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Sandia's Fuel Cell Interests and R&D Capabilities

Lennie Klebanoff
Sandia National Laboratories
Livermore, CA 94551

lekleba@sandia.gov

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Mukilteo Washington

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Sandia National Laboratories

Sandia National Laboratories

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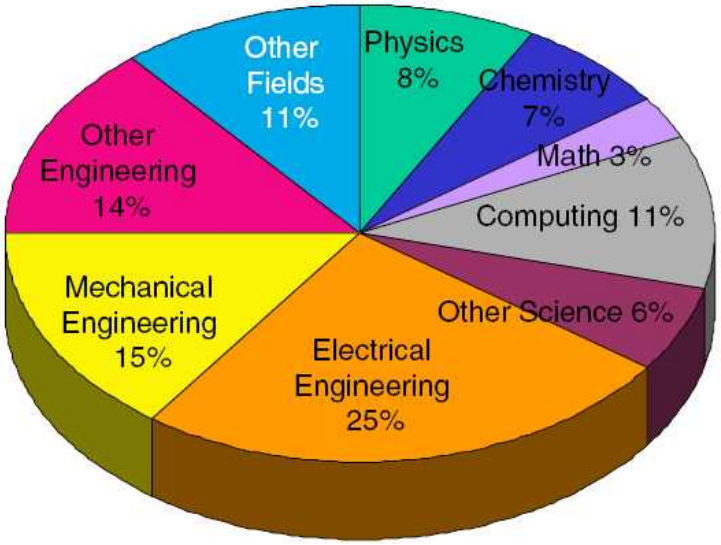
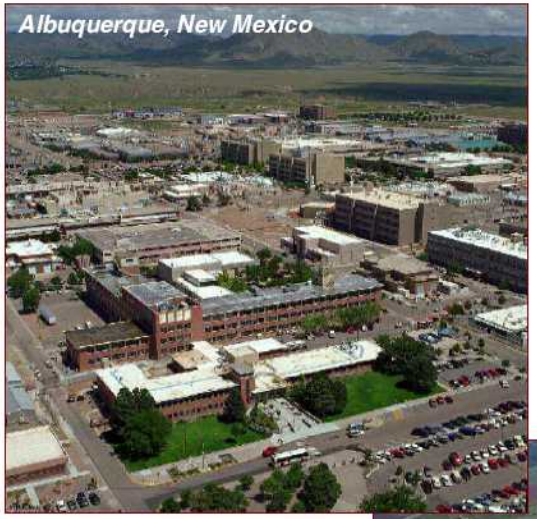
Sandia Corporation, a Lockheed Martin company, manages Sandia for the U.S. Department of Energy's National Nuclear Security Administration.





- ~ 8,300 employees
- ~ 1,500 PhDs; ~2800 MS/MA
- ~ 700 on-site contractors

Website: www.sandia.gov

Sandia's National Security Missions

Sandia National Laboratories

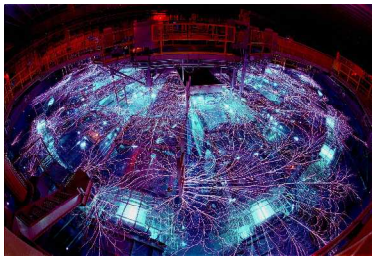
Nuclear Weapons
• Ensure a safe, secure, & reliable nuclear deterrent

Energy & Infrastructure
• Ensure clean, abundant & affordable energy and water

Nonproliferation
• Reduce proliferation of weapons of mass destruction & threat of accidents

Military Technologies & Applications
• Help maintain U.S. military weapon-systems superiority

Homeland Security
• Help protect our nation against terrorism through advanced technology



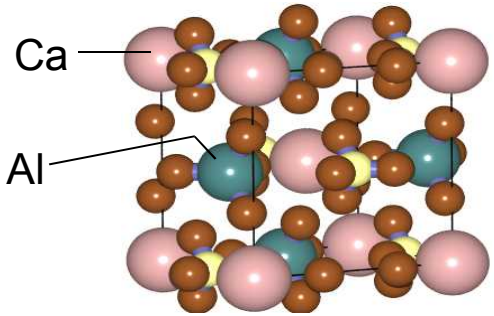
Science, Technology, & Engineering
• Conduct R&D programs to support all national security missions

Sandia's Hydrogen Program

Website: www.ca.sandia.gov/hydrogen

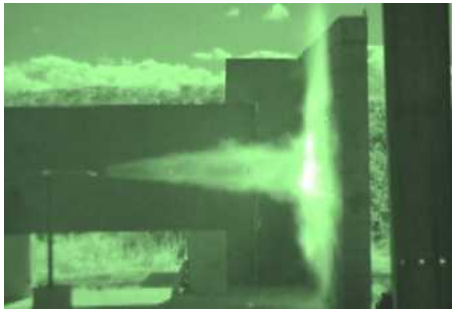
~ 50 Full Time Staff Involved

Combustion

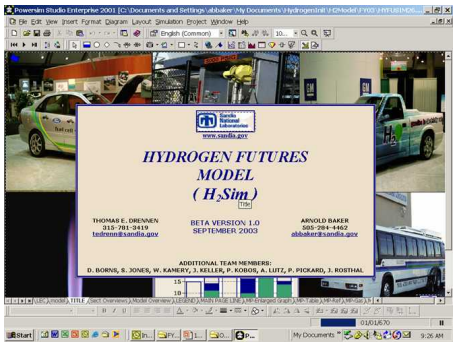


$Ca(AlH_4)(BH_4)$

H_2 Materials, Storage Engineering

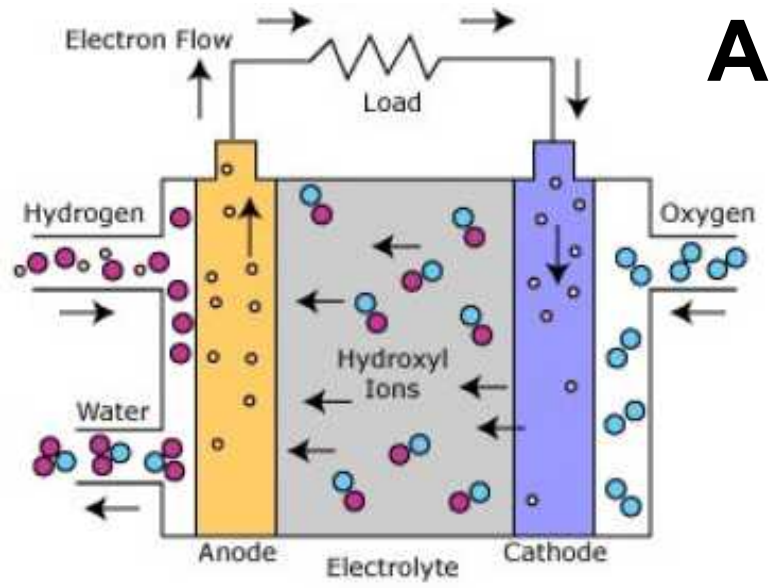


H_2 Safety



Infrastructure Modeling

Alkaline Fuel Cells



Anode: $2H_2 + 4OH^- \longrightarrow 4H_20 + 4e^-$

Cathode: $O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$

Net: $2H_2 + O_2 \longrightarrow 2H_2O$

- One of the first fuel cell technologies developed.
- Used in Apollo and Space Shuttle programs for power and water.
- Efficiencies near 60%
- Operating temperatures: 23 – 250 °C
- Electrolyte: 4-7 M KOH (immersed in a ceramic)

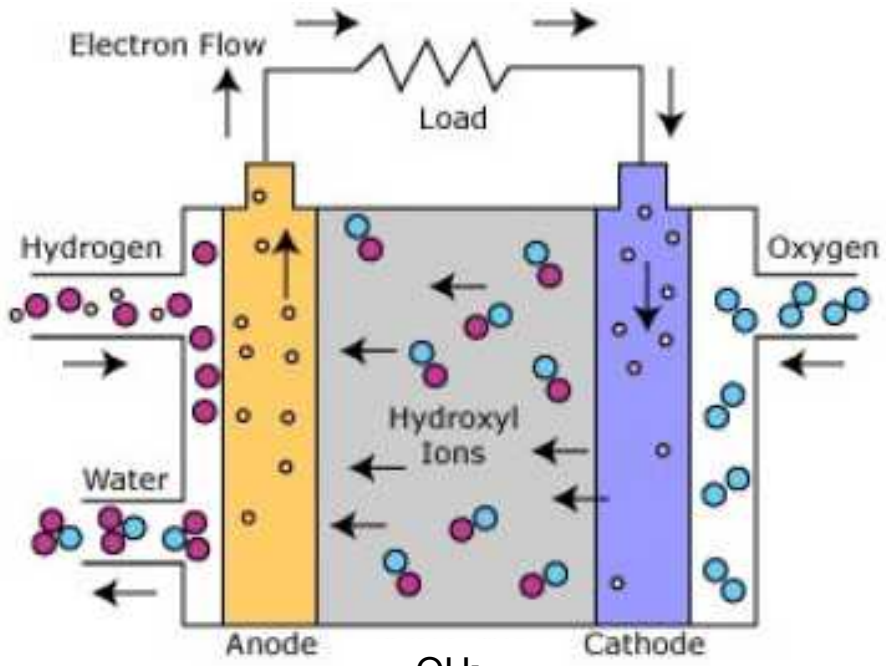
Compared to PEM fuel cells

Advantage: Works with non-precious metal catalysts (Ni, Co, etc.)

Disadvantages: Corrosive liquid electrolyte (can leak out)

H_2/O_2 must be very pure to avoid electrolyte precipitation due to carbon dioxide ($CO_2 + 2KOH \rightarrow K_2CO_3 + H_2O$), so can't use air

There has developed interest in Alkaline Exchange Membrane Fuel Cells (AEMFC) which do not contain liquid KOH (corrosive) and does not precipitate K_2CO_3



Advantages:

Enables the use of EtOH directly
Can use air as the oxidant
Non-platinum based catalyst can be used at cathode (Co, Ni)

Challenges:

Improve long term stability of membranes at higher T

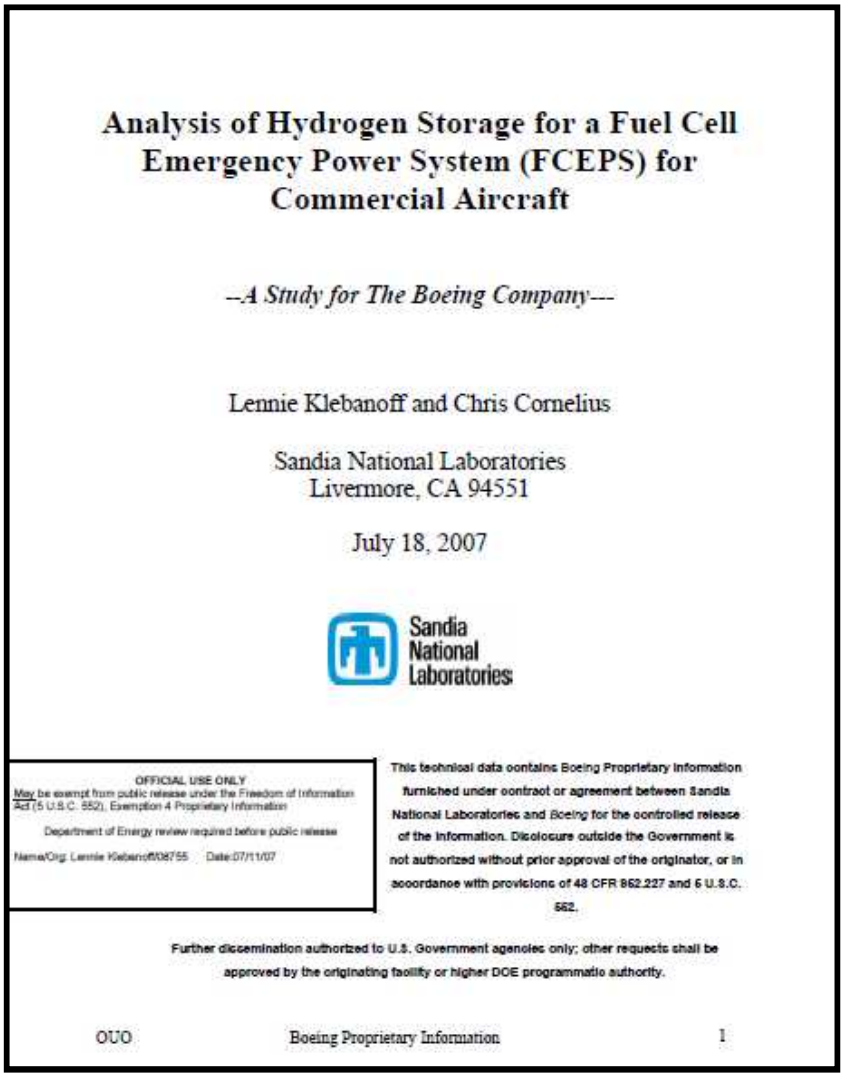
Increase membrane conductivity to improve fuel cell power.

-- a film which contains mobile OH^- ions. Does not contain K, so no carbonate precipitation

Sandia Contact:
Cy Fujimoto, Sandia-NM
Tel: 505-844-6432
Email: chfujim@sandia.gov

Analysis of Hydrogen Storage for a Fuel Cell Emergency Power System (FCEPS) for Commercial Aircraft

Sandia National Laboratories



Analysis of Hydrogen Storage for a Fuel Cell Emergency Power System (FCEPS) for Commercial Aircraft

--A Study for The Boeing Company---

Lennie Klebanoff and Chris Cornelius

Sandia National Laboratories
Livermore, CA 94551

July 18, 2007

Sandia National Laboratories

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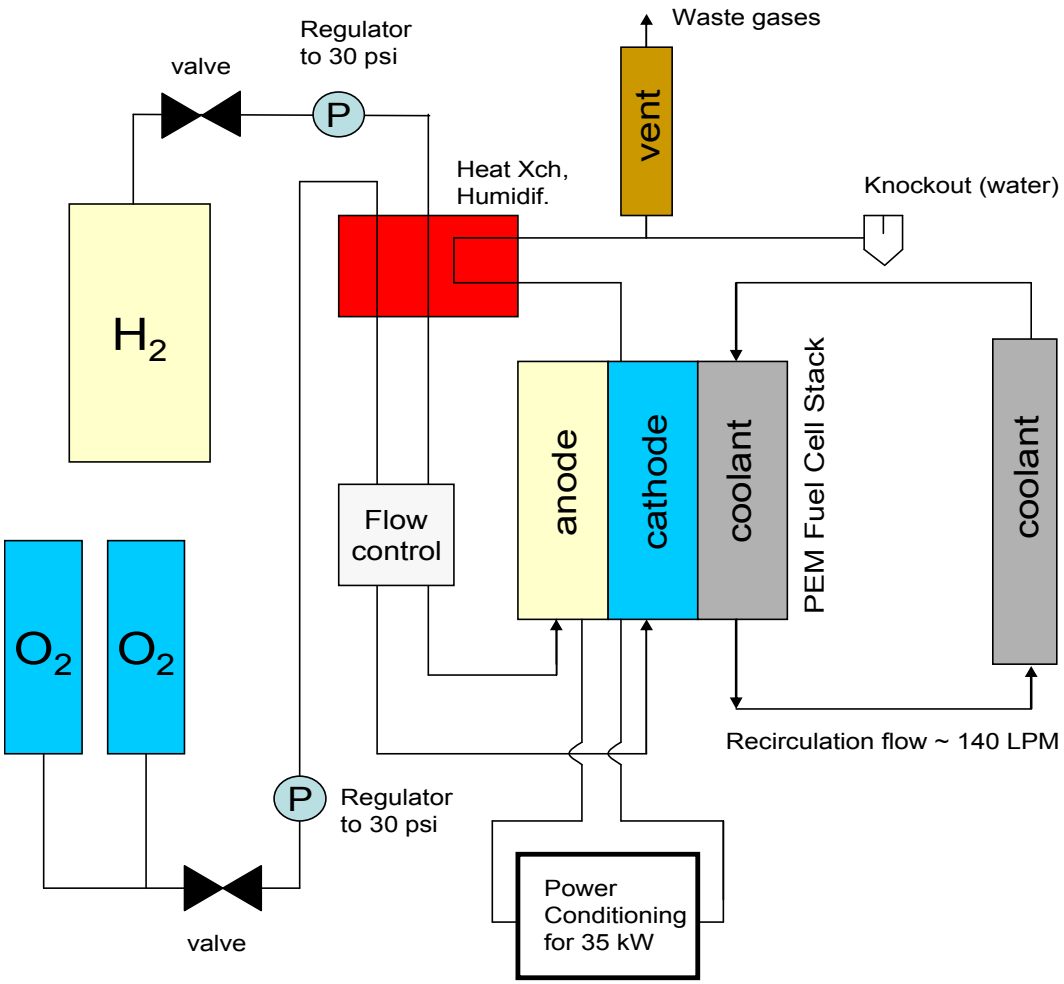
OUO Boeing Proprietary Information 1

Overview of FCEPS Based On High P H_2 Storage

Sandia National Laboratories



H_2 in 7000 psi composite tanks.

O_2 stored in two carbon steel cylinders

Comparison of High-P H_2 FCEPS with Existing RAT Technology

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Property	High-P FCEPS	Existing RAT Technology
Power (kW)	35	35
Mass (kg)	312.5	79.0*
Volume (L)	331.0	420.0*
Temperature	2 – 75 °C	- 55 – 70°C
Pressure (psi)	2 – 15.7	2 – 15.7
Safety	H_2 release, high-P concerns	Excellent
Reliability	TBD	Excellent

*Extrapolated from 25 kW RAT

Conclusion: The High-P FCEPS can perform the mission, and be an isolated (easier) introduction of fuel cell technology onto the aircraft. However, the FCEPS is not technically competitive with current RAT technology in terms of mass, reliability and safety.

Fuel Cell Light Stand Project

Sandia National Laboratories

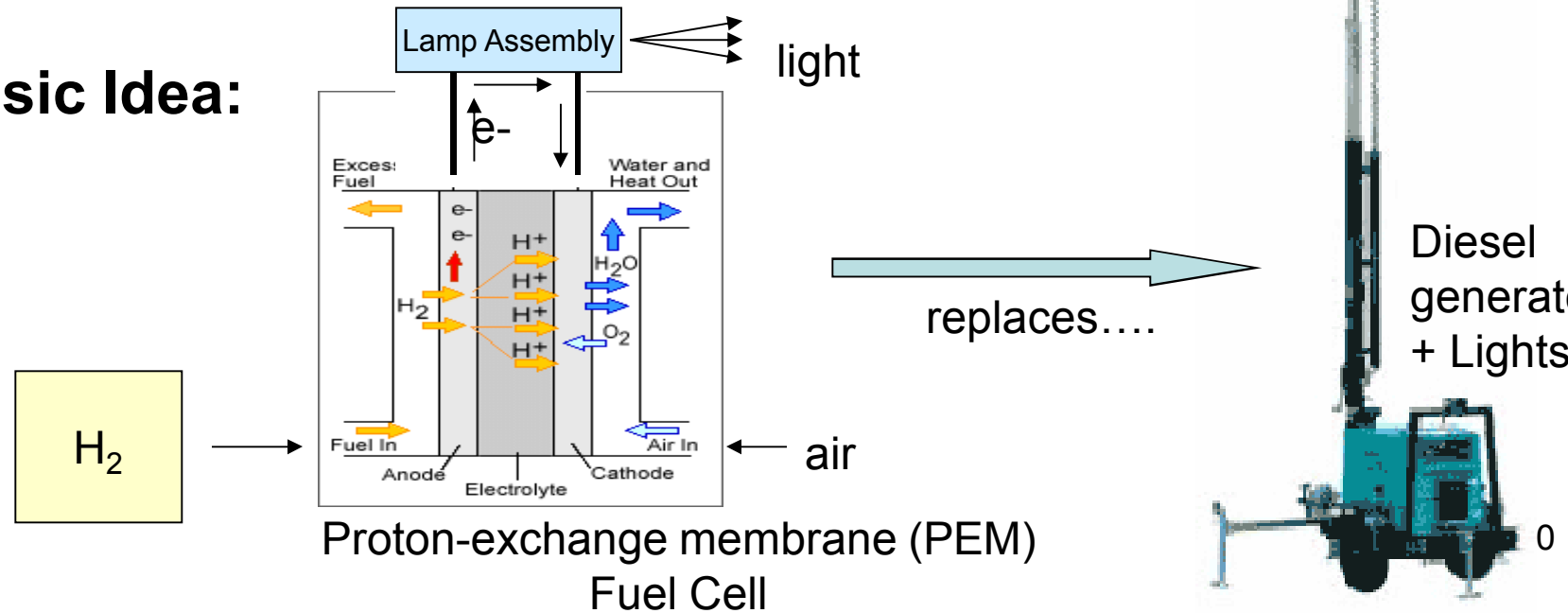
3/1/2008:

"We (Boeing) would like Sandia to lead an effort with us to bring hydrogen fuel cell technology to airport ground support equipment"

-- George Roe, Manager of Subsystems Technology, Boeing Phantom Works

Initial discussions settle on a H_2 fuel cell demonstration for mobile 5 kW aircraft maintenance lighting:

Basic Idea:



Why We Want to Do This

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The project brings clean energy technology (lighting, H_2 fuel cells) to the marketplace, testing the technologies, promoting H_2 infrastructure needs.

--an opportunity for users to gain experience with these technologies, and for a demanding field test of the technologies themselves.

Great Performance Benefits:

Greatly reduced noise with use of PEM fuel cell
No diesel particulate emissions
} **Improved worker safety**

With one unit, we displace 2730 gallons of diesel fuel/year, eliminate 27.5 metric tons/year of CO_2 if "green H_2" is used } **Good for the environment, GHG reductions**

Lots of Applications for the H_2/Fuel Cell Light:

Road work, emergency roadway lighting, aircraft/airport maintenance, film industry, disaster recovery -- **commercially attractive**

Broader Technology Implications:

Improved efficiency stationary lighting for roadways, bridges, facilities
Clean portable power for equipment, communications

A Team Has Come Together to Bring This Technology to the Marketplace

Sandia National Laboratories

Partners

Sandia National Laboratories, Technical Lead, H_2/Fuel Cell expertise

Altergy Systems (Folsom), Leading manufacturer of PEM Fuel Cells

Multiquip Inc., Leading manufacturer of construction equipment, diesel light systems

Caltrans, Transportation Expertise, Field Testing

Boeing, Technology innovation, fuel cell technology for aviation

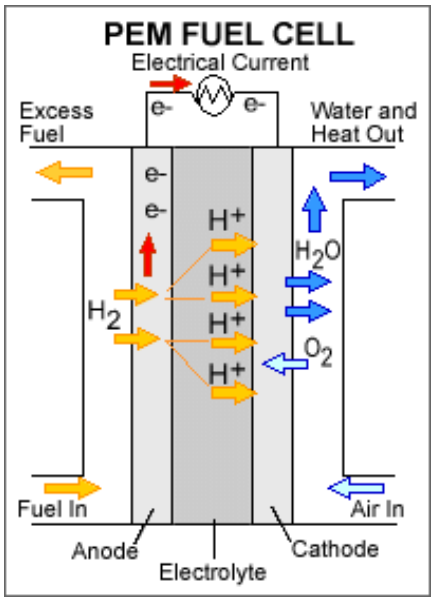
Lumenworks/Luxim, Advanced lighting technology and design

Golden State Energy, Energy technology analysis, project coordination

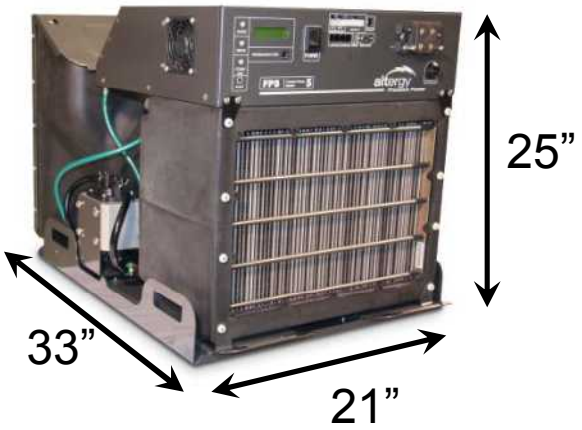
California Fuel Cell Partnership, Fuel cell technology expertise

San Francisco International Airport, alternative energy and aviation

PEM Fuel Cell



Altergy FPS-5 (5kW)



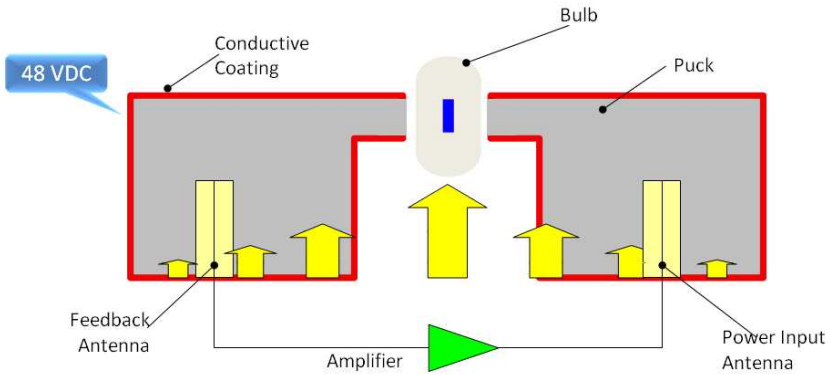
$H_2 + ½O_2 \rightarrow H_2O$

- High power density combined with low weight and volume
- Operate at ~80 ºC; allows for fast start and better durability
- Requires pure H_2 from storage system
- Oxygen obtained from ambient air
- 43% efficiency, much better than 27% efficiency of existing diesel lighting
- No CO_2, NO_x or particulates emitted
- No moving parts, very quiet operation

-- Technology can be used for portable power, remote operations for communication, data systems

New Lighting Technology: High Efficiency Plasma Light Source

Sandia National Laboratories



1) Amplifier feedback circuit establishes electric field
2) Field ionizes gas and creates plasma ⇒ Purple glow emission
3) Plasma vaporizes the salts ⇒ Blue light emission

-- spatially localized source allows high-efficiency reflector design, increasing overall efficiency

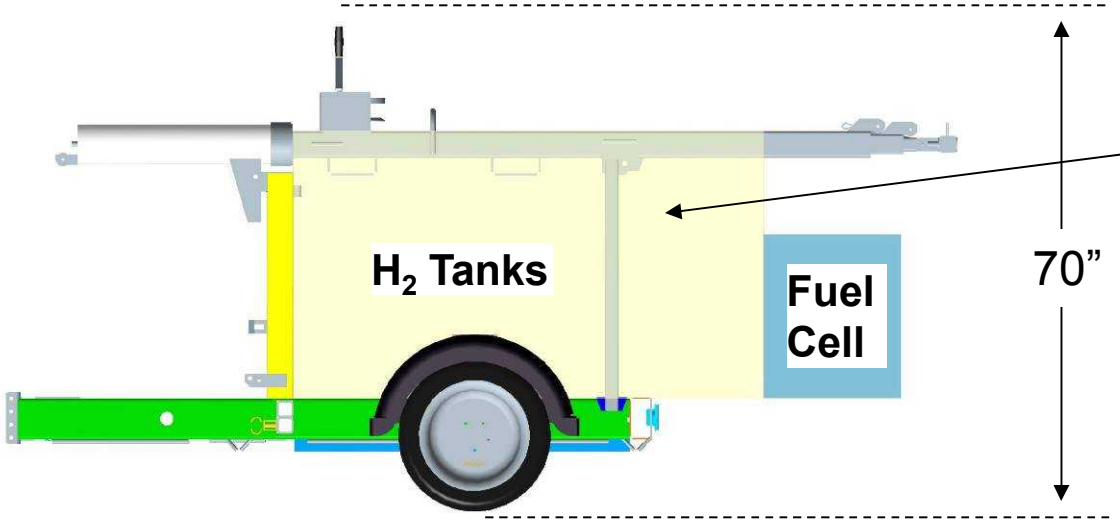
Luxim Corporation is donating lighting hardware and reflector design to this project as "in-kind" contribution

- High Efficiency – 120 lumens/watt
- Long Life – 30,000 hours
- Color Rendering up to 96 CRI
- Dimmable to 20%
- Instant On
- Rapid Re-strike
- Compact source size (1/4" x 1/4")
- Directional Source
- Operates in all Orientations
- Programmable & Addressable
- No Audible Noise or Flicker

A 2-Prong (Alpha, Beta) Approach

Sandia National Laboratories

Mutliquip, Altergy are currently building a “alpha” system using basic technology to get early learning, and to field test if appropriate



Employ 3500psi tanks of H_2

Altergy 5kW PEM fuel cell

Mutliquip Trailer

- **5 kW of continuous power**
- **10.5 kg of hydrogen**
- **30 hour duration at continuous 5kW operation**

Difficulties with Alpha System:

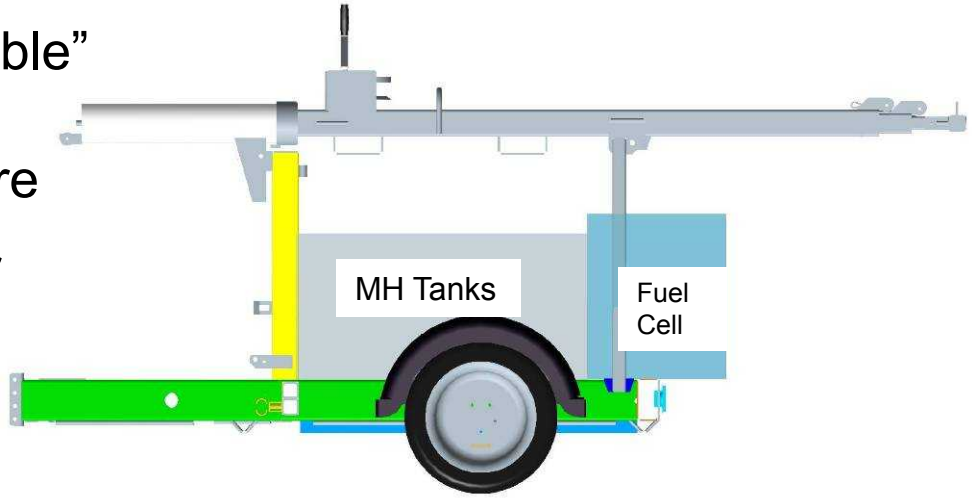
- **Envelope larger than existing systems**
- **Run time less than current 48 hour standard**
- **Requires source of 3500psi H_2**
- **Commercial viability not clear (size, duration, HP safety)**

A Metal Hydride "Beta" System May Be More Commercially Viable Unit (TBD)

Sandia National Laboratories

Hydrogen concentrated in a "reversible" chemical compound ABH_2, requires half the volume, refuel at low pressure

Metal Hydride system would meet or exceed existing durations in a reasonable envelope, but increased weight (~3500 lbs)



5 kW of continuous power
10.5 kg of hydrogen
Duration at 5kW = 30 hours

Metal Hydride System would be an advanced "beta" unit:

- No systems commercially available, more expensive
- Sandia would integrate and test, with field testing at Caltrans, SFO

Construction of Beta Unit Requires Securing External Funding (TBD)

Summary

Sandia is interested in improving fuel cell technology, and bringing this technology into mainstream use, including aviation.

We believe it is in the National Interest because H_2/Fuel Cell technology can reduce CO_2 emissions, and reduce our dependence on increasingly scarce and unstable foreign sources of petroleum.

****** Sandia is interested in partnering with others to achieve these goals!***