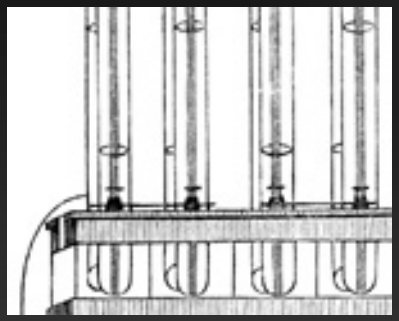

1839

2003

FUEL CELLS

“Been a Long Time Coming”

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USDA Forest Service Missoula Technology & Development Center

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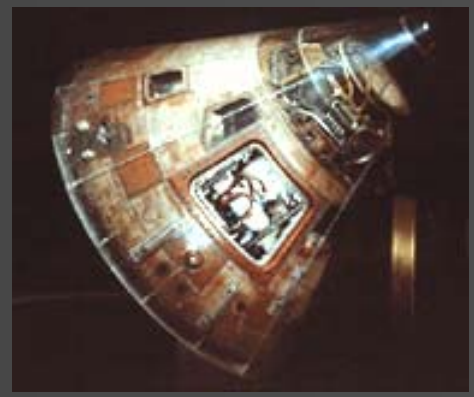
Facilities and Asset Management Conference

Fuel Cell Background

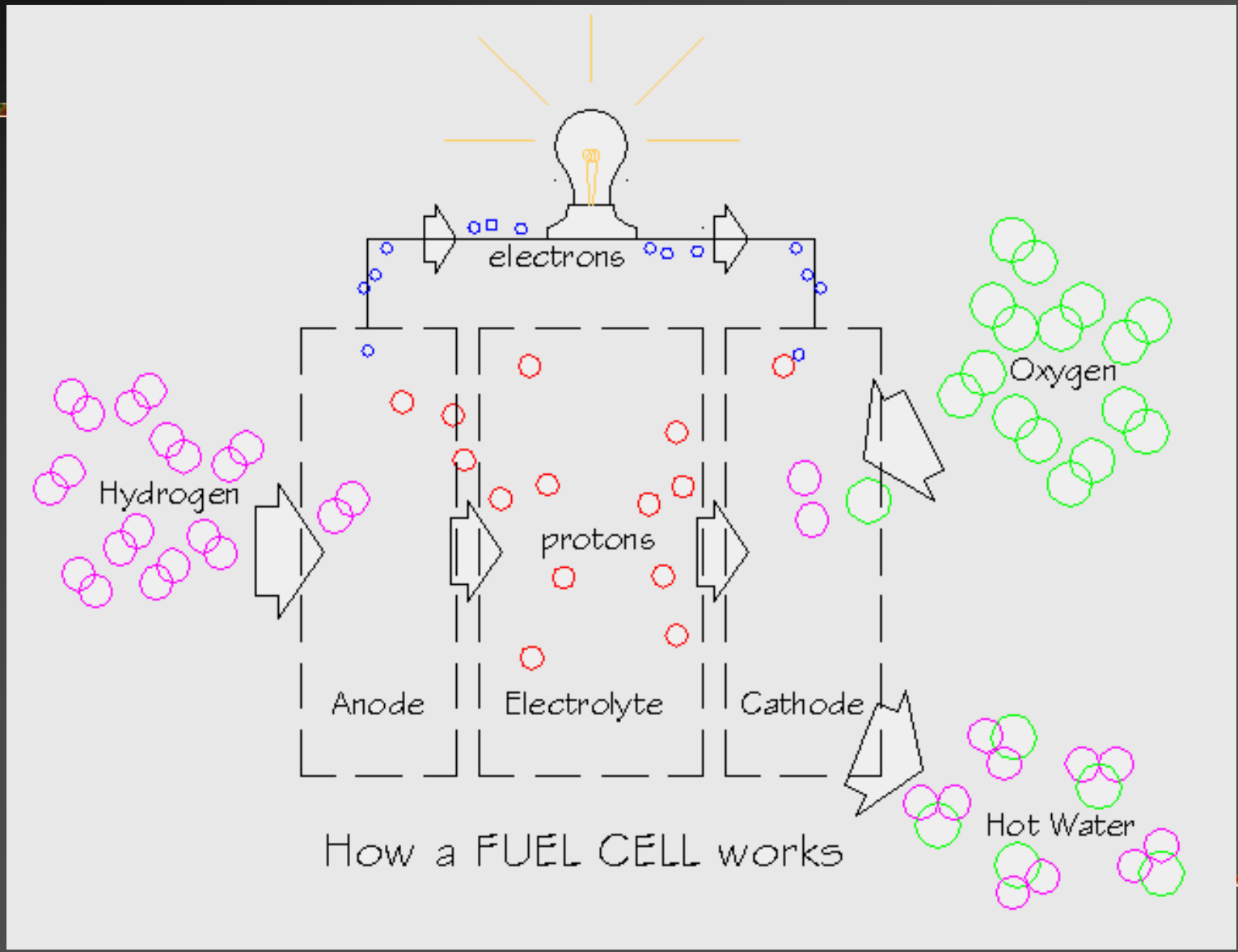


- Invented by Sir William Grove, 1839
  - Languished due to abundant fossil fuel, invention of steam engine, infancy of electrical power usage
- Adopted by NASA for Apollo space program
  - Nuclear power dangerous
  - Solar power bulky
  - Batteries heavy
  - Francis Thomas Bacon's British sub fuel cells reliable enough to attract NASA/Pratt & Whitney
  - They were EXPENSIVE!

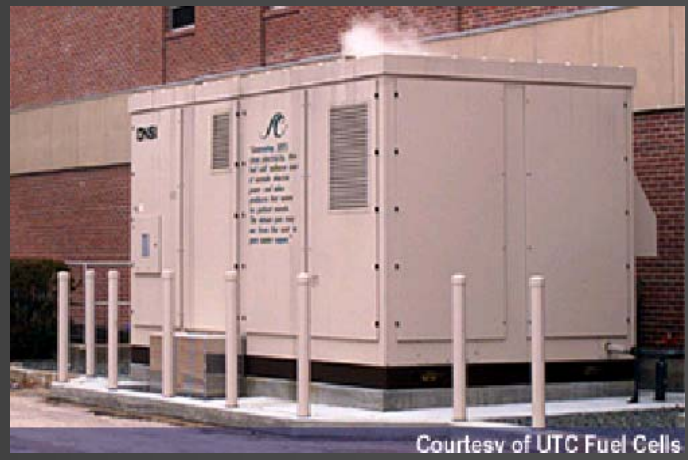
How Fuel Cells Work

- Essentially large batteries with constant fuel input
  - Hydrogen and oxygen in
  - Electricity, heat, and water out
  - Electric power from electrons moving between anode and cathode
  - Chemical process, not combustion
  - Virtually no pollution

Fuel Cell Schematic



Powering Fuel Cells


Courtesy of UTC Fuel Cells

- All fuel cells utilize hydrogen
- Most current models use:
  - Hydrogen split from fossil fuels such as propane using a reformer
  - Liquid hydrogen or compressed hydrogen gas
    - Storage problem – large volume
- New hydride slurry
  - Nonexplosive, nonflammable
  - Denser storage
    - 2x liquid
    - 10x compressed gas

Powering Fuel Cells

continued

- Problem: it isn't cheap to make hydrogen
  - Can split hydrogen from water using solar or wind power – that's "green", but expensive
  - Can split hydrogen from conventional fuels using electricity – that's no greener than the power plant, more $ & less efficient than using electricity directly
  - Cheapest option right now for medium & large units: supply fuel cell with clean fossil fuel (natural gas, propane) and split hydrogen off with reformer
- Future: hydrogen for your car, electricity for your house in one package

Types of Fuel Cells

- Alkaline
  - Small, quick
  - NASA, vehicles
- Direct Methanol
  - Similar to PEM
  - No reformer needed
  - Tiny to midsize
  - Appliances (clocks, cell phones, laptops)
- Phosphoric Acid
  - Large, heavy
  - Big buildings & big vehicles
- Proton Exchange Membrane (PEM)
  - Cool, quick
  - Small buildings, vehicles

Types of Fuel Cells continued

- Molten Carbonate
  - Hot, various fuels
  - Major power utilities
- Protonic Ceramic
  - No reformer
  - Stationary power, vehicles
- Regenerative
  - Solar powered using water
  - No fossil fuel needed
- Solid Oxide
  - Long-lived, durable
  - Stationary power
- Zinc-Air
  - Lightweight
  - Regenerate via power grid connection
  - Electronics, vehicles

Where Can You Use a Fuel Cell?

- When the price comes down, you'll be able to use fuel cells everywhere you need electric power.

- Fuel Cell Vehicles
  - There are already some on the road
    - All use hydrogen fuel
    - Still very expensive to manufacture and to fuel

Where Can You Use a Fuel Cell?

continued

- At your home or office
  - Some power system theorists say the future will be decentralized – the grid will disappear
- Probable FS & BLM applications include:
  - Power for fire camps & remote work stations
  - Recreation site water pumps
  - Remote monitoring equipment
  - Portable field equipment

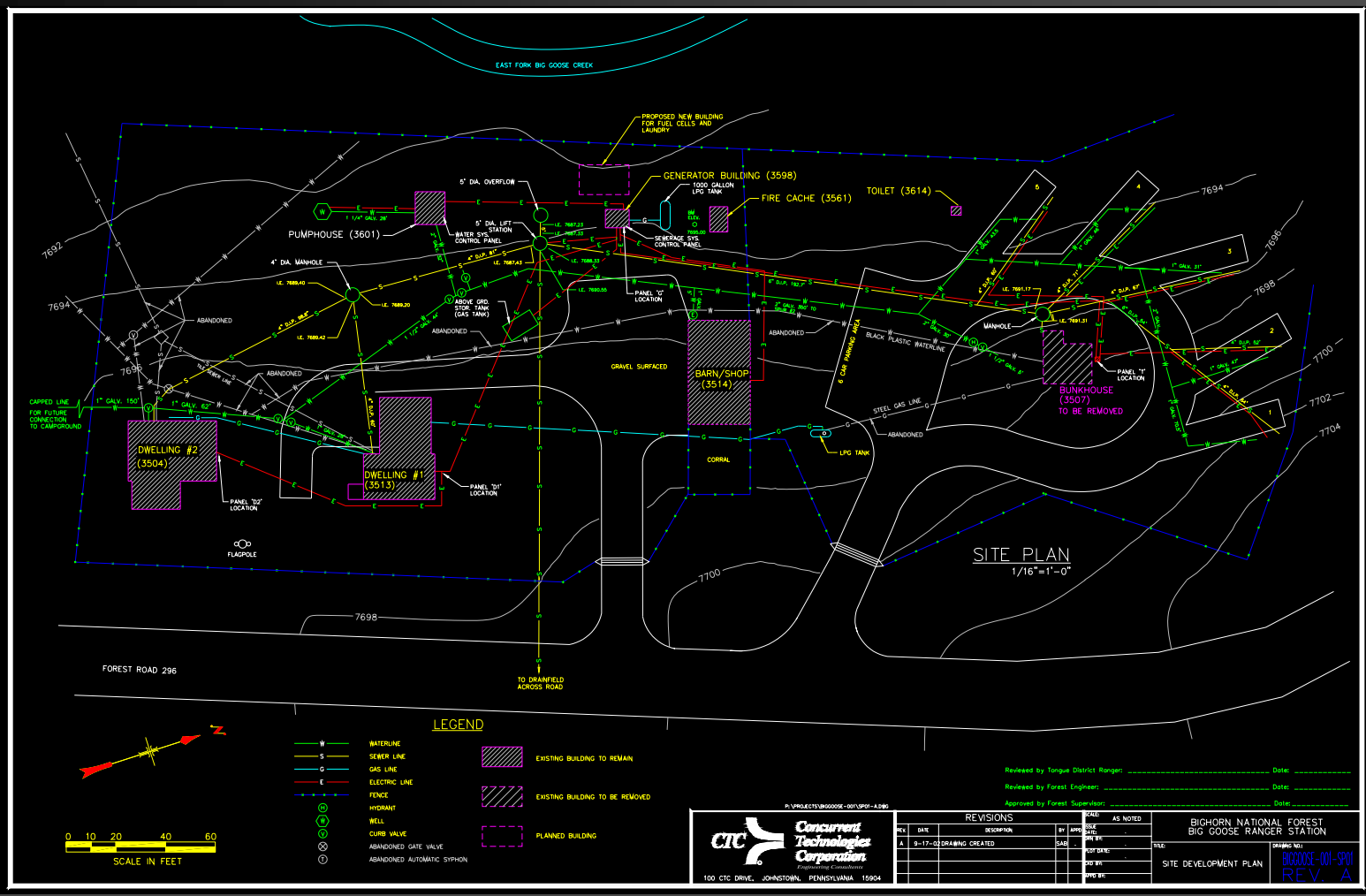
What Does a Fuel Cell Cost?

- Tiny – under 100 W: Under $100 per watt
  - Battery replacements, but lighter, last longer
- Small – 1kW to 5 kW: $8000 per kW
  - Recreation, emergency, back-up power
- Medium – 5 to 50 kW: $20,000 per kW
  - stationary domestic or light commercial
- Large – Over 100 kW: $10,000 per kW
  - Hospitals, data centers, etc.
- COMMERCIAL VIABILITY: Under $1,000/kW

Fuel Cells for Remote Sites

- Project: install a demonstration fuel cell at a remote administrative site
  - Learn availability, cost, logistics, feasibility
  - Assemble mostly outside funding
    - ERDC/CERL Fuel Cell Program (DOD)
    - Federal Energy Management Program (DOE)
    - National Energy Technology Laboratory (DOE)
    - Propane Education & Research Council
  - Learn operation, maintenance, problems
  - Publish findings for benefit of FS & partners

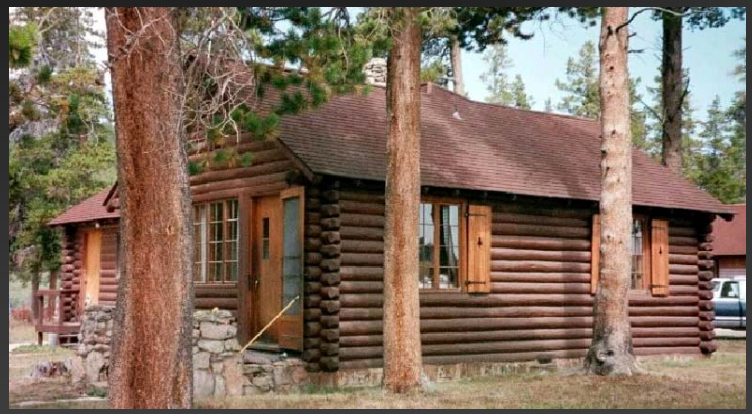
Big Goose Fuel Cell Project



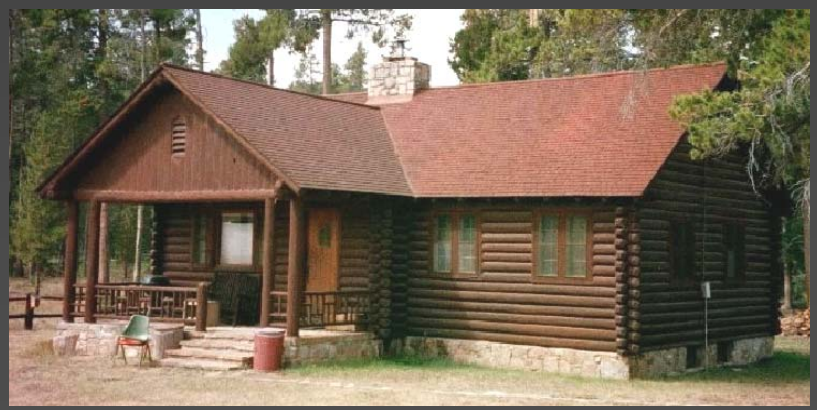
The Big Goose Ranger Station Site - Bighorn National Forest

- Nearest Power Line: 7 miles away
- Elevation: 7,700 feet above sea level
- West of Sheridan, Wyoming

The Big Goose Site



Historic buildings with propane and wood heat & appliances.



Cranky old propane generator powers sewer lift station, well, lights, and outlets. Remote controlled!

Naive Beginnings

- Went to FEMP distributed energy conference in Atlanta in May 2002 to make connections
  - “I have $40,000 and I want to buy a 10 kW fuel cell to install next summer”.
  - - LAUGHTER -
  - Mike Binder, head of the fuel cell program for DOD US Army Corps of Engineers Engineering Research and Development Center’s Construction Engineering Research Laboratory was interested.
  - Invited him to a meeting at Big Goose. He brought a design and development team. FS brought other partners.

The Gritty Reality

- Budget is now over $500,000
  - $245,000 for 10 kW fuel cell
  - $150,000 for ancillary work
  - $92,000 for design & construction engineering
  - $23,000 for interpretation & publications
- It’s not always easy to write a MOA
- Installation is summer 2004, not 2003
- District must get better power than existing
  - Will provide new back-up generator
  - Will improve wiring, heat, & appliances

Bring Me a Fuel Cell that Works

- High elevation, non-grid-tied, propane fuel, and winter site shut-down = complications
  - Tough finding a fuel cell that:
    - Has low enough minimum power output that the fuel cell system won't use more propane than the existing generator
    - Can sit idle or shut down for 6 months a year in sub-zero temperatures
    - Doesn't require a trained maintenance technician on site to baby-sit

But the Good News Is…

- We’ve got the funding
- We have a fuel cell that will work at Big Goose – an Acumentrics 10 kW solid oxide fuel cell
- The contracts have been awarded
- Construction will begin in June 2004
- We’ve learned a lot, and fuel cells really ARE coming

Resources

- Financing Distributed Energy Generation (from FEMP) http://fsweb.wo.fs.fed.us/eng/programs/facilities/sus_green/DistribEnergyResFinancing.pdf
- FSweb Green Building http://fsweb.wo.fs.fed.us/eng/programs/facilities/sus_green/
- ERDC/CERL Fuel Cell Program http://www.dodfuelcell.com/
- FEMP http://www.eere.energy.gov/femp/
- NETL http://www.netl.doe.gov/
- PERC http://www.propanecouncil.org/
- National Fuel Cell Resource Center http://www.nfcrc.uci.edu/
- Fuel Cells 2000 http://www.fuelcells.org