

Fuel Cell Operations at Department of Defense (DoD) Hydrogen Demonstration Projects

2011 Fuel Cell Seminar & Exposition

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The logo for LMI (Los Alamos Mission Institute) features the letters 'LMI' in a dark blue, serif font. A small orange flame-like graphic is positioned above the 'I'. The logo is set against a background of a dark blue wavy line that spans the width of the slide.

LMI

Outline

- Describe projects & transition process
- Review business case
- Outline key variables that drive cost
- Present results & transition decisions

DLA's Hydrogen and Fuel Cell Program

4 Fuel cell demonstration projects

Locations:

DDSP: 40 forklifts, 2 extended range vehicles, delivered (cryogenic) H₂, indoor dispensing, solid H₂ storage

DDWG: 20 forklifts, onsite natural gas reformation for H₂, mobile refuelers

DDJC: 20 forklifts, electrolysis for H₂

JBLM: 19 forklifts, 1 bus, wastewater digester gas H₂, mobile refueler

Duration: 2 years each

Business Case Analysis: Performance/cost data collected by NREL & LMI

DLA Distribution Susquehanna, PA (DDSP)

- Carries 963,829 stock numbers worth \$14.5B
- Responsible for 38% of DLA controlled assets
- MHE pilot program description:
 - Retrofit 20 battery forklifts with fuel cells
 - In addition, 20 new fuel cell forklifts
 - 2 indoor H2 dispensers
 - Deliver liquid H2, onsite storage
- Operational Feb '09 to Sept '11
 - >43,000 fuelings
 - >30,000 kg of H2 dispensed
 - >150,000 operating hours



DLA Distribution Warner Robins, GA (DDWG)

- \$12B inventory
- Parts & equipment for F-15, C-130, C-5, & C-17
- Pilot Description:
 - Retrofit 20 battery forklifts with fuel cells
 - H2 reformed on site from natural gas
 - Test mobile refueling
- Operational Nov 2009 – Nov 2011
 - >3,000 fuelings
 - >2,300 kg of H2 dispensed
 - >10,000 operating hours



Defense Depot San Joaquin, CA (DDJC)



- >676,000 stock numbers, value \$5B
- Pilot Description:
 - Replace 20 propane forklifts
 - H2 production from electrolysis
- Operational 11/2011 – 11/2013

Joint Base Lewis-McChord, WA (JBLM)



- Army / Air Force Joint Base
- Pilot Description:
 - 19 new forklifts; H2 bus
 - H2 production from waste digester gas
- Operational 10/2011 – 10/2012

Transition planning not yet begun for either site

Business Case Analysis

- Has been or will be conducted for all 4 pilots
- Used by DLA decision makers to inform transition decisions
- Includes cost information about forklift operations, maintenance, and infrastructure to compare fuel cells with incumbent power sources
- Fuel cells & H2 infrastructure purchased under R&D – **sunk costs**
- BCAs specific to the pilots
- Several key variables identified

Business Case and Operational Data

Costs Considered:

- Fuel cell vs. Battery costs
- Fueling vs. Charging infrastructure costs
- Maintenance costs
- Utility costs
- Labor costs
- Floor space requirements
- Refueling vs. recharging time
- Equipment lifespan

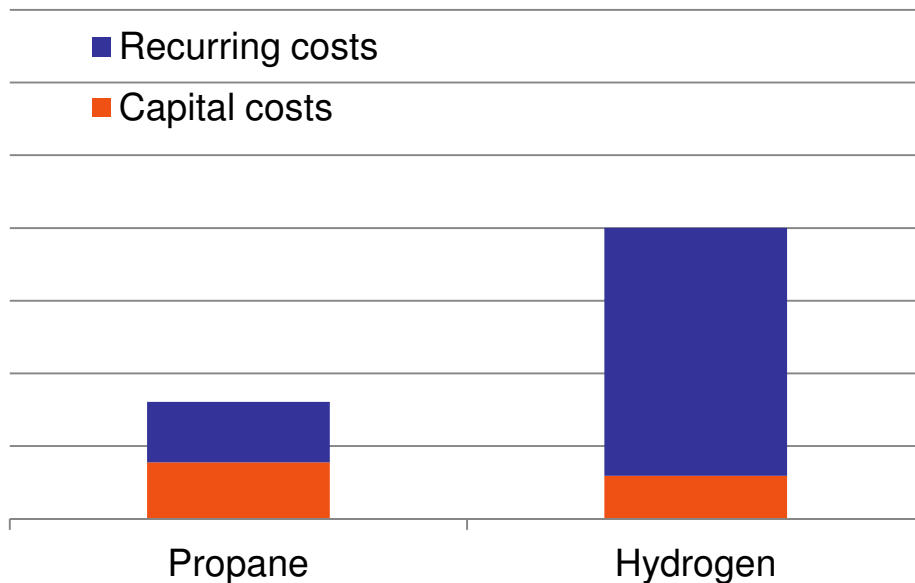
Operational Data Collected:

- Continuous and peak power
- Operational efficiency and degradation
- Overall lifecycle efficiency
- Mean time between failures and failure analysis
- Filling/dispensing operations
- Hydrogen production quality (purity)
- Balance of plant factors (kWh in/out)
- Other runtime details

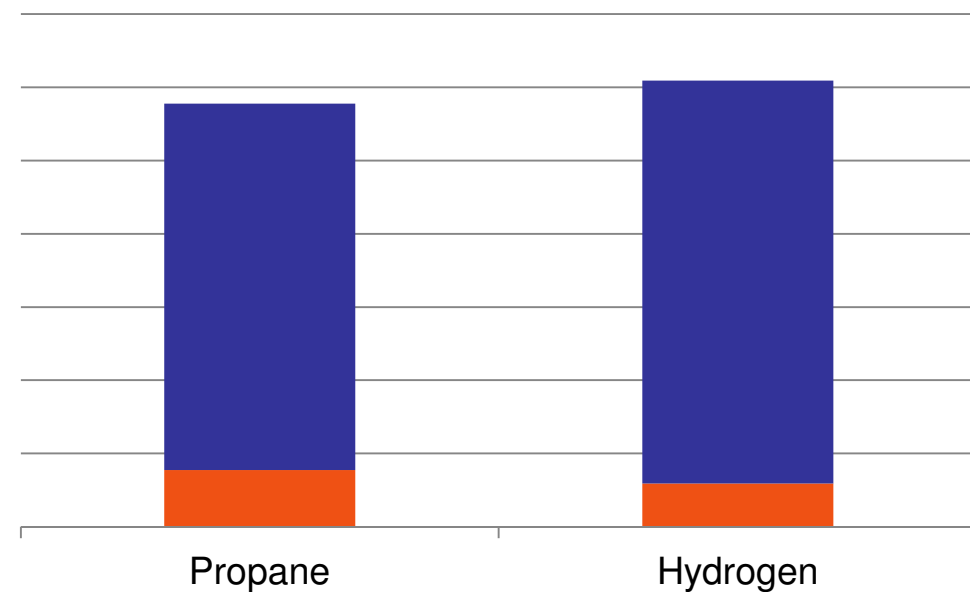
Key variable 1: Intensity of use

- To be economic, hydrogen lifts need to be used intensively
- Costs increase less with use than for alternative technologies

Annual costs: 10 op hours / week



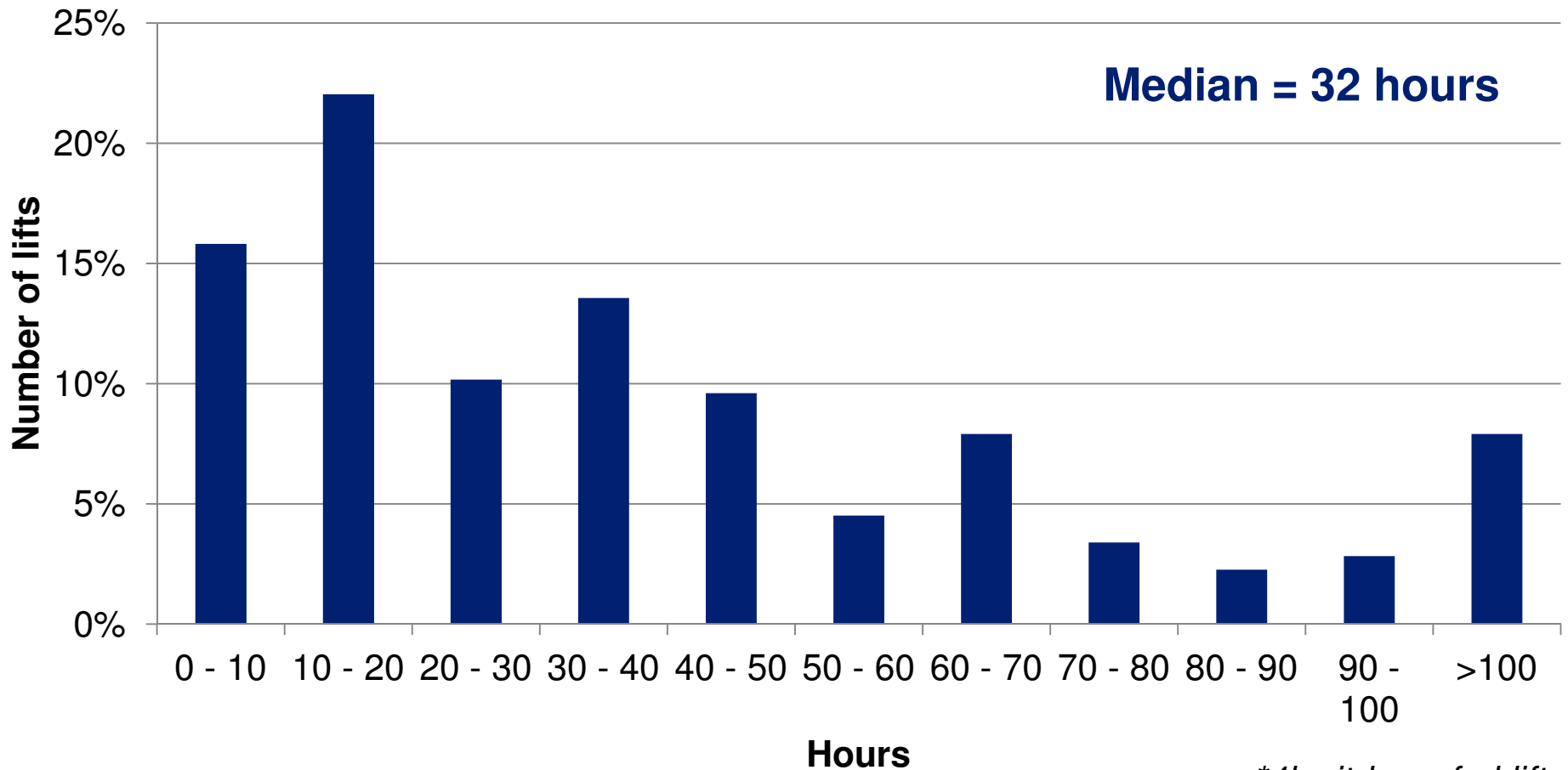
Annual costs: 60 op hours / week



**Preliminary data, DDJC*

But Forklift Utilization Rates Not Particularly High

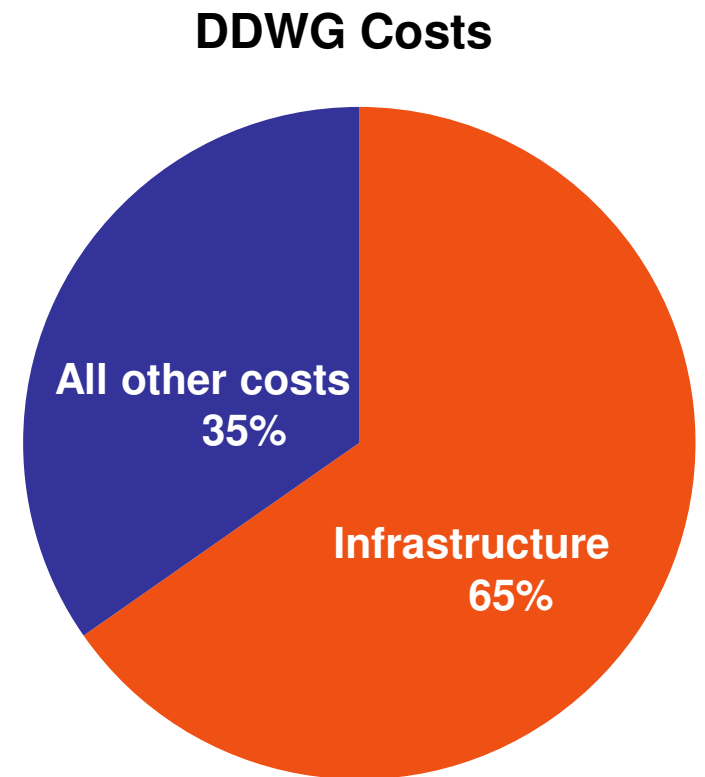
DDWG forklift monthly utilization



**4k sitdown forklifts
Feb – Apr 2011*

Key variable 2: Size of fleet

- Business case is difficult for small fleets (<60 forklifts)
- Hydrogen infrastructure is largest expense; a large fleet reduces per-forklift infrastructure costs



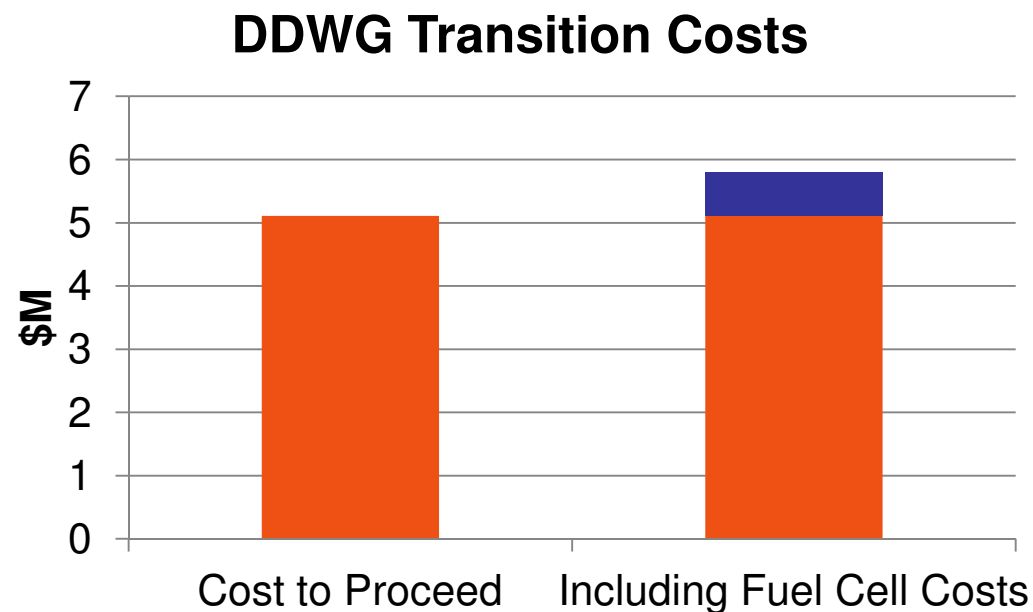
**Delivered gaseous H₂, 20 fuel cell forklifts*

Key variable 3: H2 infrastructure

- H2 infrastructure:
 - Single largest project expense; intelligent design & sizing is important
 - Our business case analysis treated H2 infrastructure capital costs as **sunk costs** because they were funded as part of an R&D program.
 - Going forward, only infrastructure **operating costs** were analyzed
- H2 supply:
 - At limited scale of operations, generally cheaper to use delivered H2 than to self-generate
 - Delivered liquid H2 cheaper per unit than gaseous, but adds infrastructure costs
- H2 onsite generation:
 - Electrolysis is best for small operations (<100 kg/day)
 - Reformation from natural gas or wastewater may be cost effective for large operations if equipment reliability is high

Key variable 4: Fuel cell costs

- Fuel cell capital costs not included in analysis
 - Greenfield sites need to consider these costs
 - \$25k - \$35k per fuel cell
 - Represent 10% - 15% of total project costs



**Delivered gaseous H2, 20 fuel cell forklifts, costs over 9 years*

Key variable 5: Existing operations

- How operations are conducted determines H2 competitiveness
 - Battery substitution
 - Key factor: how long does swapping batteries take?
 - Manual swaps: 15 - 20 minutes
 - With battery change infrastructure: <5 minutes
 - Key factor: how many forklifts & batteries does 1 fuel cell forklift replace?
 - 2-3 shift operation with battery infrastructure: 2-3 batteries, 1 forklift
 - 1 shift operation: 1 battery forklift
 - 2 shift operation with no battery infrastructure: 2 battery forklifts
 - Propane substitution
 - Propane tank changeout: ~5 minutes
 - H2 refueling: ~5 minutes

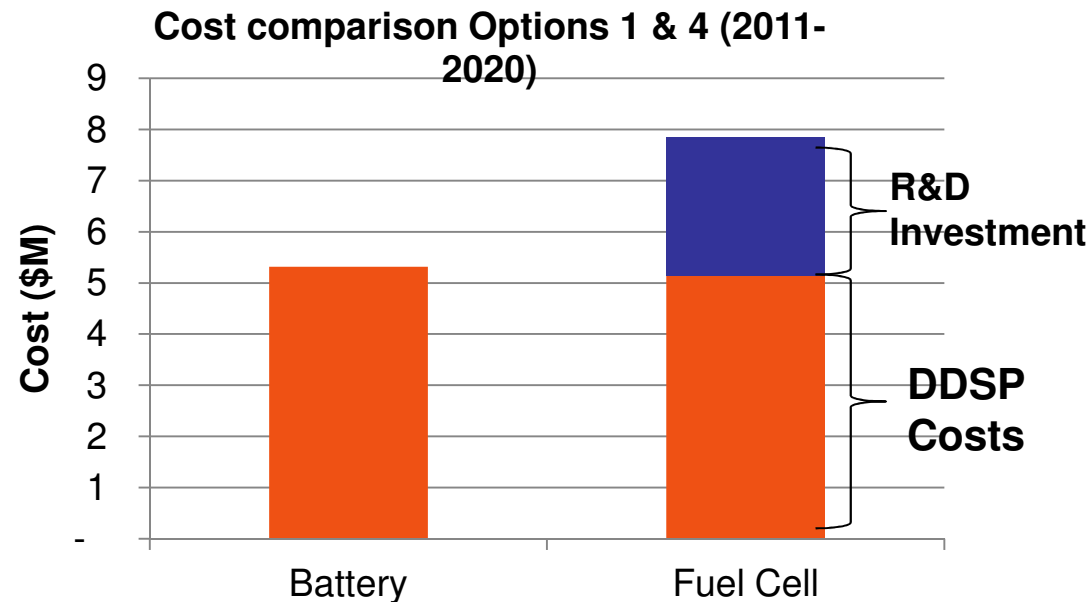
Less important variables

- Many variables have relatively little impact
 - Electricity prices
 - Labor rates
 - Battery degradation during operation



Results: DDSP

- 4 options considered:
 1. Back to batteries
 2. Continue with 40 fuel cell forklifts (fl's)
 3. Replace all 500 DDSP battery fl's with 375 fuel cell
 4. Expand by 50 fuel cell fl's, replace 87 battery fl's
- Options 2 & 3: No positive business case
- Option 4: w/ R&D paying for new fuel cells, positive business case



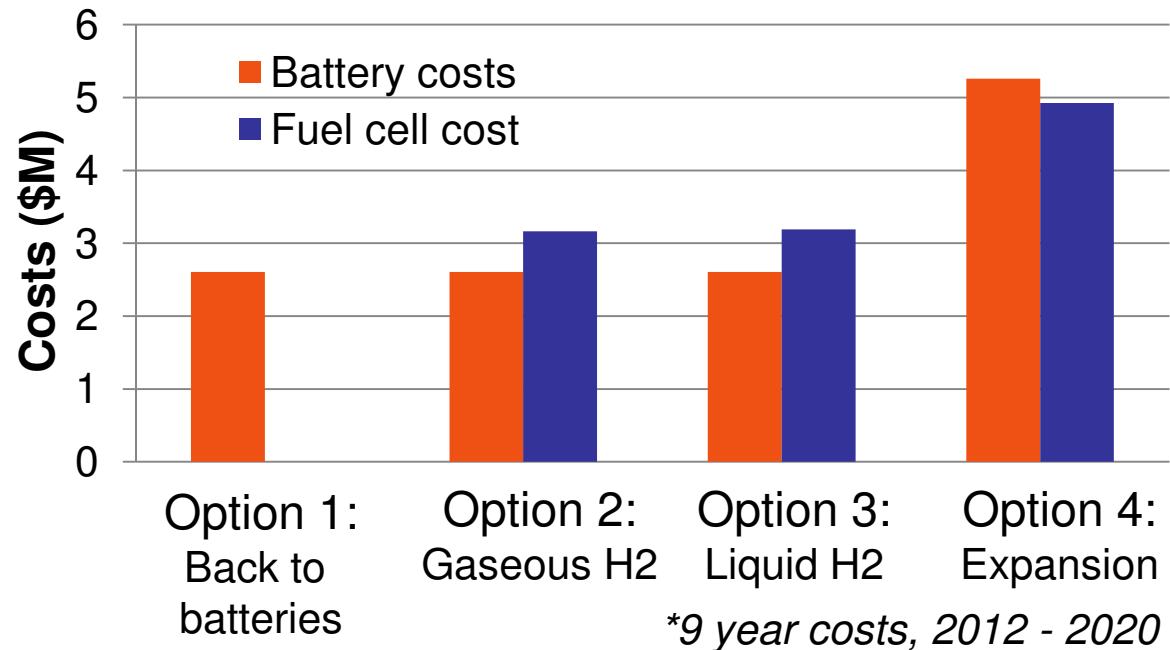
**10 year costs, through 2020*

DLA Leadership selected Option 1

Results: DDWG

- 4 options considered:
 1. Back to batteries
 2. Continue with 20 fuel cells, gaseous hydrogen delivery
 3. Continue with 20 fuel cells, switch to liquid H2 delivery
 4. Expand by 35 fuel cells, switch to liquid H2 delivery, downsize infrastructure
- If R&D pays for fuel cells, 4th option shows positive business case

DDWG Costs: Fuel cells v batteries



DLA Leadership selected Option 1

Transition Lessons Learned

- Cost is a barrier
 - Fuel cells still an emerging technology
 - Fuel cell and H2 infrastructure costs need to decrease to solidify the business case
- Infrastructure sizing is important and requires detailed planning and understanding of needs
- Alternative technologies also improving; e.g., batteries lasting longer
- Plan for future expansion in initial design
- Strong program leadership can make things happen, but...
- Must have user buy-in from top to bottom

Summary

- Under certain conditions, fuel cells can be economically competitive with batteries & propane forklifts
 - Requires a large fleet, high op-tempo, and well designed infrastructure
 - Productivity gains help make business case
 - May be some forklift O&M cost reduction with fuel cells
 - But high upfront costs and ongoing infrastructure support costs render economics marginal
- DLA has decided not to transition first two pilot projects
 - Positive business case would require further investment
 - Reluctance due to uncertainty of new technology and of future costs
- Get more details at: <http://www.dlafuelcells.org/>

Thank you!