Economic Aspects of Fuel Cell Forklifts:
What Have We Learned from Two Defense Logistics Agency (DLA) Pilot Projects?

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Dr. Michael E Canes, Distinguished Fellow, LMI
Outline

• Project description
• Literature review & past experiences
• Methodology
• Key assumptions
• Results
• Key inferences & broader implications
Defense Logistics Agency (DLA)

- Department of Defense’s largest logistics combat support agency
- Provides worldwide logistics support in war and peace time
- Operates many large distribution centers
- Good test subject for hydrogen-powered material handling equipment (forklifts)
4 fuel cell pilot (R&D) projects – 2 starting, 2 nearing completion

Approach:
• Pilot multiple H2 generation, dispensing and fuel cell technologies to power MHEs in warehouse operations at 4 locations over 2 years each
• Collect & analyze operational & cost data

Collaborators:
• Managed by DLA R&D.
• 3 Leading Fuel Cell Mfg’ers, 2 Leading Hydrogen Mfg’ers, various support contractors

Nearing Completion:
DLA Distribution Susquehanna PA (DDSP):
40 forklifts, 2 extended range vehicles, delivered (cryogenic) H2, indoor dispensing

DLA Distribution Warner Robins, GA (DDWG):
20 forklifts, onsite natural gas reformation for H2, mobile refuelers

Just Starting
DLA Distribution San Juaquin, CA (DDJC):
20 forklifts, electrolysis for H2

Joint Base Lewis-McChord, WA (JBLM):
19 forklifts, bus, wastewater digester gas H2, mobile refueler
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
  - 20 new fuel cell forklifts
  - 2 indoor H2 dispensers
  - Delivered liquid H2, onsite storage, pumps and pipeline
- Operations Feb 2009 - Sept 2011
  - >43,000 fuelings
  - >30,000 kg of H2 dispensed
  - >150,000 operating hours
• $12B inventory
• Parts & equipment for F-15, C-130, C-5, & C-17 aircraft
• Pilot Program Description:
  – Retrofit 20 battery forklifts with fuel cells
  – Reform H2 onsite from natural gas
  – Test mobile refueling
• Operational Nov 2009 – Nov 2011
  – >3,000 fuelings
  – >2,300 kg of H2 dispensed
  – >10,000 operating hours
Studies & past experiences

- Battelle found that lifecycle costs of fuel cell forklifts can be less than those of battery forklifts*

- Fuel cell manufacturer websites
  - Describe savings from avoiding battery changeouts
  - Cite costs of space for battery infrastructure
  - Cite productivity gains from use of fuel cells

- Several commercial customers currently use fuel cell forklifts in high-tempo retail & food warehouses:
  - Coca-Cola
  - FedEx
  - Walmart
  - Wegmans
  - Whole foods

- Receive 30% tax credit on fuel cell purchase

Economic Analysis (Business Case)

• Used by DLA decision makers to inform transition decisions – keep, expand or drop fuel cells in MHEs?
• Analysis includes cost information about forklift operations, maintenance, and infrastructure to compare fuel cells with alternative power sources (batteries & propane)
• Analyses specific to these particular pilots – complete for DDSP & DDWG
• Several important cost drivers identified
Key assumptions

• 10-year time scale
• Capital costs depreciated over time
• Fuel cells & H2 infrastructure purchased under R&D – *sunk costs*
• Equipment scrapped at end of useful life
• Recurring costs assumed constant in real terms throughout period of analysis
Data

Costs Considered:

• Fuel cell & battery acquisition costs
• Forklift acquisition costs
• Fueling vs. charging infrastructure costs
• Forklift & fuel cell, battery or propane-related maintenance costs
• Utility costs
• Labor costs
• Floor space requirements & costs
• Refueling vs. recharging time
• Equipment life spans
Results

Key variable 1: Intensity of use

- To be competitive, fuel cell lifts need to be used intensively.
- Costs increase less with use than for alternative technologies.

Annual costs: 10 op hours / week

- Recurring costs
- Capital costs

Propane
Hydrogen

Annual costs: 60 op hours / week

- Recurring costs
- Capital costs

Propane
Hydrogen

*Preliminary data, DDJC*
But Forklift Utilization Rates Not Particularly High

DDWG forklift monthly utilization

Median = 32 hours

*4k sitdown forklifts
Feb – Apr 2011
Results
Key variable 2: Size of fleet

- Business case is difficult for small fleets (<60 forklifts)
- Hydrogen infrastructure is the largest expense; per-forklift infrastructure costs drop with the size of fleet

*Delivered gaseous H2, 20 fuel cell forklifts*
Results
Key variable 3: H2 infrastructure

• H2 infrastructure:
  – Single largest project expense; intelligent design & sizing is important
  – Our business case analyses 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 a limited scale of operations, it is cheaper to use delivered H2 than to self-generate
  – Delivered liquid H2 is cheaper per unit than gas, but adds infrastructure costs

• H2 onsite generation:
  – Electrolysis is best onsite choice for small operations (<100 kg/day)
  – Reformation from natural gas or wastewater might be marginally cost effective for large operations if equipment reliability is high, but difficult to compete with centralized H2 manufacture and delivery
Results

Key variable 4: Fuel cell costs

- Fuel cell capital costs not included in BCAs
  - Greenfield sites need to consider these costs
  - Are coming down but still $25k - $35k per fuel cell
  - Represent 10% - 15% of total project costs

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

Key variable 5: What competing against?

- How operations are otherwise 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

- Propane substitution
  - Propane tank changeout: <5 minutes
  - H2 refueling: ~5 minutes
Results

Less important variables

- Some variables have relatively little impact
  - Electricity rates
  - Labor rates
  - Battery degradation during operation
BCA 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 cells
  4. Expand by 50 fuel cell fl’s, replace 87 battery fl’s

- Options 2 & 3: No positive business case
- Option 4: With R&D paying for new fuel cells & infrastructure expansion, obtain a positive business case

DLA Leadership selected Option 1
BCA 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, positive business case for 4th option

**DDWG Costs: Fuel cells v batteries**

*9 year costs, 2012 - 2020*

**DLA Leadership selected Option 1**
Key Inferences

• Under certain conditions, fuel cell forklifts can be economically competitive
  – Requires a large fleet & high op-tempo
  – Infrastructure sizing is important - requires detailed planning and understanding of needs
  – Productivity gains relative to batteries help make business case
  – May be some forklift O&M cost reduction with fuel cells
  – But alternative technologies also improving; e.g., batteries last longer
  – High upfront costs and infrastructure O&M must come down to improve the economics

• DLA has decided not to transition first two pilot projects
  – Positive business case would require further investment
  – Reluctance due to uncertainty of new technology, possible exposure to higher costs in the future
Broader Implications

- DLA R&D projects very useful in clarifying the strengths and weaknesses of fuel cell MHEs
- The technology works and its use could be expanded
- But to be economic, it requires large fleets which work intensively because:
  - H2 infrastructure is expensive
  - Batteries are cheaper
  - Fuel cell, hydrogen infrastructure O&M are expensive and those costs need to be spread over large numbers
- Will conduct BCAs of the remaining DLA projects and see how early conclusions hold up
Thank you!

• Dr. Michael Canes  
  Distinguished Fellow  
  LMI  
  mcanes@lmi.org