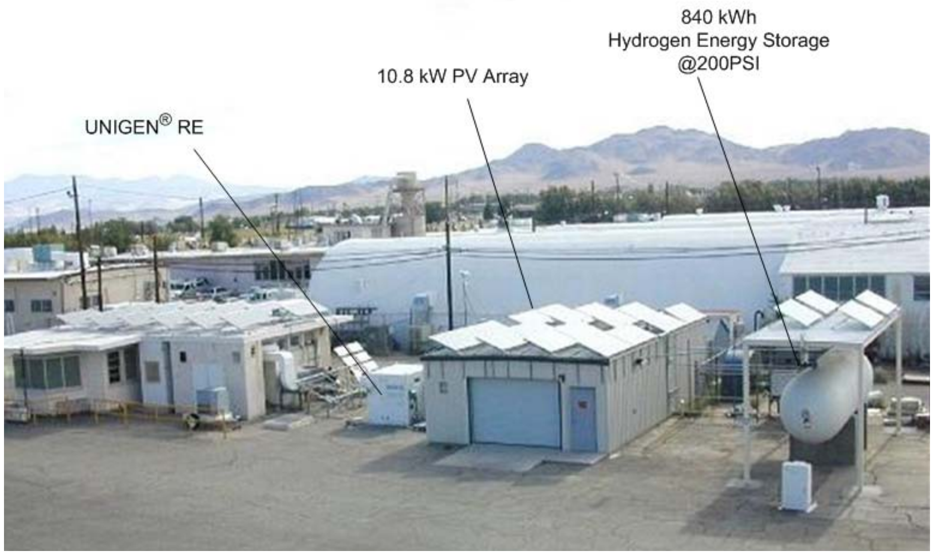
- 10kW (net) of backup
- Up to 8 hours of operation
- Outdoor high-pressure hydrogen electrolyzer
- 3 Plug Power GenCore® fuel-cell modules

Renewable Hydrogen Based Energy Storage

- China Lake Project
- Battery Replacement

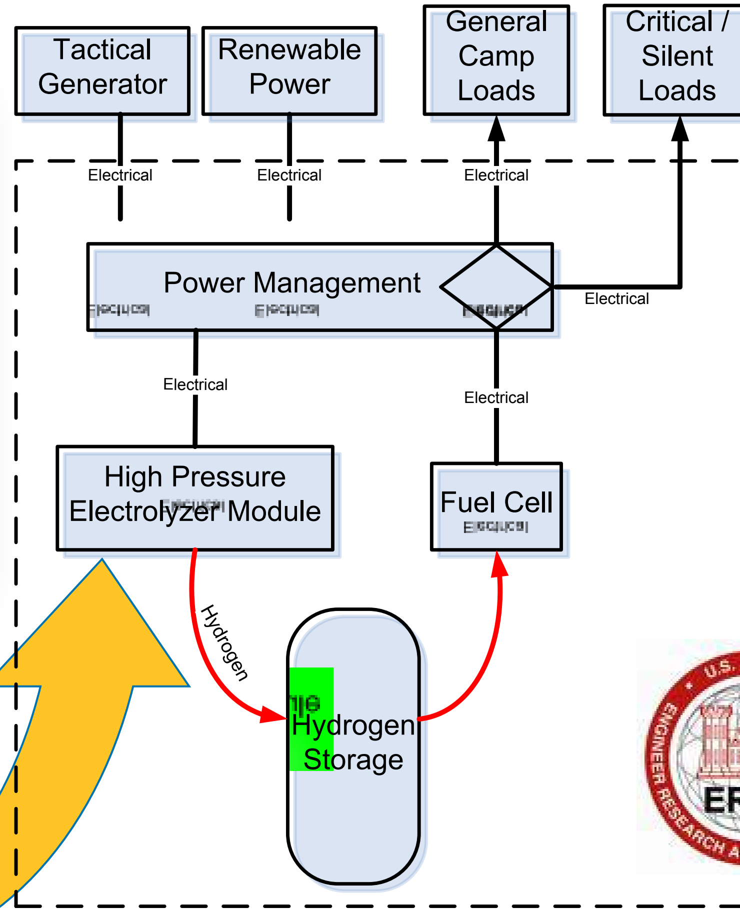
Project System Parameters:

- 24/7 Power from Photovoltaics
- 10.8 kW Photovoltaic Array
- 840 kWh stored as H_2 @ 200 psi
- Two 1.2 kW PEM Fuel Cells



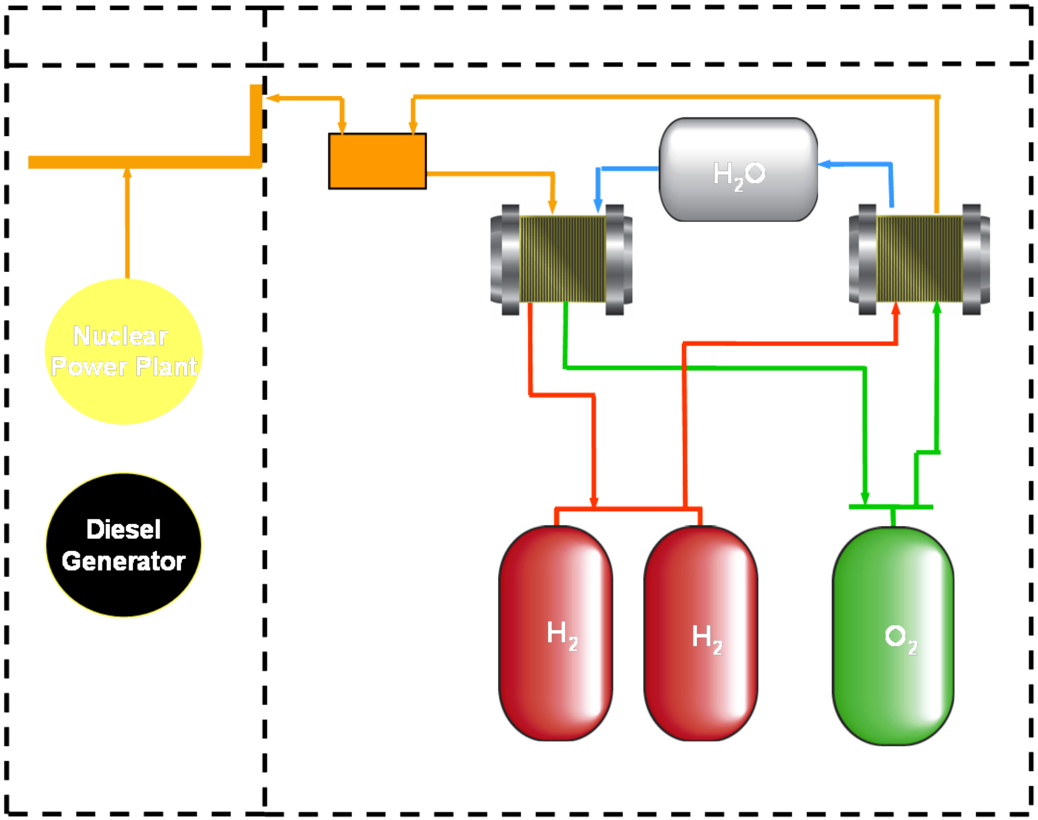
Army CERL Silent Camp® System Concept

Silent Camp high pressure electrolyzer in outdoor rated cabinet



"Regenerative Fuel Cell" integrated into CERL's Silent Camp system concept

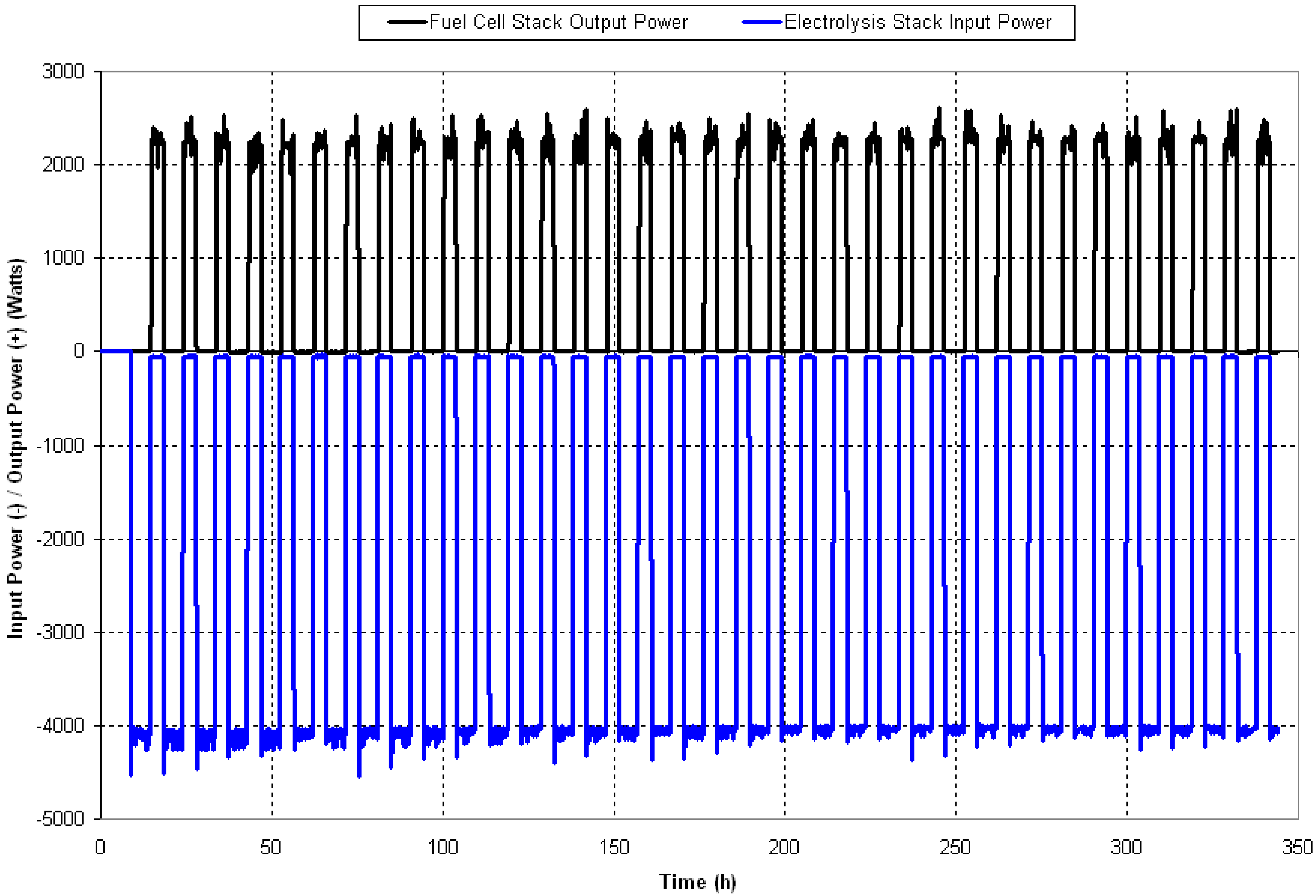
2 kW Closed Loop Regenerative Fuel Cell System



Proton's closed loop RFC system on test, demonstrating feasibility of UUV power concept

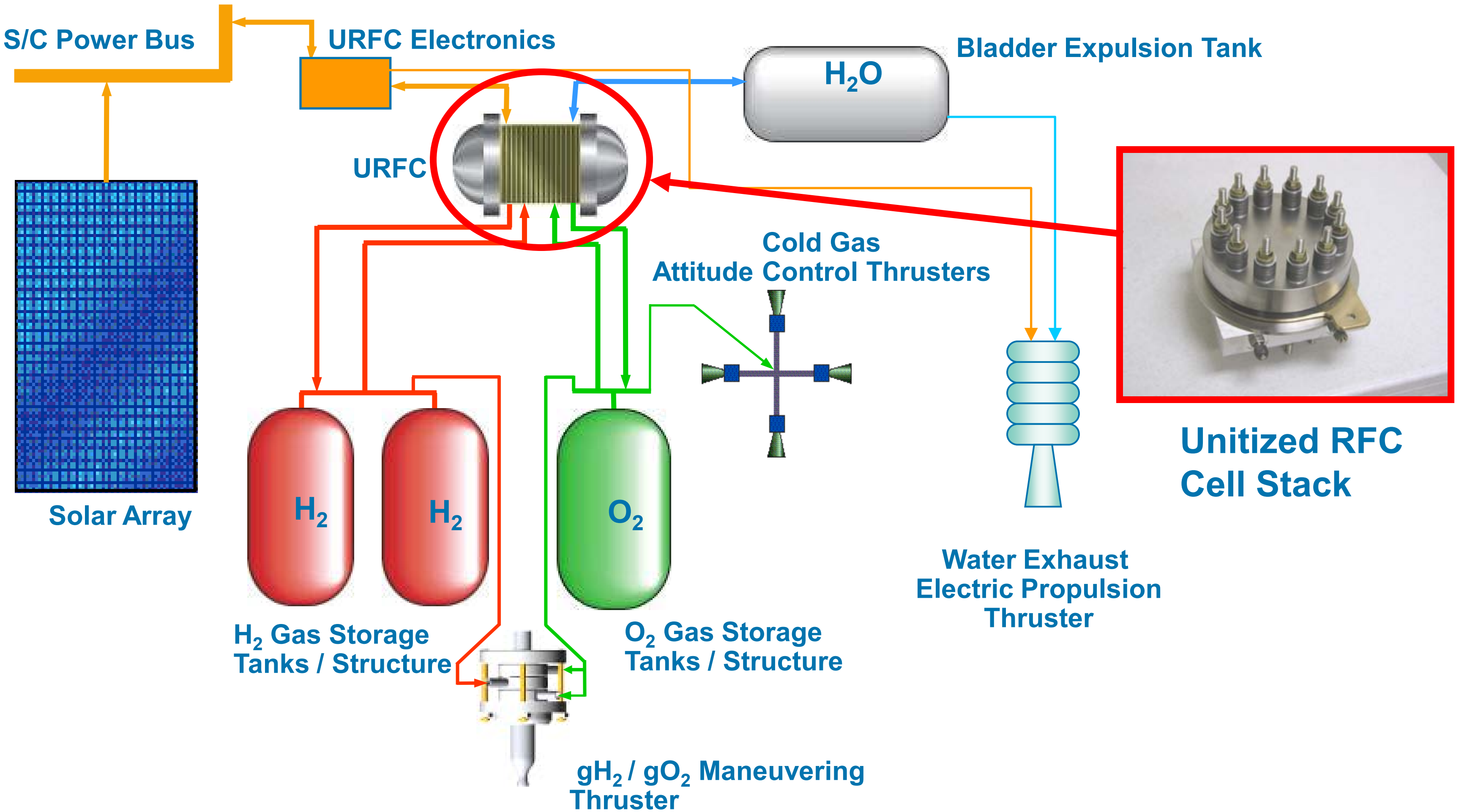
System Details:
Fuel Cell – 4.4 kW Commercial H_2/Air stack
Electrolyzer – HOGEN® S-series stack, modified for 400 psi balanced pressure

Charge / Discharge Cycle Data for RFC System

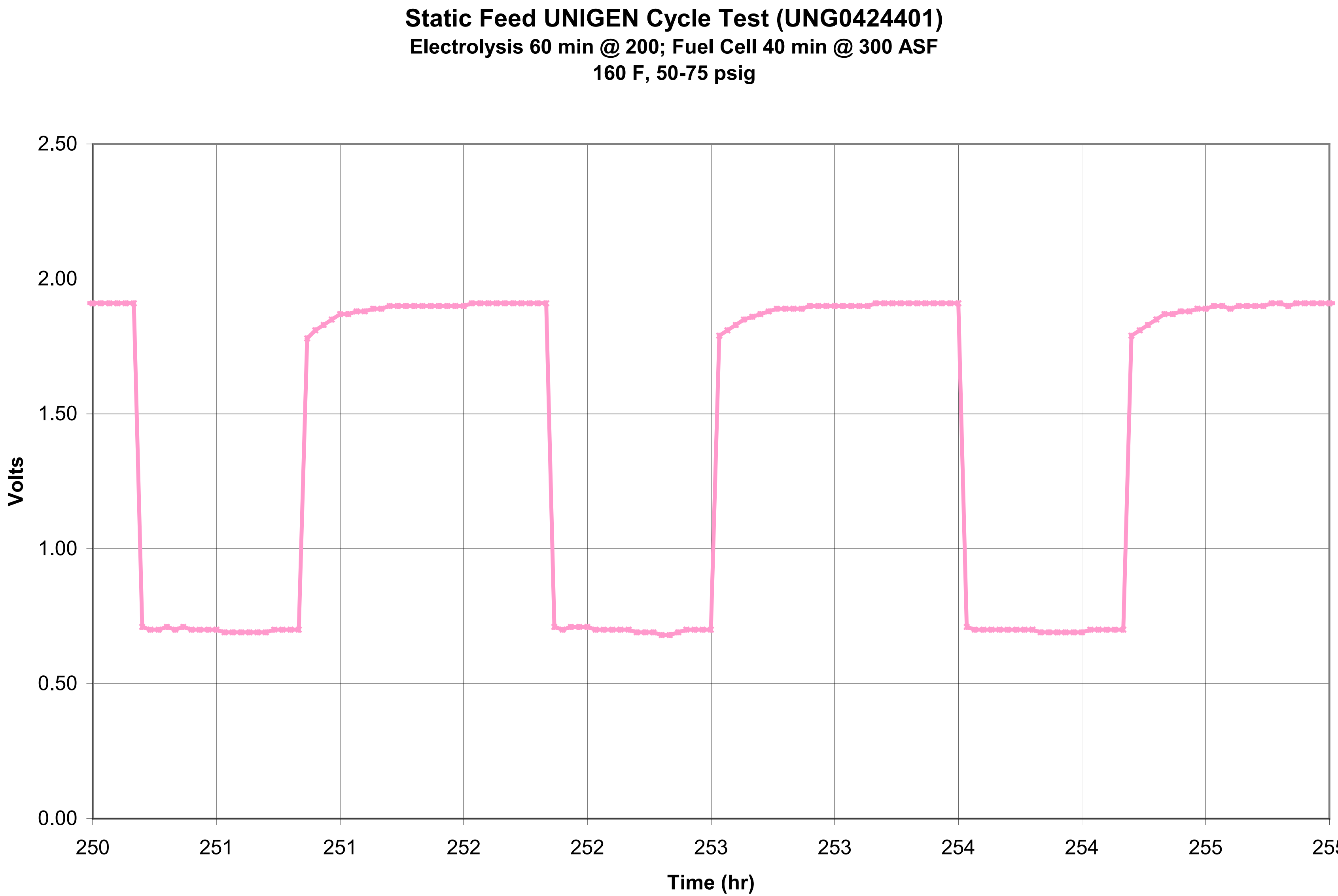


Energy Storage Plus On-Board Fuel Production

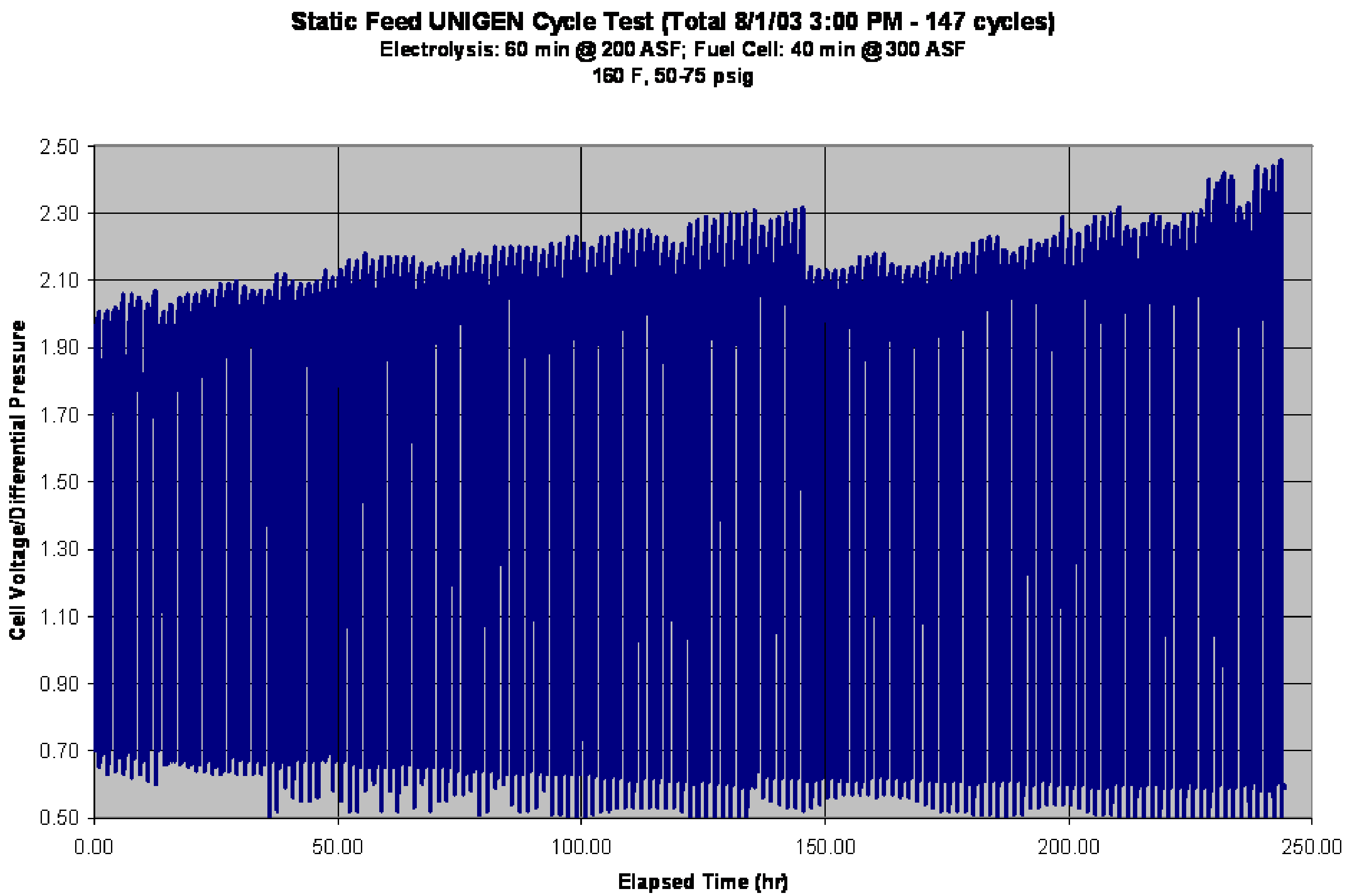
DARPA Water Rocket: Unitized, Zero-G RFC



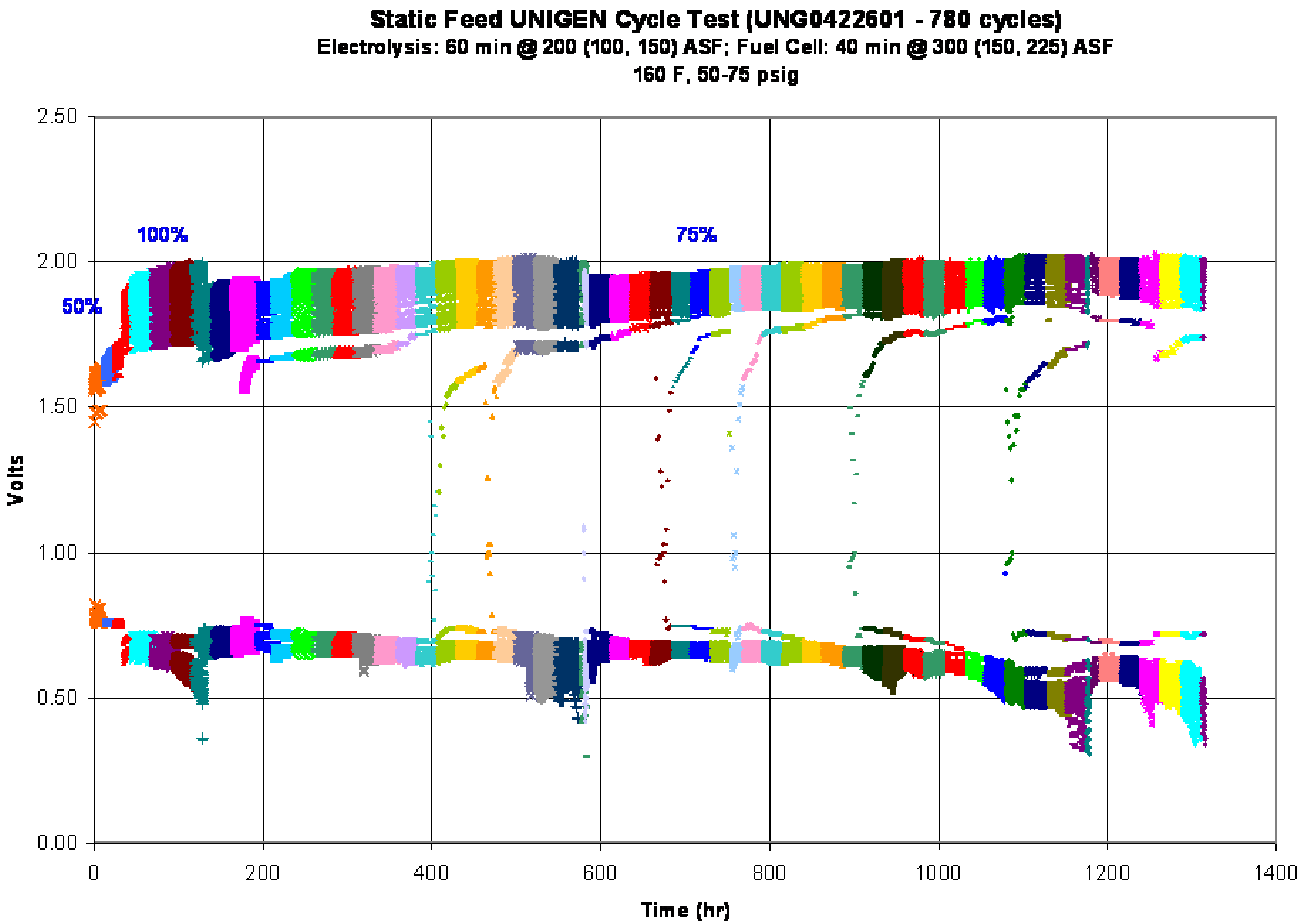
Closed-Loop Static URFC Cycles



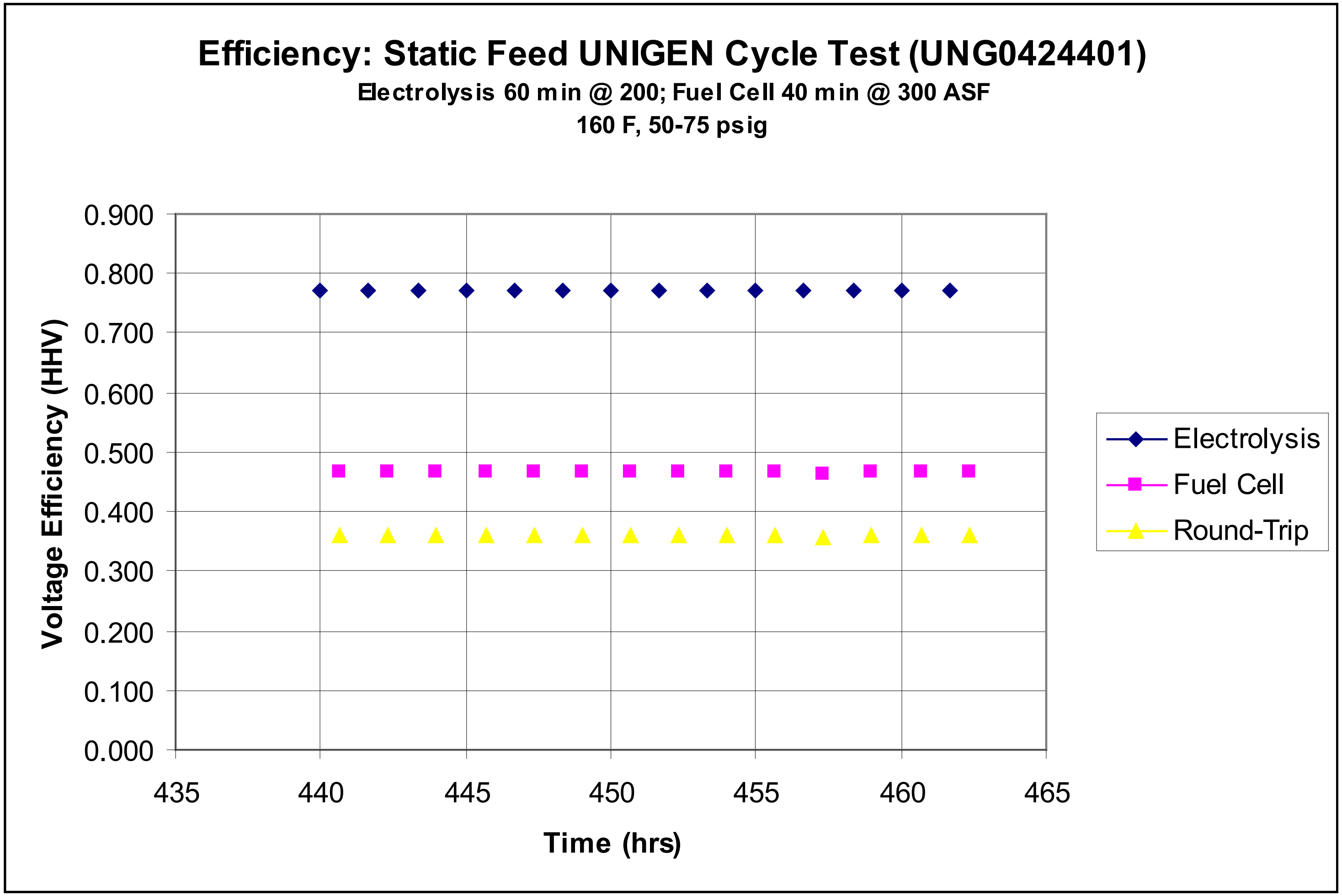
Static URFC ~150 Closed-Loop Cycles



Static URFC 1,300 h Closed-Loop Cycles



Roundtrip Efficiency of URFC Test Stack 37%



Cycle #264 --- #278

Unitized Versus Discrete RFC

- Grid Support Requirements
  - Size (kW to MW)
  - Operating mode (Charge – Discharge Cycle)
  - Time scale (ratio of stack as % of total system)
- Performance Compromise
  - Non-optimum catalysts, electrode structures
  - Up to 70% penalty for unitized approach vs. discrete
- BoP complexity
  - Water, thermal management
- Leveraging Mature Technology
  - Commercial readiness of PEM fuel cells & electrolysis

Grid Energy Storage Applications

- Distributed Energy Storage
  – 25-200 kW, 2-4 hrs, secondary (customer) voltage
- Load Shifting
  – kW's to MW's, up to 10 hrs, various voltages
- Substation Grid Support
  – 1-20 MW, 2-6 hrs, distribution voltage
- PV Voltage Transient Support
  – Up to MW's, 1 sec to 20 min, distribution voltage
- Wind Smoothing
  – 1-100 MW, 2-15 minutes, distribution voltage

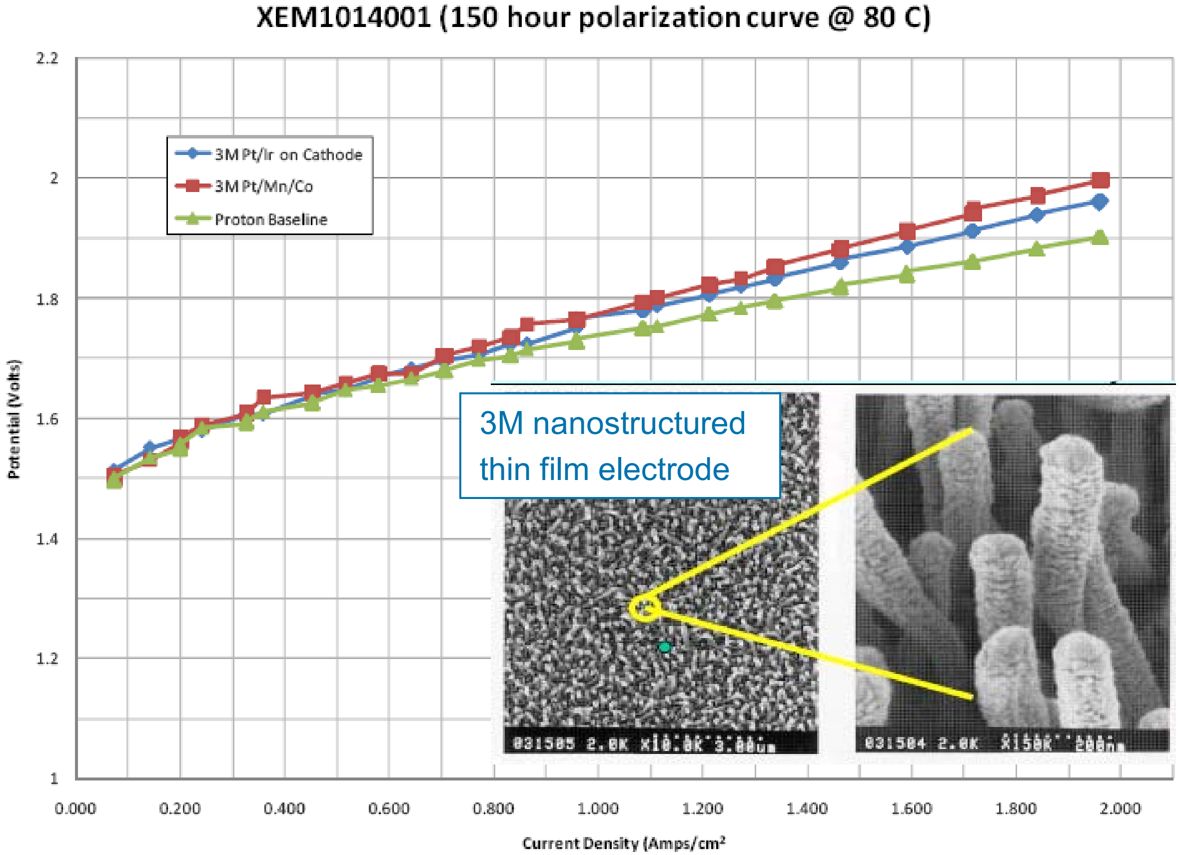
Ref: EPRI Energy Storage Systems Project, 2010, TTC

Development Needs

- Materials Development
  - Bifunctional catalysts, electrode structures, GDLs, membrane robustness for electrolysis
  - Oxygen compatibility
  - Complications of pressure generation
- System Development
  - Integration of separate BoP's, gas drying, power, thermal & water management
  - Benefit of pressurized oxygen?
- Manufacturing
  - Lack of supply chain for electrolysis, active area scale vs. pressure, need for automation to drive cost reductions

Catalyst Loading

- Alternate electrode structure shows near equivalent performance for 10x lower loading



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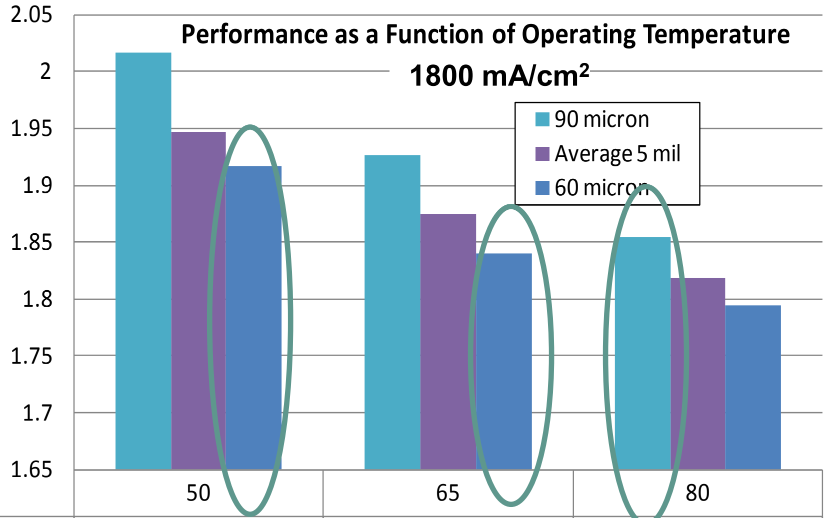
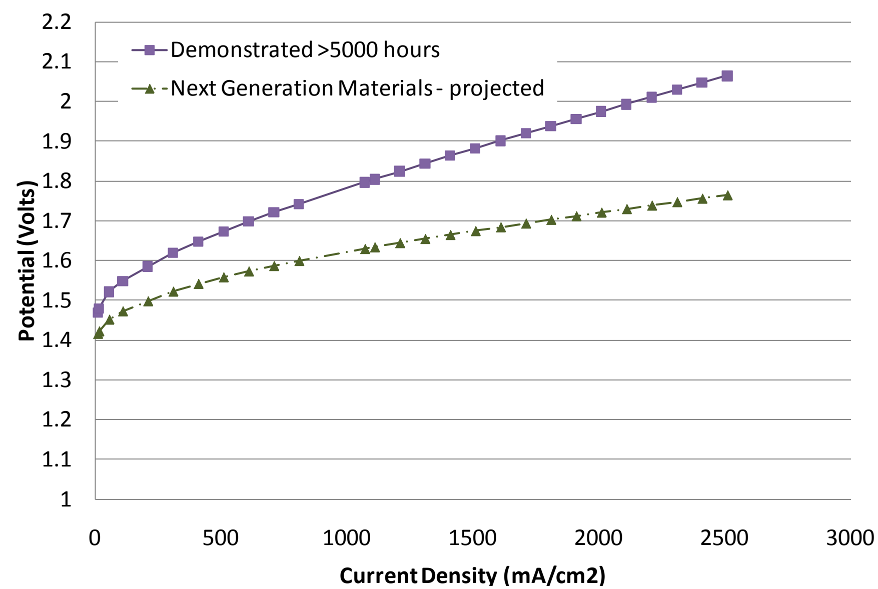
THE LEADER IN ON SITE GAS GENERATION.

Performance Improvements



	50	65	80
90 micron	2.017	1.927	1.855
Average 5 mil	1.947	1.875	1.818
60 micron	1.917	1.840	1.794

Demonstrated >85% efficiency @ 80°C and 1.8 A/cm² at production-scale cell and 200 psi differential pressure



PROTON THE LEADER IN ON SITE GAS GENERATION.

Production Scale

65 Kg/day (200 kW_{in})

1 MW BPS PEMFC

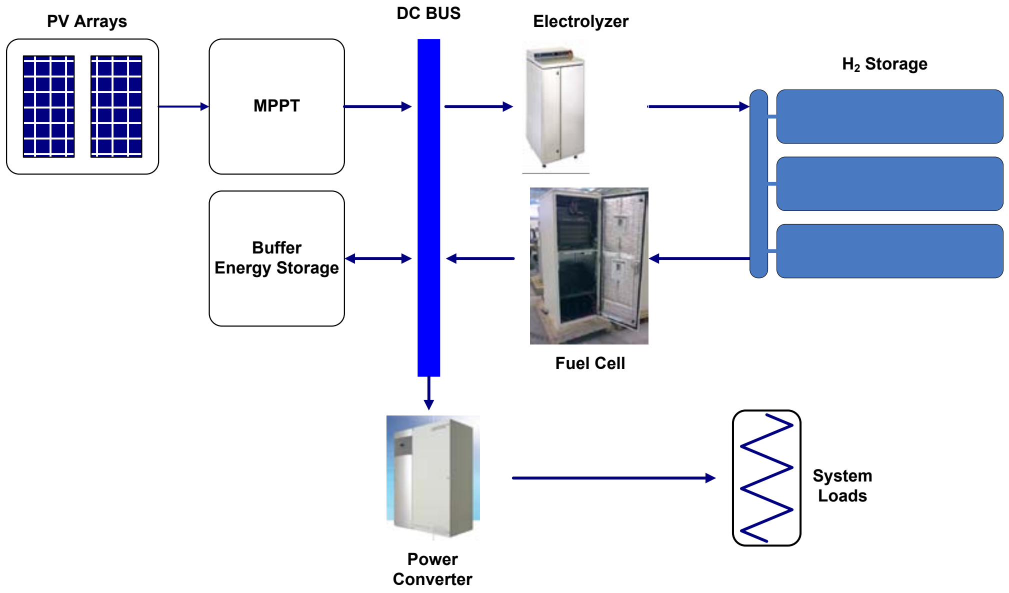
Fluids Side

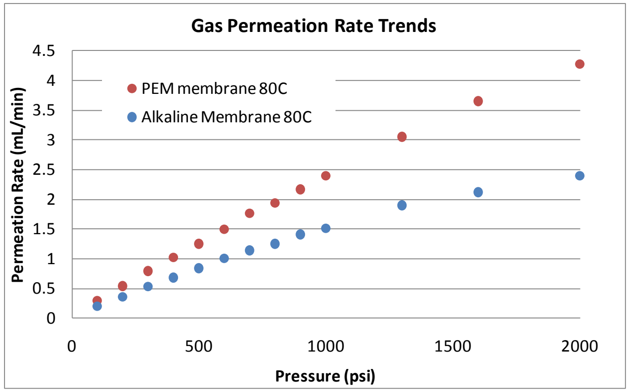
Electrical Side

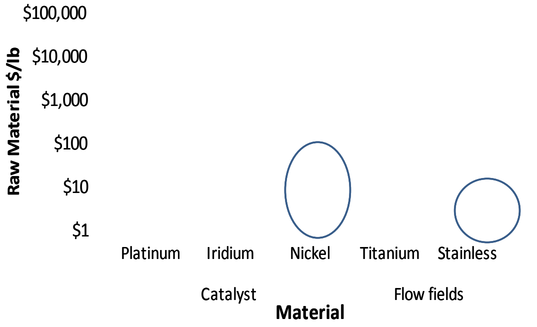
Future Work

AEM-based Regenerative Fuel Cell

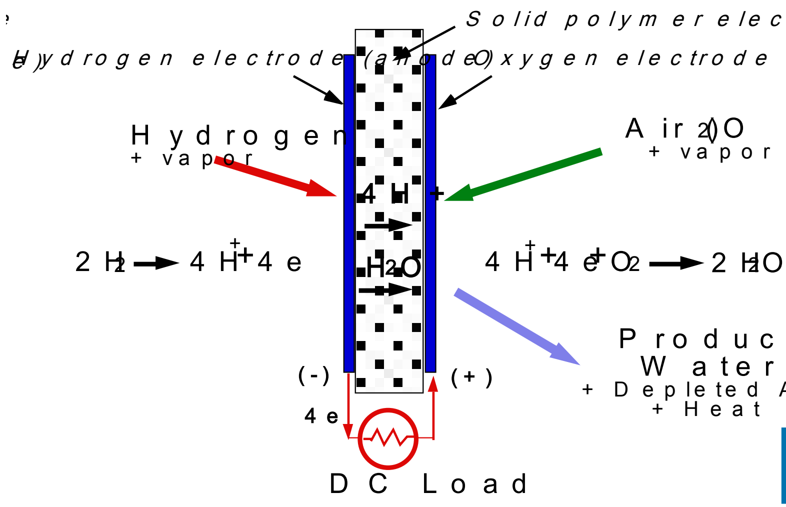
- Develop a low-cost, high efficiency
- Tightly integrated electrolyzer / fuel cell system
- Advanced rechargeable energy storage device for grid buffering.

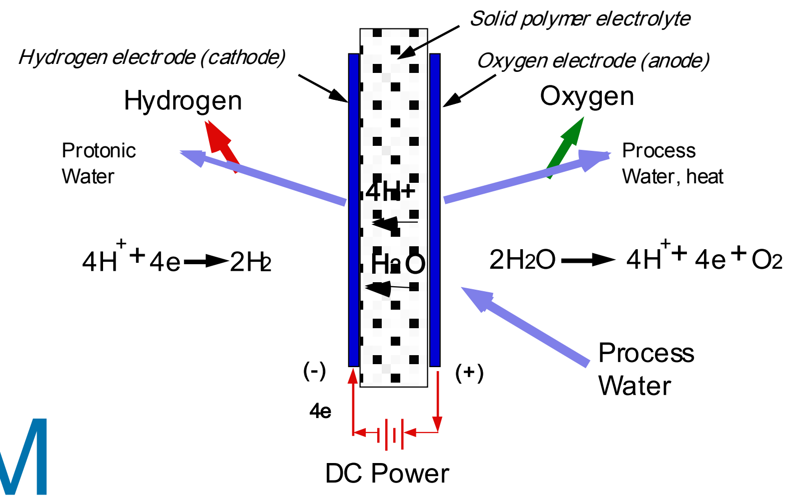






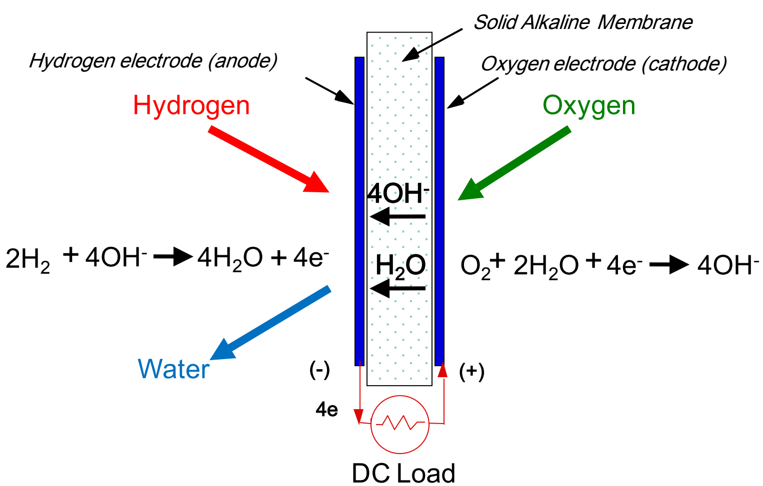
PEM / AEM Cell Comparison

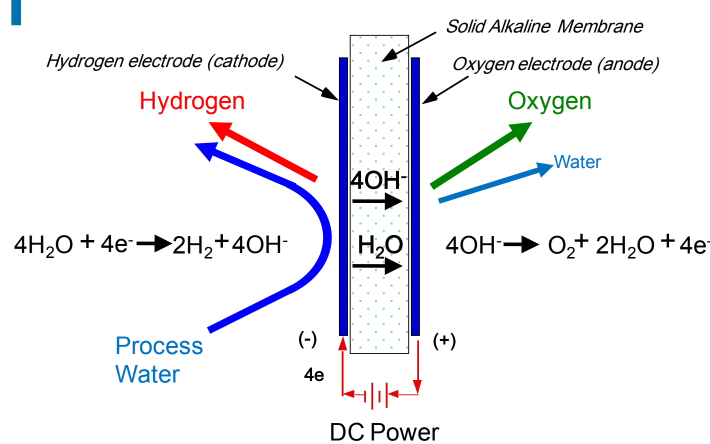




PEM

AEM





Summary

- Demonstrated history in development of regenerative fuel cell systems
- Single stack – dual stack debate depends on application
- Integration of existing technology can bridge gap
- Single stack is longer term approach
- Both options need materials & systems development and can benefit from manufacturing scale

Thank you!

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