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Market Opportunity Assessment of Direct Hydrogen PEM Fuel Cells in Federal and Portable Markets

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DOE Annual Program Review

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FCP9

Overview

Timeline

- Project start date: November 2003
- Project end date: October 2008
- Percent complete: 85% (Mar 2008)

Barriers

- All distributed generation systems barriers
- All fuel-flexible fuel processor barriers
- All fuel cell component barriers

Budget

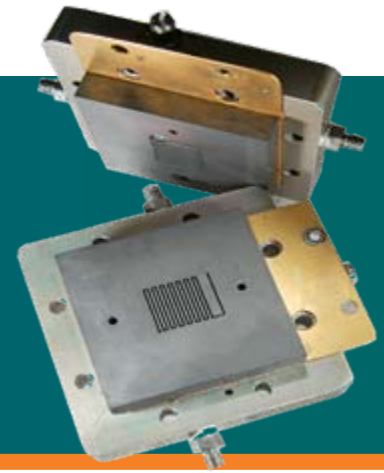
- Total Project Funding: DOE Share $3,163,843 and No Contractor Cost Share
- Funding received in FY04: $526,548
- Funding received in FY05: $650,659
- Funding received in FY06: $599,013
- Funding received in FY07: $703,283
- Funding received in FY08: $684,340

Assistance

- H2A, NREL
- More than 60 companies and agencies have participated in facilitated discussions
- More than 350 current or candidate users have participated in surveys, interviews, and focus groups

Project Objective

To assist DOE in developing fuel cell systems by analyzing the technical, economic, and market drivers of polymer electrolyte membrane (PEM) fuel cell adoption*.



Support in 2007 included:

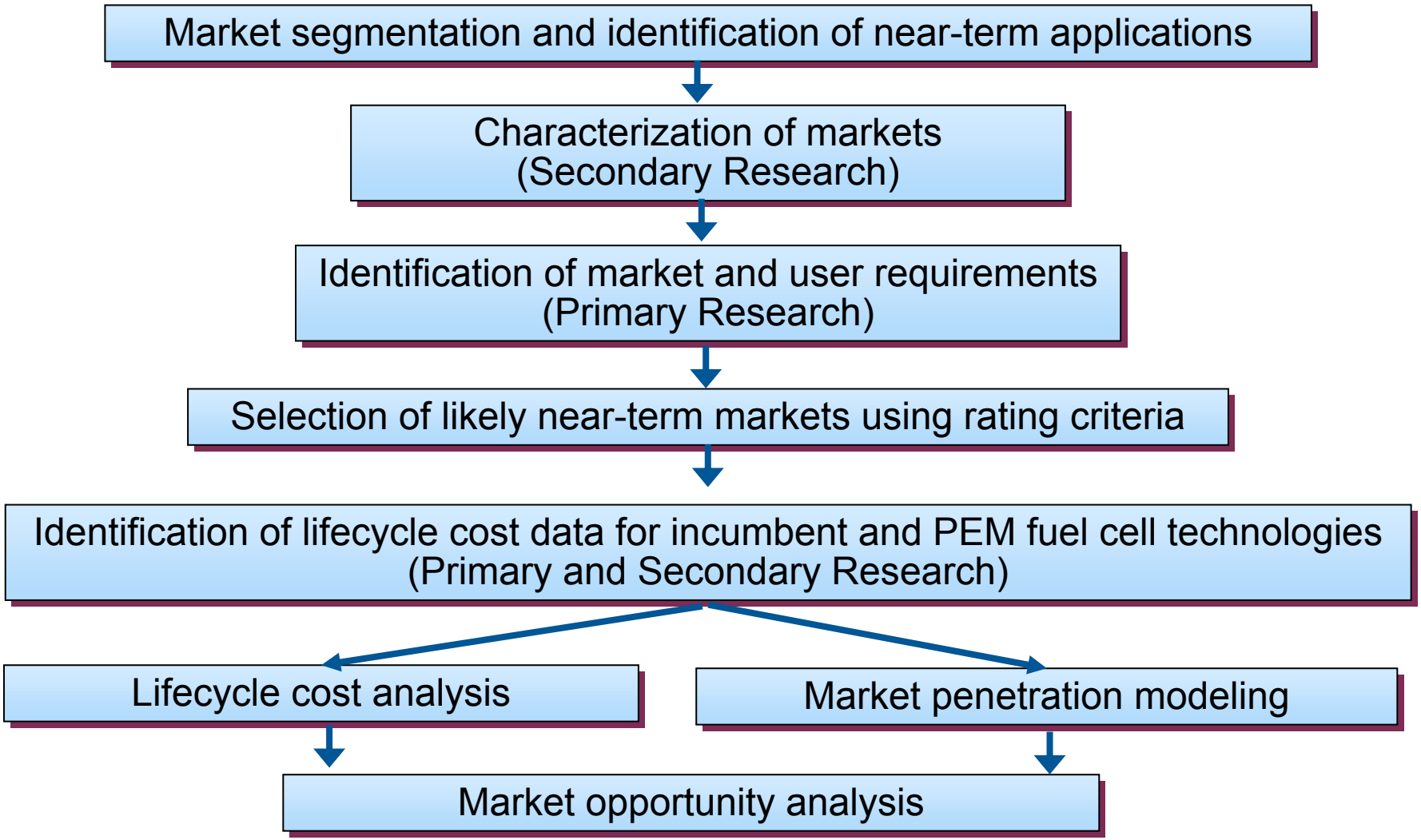
- Economic analysis of near-term markets in the federal and portable market sector
  - Market segmentation of 1–250 kW PEM fuel cell into near-term (2008) and mid-term (2012) opportunities
  - Lifecycle cost analysis of PEM fuel cell and competing alternatives
  - Market opportunity assessment of PEM fuel cell in near-term markets
- State and local agencies of emergency response market engagement
  - Development of a candidate user database
  - Market engagement through targeted e-mailing of educational materials and by facilitating teleconferences on PEM fuel cell applications and installations
  - Conference presentations at venues frequented by user community

**Note: Scope of the project is limited to direct hydrogen PEM fuel cells in the 1 kW to 250 kW size range. Scope does not include vehicle applications, direct methanol fuel cells, and reformed methanol fuel cells.*

Milestones

- Submitted final near-term markets report – Available at http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/pemfc_econ_2006_report_final_0407.pdf
- Completed analysis of federal markets - October 2007; submitted draft reports - October 2007.
- Completed analysis of portable markets - April 2008
- Conducted two state and local emergency response stakeholder teleconferences
  - August 2007
  - February 2008

Approach: Methodology



Approach: Selection of Near-Term Markets

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Criteria for Selecting Priority Near-Term Markets

- PEM fuel cells offer unique value to market segment not met by competing technologies
- PEM fuel cell product characteristics and their potential benefits must fit user requirements (high-priority needs)
- Sufficient market size and growth potential of the market segment ensures current and continued fuel cell adoption
- Cost of reaching the market, including product development and marketing, is reasonable
- PEM fuel cell products are available for immediate application or can be developed over the short term

Approach: Market Segments Analyzed

Federal Market		Portable Market	
		Commercial Market	Government Market
National Aeronautics and Space Administration (NASA)	Department of Veterans Affairs (VA)	Video Cameras for Broadcast TV	Consumer Electronics (Computers, Cell Phones, PDAs, Digital Cameras, Portable Audio Devices, Video Game Consoles, and Battery Chargers)
Department of Transportation (DOT) – Federal Aviation Administration (FAA)	Department of Interior (DOI) – National Park Service (NPS), National Fish and Wildlife Service (FWS), United States Geological Survey (USGS), Bureau of Land Management (BLM), Bureau of Reclamation (BoR), National Interagency Fire Center (NIFC)	Recreational APU Markets	Communication and Security Devices
Department of Homeland Security (DHS) – United States Coast Guard (USCG), Customs and Border Protection (CBP), Federal Emergency Management Agency (FEMA)		Portable Traffic Signage	Portable Generators
Department of Commerce (DOC) - National Oceanic and Atmospheric Administration (NOAA)	United States Postal Service (USPS)	Advertising Billboards	Soldier Power
Department of Energy (DOE)	Department of Defense (DOD) – Army, Navy, Air Force, Defense Logistics Agency (DLA), Office of the Secretary of Defense (OSD), Army Corps of Engineers (USACE)	Portable Generators Markets: Construction, Residential, Other	Unmanned Aerial Vehicles
United States Department of Agriculture Forest Service (USDA FS), USDA Natural Resources Conservation Service (NRCS)	Department of Justice (DOJ) – Bureau of Prisons	Cordless Power Tools	Unmanned Underwater Vehicles
General Services Administration (GSA)	Environmental Protection Agency (EPA)	Medical Devices	
	United States Postal Service (USPS)		

Technical Accomplishments: Highlights

- Economic analysis of near-term markets
  - Worked with the U.S. Fuel Cell Council to ensure inputs were received from industry through the course of the federal and portable market study *(13 completed surveys were obtained; 2 meetings were conducted)*
  - Identified near-term and mid-term markets where PEM fuel cells offer value over competing alternatives in the federal and portable market sector
  - Performed comprehensive marketing research through primary and secondary methods to understand user requirements in various markets
  - Applied modified H2A model to allow cost comparisons between fuel cells and alternative electricity generation
  - Estimated market penetration in federal markets
  - Developed value propositions for PEM fuel cells in two near-term federal markets and one portable market
  - Presented results at various meetings and disseminated information to candidate users
- Near-term market engagement
  - Developed database of candidate users in the emergency response market segment
  - Conducted two emergency response teleconferences with candidate users, US Fuel Cell Council, and DOE

Technical Accomplishments: Federal Near-Term and Mid-Term Markets

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Near-term Markets (2008)	Mid-term Markets (beyond 2012)
Unique value proposition – Purchase not based solely on capital cost	**PEM fuel cells can provide value if barriers including reliability, hydrogen storage, and capital cost are addressed**
• FAA • DOD, DLA • NOAA • DOI, BoR • DHS, CBP • USPS • DOD, Air Traffic Control • DOI, NIFC • USDAFS	• DOD – Army, Air Force • DHS, USCG • DHS, FEMA • USDA, NRCS • DOE • EPA • GSA

Federal Market Analysis

Federal Aviation Administration (FAA): Market Analysis Summary

Market Description	The FAA is responsible for overseeing civilian air transportation in the U.S. The FAA manages air traffic in the U.S. through a network of towers at more than 19,000 airports. Backup power is provided to these towers.
Market Size	Approximately 15,000 towers.
Replacement Rate/Growth Rate	Replacement rate unknown. Growth is anticipated for backup power for radio tower sites. FAA is interested in extending backup power to 72 hours for critical sites, remote sites, and sites where grid power is unreliable.
Current Mode of Operation	Batteries and propane generators.
Impact of Downtime	Significant impact as downtime disrupts air traffic control.
Factors Considered When Evaluating Power Systems	Reliability, fuel availability, start-up time, lifetime.
Factors That Most Influence Decision to Purchase Alternative Power Source	Reliability, maintenance, ease of use, cost.
Satisfaction With Current Technology	Not satisfied with current technologies. Issues with battery lifetime and maintenance. Concerns with generator maintenance and high capital cost.
Have Alternatives Been Considered?	Yes, PEM fuel cells have been installed.
Approach to Capital Purchase Decision Making	Consider capital cost, maintenance cost, and ease of use. Past experience with the system also is considered.
Importance of Funding Available in Purchasing	Would consider government subsidies when purchasing.

FAA: Lifecycle Cost Analysis Assumptions

Backup Runtime	kW	Fuel Replacement	Battery/ Fuel Cell Replacement	H-PEMFC Comparison	Lifecycle Assumptions
Scenario 1 – Radio Transmit/Receive Site					15-year system life No residual value 8% discount rate 2.3% inflation rate
24, 48, 72 hours	0.6	Annually	3- and 5-year Battery 10-year PEM Fuel Cell	To battery system (Outdoor Installation)	
Scenario 2 – Radio Communication Link Repeater Site					
24, 48, 72 hours	3	Annually	3- and 5-year Battery 10-year PEM Fuel Cell	To battery system (Outdoor Installation)	
Scenario 3 – Remote Communication Air/Ground Site					
24, 48, 72 hours	5	Annually	3- and 5-year Battery 10-year PEM Fuel Cell	To battery system and to generator system (Outdoor Installation)	

FAA: Cost Analysis of PEM Fuel Cell Backup Power for Radio Transmitter Receiver (RTR) Tower

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	24 Hours Backup Runtime			48 Hours Backup Runtime			72 Hours Backup Runtime		
	Battery (3-year)	Battery (5-year)	PEM Fuel Cell	Battery (3-year)	Battery (5-year)	PEM Fuel Cell	Battery (3-year)	Battery (5-year)	PEM Fuel Cell
Net Present Value of Total Capital Costs ($)	12,178	9,016	25,769	22,670	16,345	25,769	32,042	23,600	25,769
Net Present Value of Total O&M Costs ($)	28,771	28,771	8,511	35,963	35,963	8,841	43,156	43,156	9,161
Net Present Value of Total Costs of the System ($)	40,949	37,786	34,281	58,633	52,309	34,610	76,198	66,756	34,930

FAA: Cost Analysis of Backup Power for Radio Communications Link Repeater (RCLR)

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	24 Hours Backup Runtime			48 Hours Backup Runtime			72 Hours Backup Runtime		
	Battery (3-Year)	Battery (5-Year)	PEM Fuel Cell	Battery (3-Year)	Battery (5-Year)	PEM Fuel Cell	Battery (3-Year)	Battery (5-Year)	PEM Fuel Cell
NPV of Total Capital Costs ($)	49,523	33,712	40,904	94,405	62,783	42,609	139,287	91,853	44,314
NPV of Total O&M Costs ($)	28,771	28,771	9,161	35,963	35,963	11,428	43,156	43,156	13,047
NPV of Total Costs of the System ($)	78,294	62,483	50,065	130,368	98,746	54,038	182,443	135,010	57,361

FAA: Cost Analysis of Backup Power for Remote Communications Air/Ground Site (RCAG)

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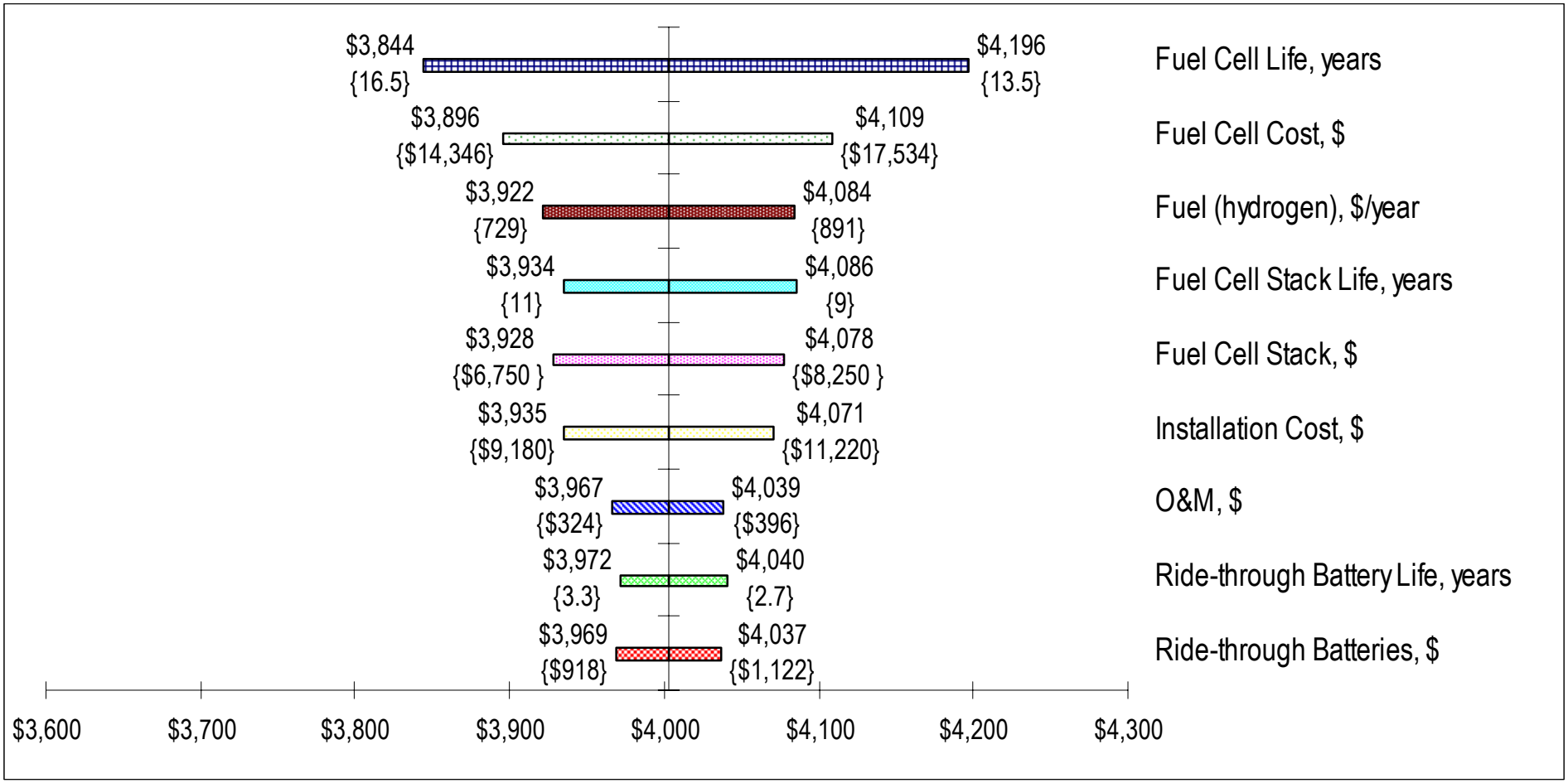
	24 Hours Backup Runtime			
	Battery (3-Year)	Battery (5-Year)	Generator (20 kW)	PEM Fuel Cell
NPV of Total Capital Costs ($)	84,433	58,081	51,165	48,114
NPV of Total O&M Costs ($)	28,771	28,771	25,834	8,791
NPV of Total Costs of the System ($)	113,204	86,852	76,998	56,905
	48 Hours Backup Runtime			
	Battery (3-Year)	Battery (5-Year)	Generator (20 kW)	PEM Fuel Cell
NPV of Total Capital Costs ($)	157,500	104,796	51,165	50,956
NPV of Total O&M Costs ($)	35,963	35,963	26,703	11,488
NPV of Total Costs of the System ($)	193,463	140,759	77,867	62,444
	72 Hours Backup Runtime			
	Battery (3-Year)	Battery (5-Year)	Generator (20 kW)	PEM Fuel Cell
NPV of Total Capital Costs ($)	230,566	151,510	51,165	53,797
NPV of Total O&M Costs ($)	43,156	43,156	27,562	14,186
NPV of Total Costs of the System ($)	273,722	194,666	78,726	67,983

FAA: Sensitivity Analysis 5 kW RCAG Site Providing 72 Hours of Backup Power

Highest Cost Leverage: (1) fuel cell life, (2) fuel cell cost, (3) hydrogen cost, and (4) stack life.



FAA: Value Proposition

- PEM fuel cells offer lower lifecycle cost than batteries for applications less than 5 kW for extended backup runtimes
- Compared with batteries, PEM fuel cells
  - Are compact
  - Offer longer, continuous runtime
  - Have lower maintenance requirements
  - Can be monitored remotely
  - Maintain steady voltage
  - Are more durable in harsh environments
- Reliability data are critical for PEM fuel cells to penetrate this market segment

Defense Logistics Agency (DLA): Market Analysis Summary

Market Description	The DLA's Defense Distribution Center operates 26 distribution depots, which provide ~5.2 million items per year to U.S. military personnel. Use forklifts to stack, retrieve, and transport goods in facilities. Operate forklifts for one or two 8-hour shifts per day, 5 days per week. Maintain surge capacity to accommodate short-term increases in demand, which extend shift durations.
Market Size	DLA has approximately 4,000 forklifts.
Replacement Rate/Growth Rate	Major growth not anticipated. Aging vehicle replacement rate ~20% per year.
Current Mode of Operation	Battery-powered (~50% of DLA's inventory) for indoor use; typically lead-acid or Ni-Cd. Diesel/propane ICE-powered for heavy materials handling and outdoor use.
Impact of Downtime	Loss of productivity, disruptions in distribution of critical supplies for military, increased O&M costs.
Factors Considered When Evaluating Power Systems	Most important to users: reliability, capital and O&M costs, and ease of use. Other considerations: useful life, emissions, durability, and availability of parts.
Factors That Most Influence Decision to Purchase Alternative Power Source	Users are not directly responsible for making such decisions.
Satisfaction With Current Technology	Users are generally satisfied with performance of electric and ICE-powered forklifts. Batteries out-perform diesel and propane ICEs with respect to emissions and start-up time; not as good as ICEs with respect to capital costs, O&M costs, or ease of use. Battery-powered forklifts are more expensive to purchase than ICE units but have lower lifecycle costs (e.g., maintenance, fueling) and a longer useful life. Ease of refueling, increased lift capacities, and capacity for outdoor use are the primary benefits of ICE forklifts.
Have Alternatives Been Considered?	Yes, better battery systems and hydrogen fuel cells.
Approach to Capital Purchase Decision Making	DLA headquarters allocates funding for capital purchases (e.g., forklift replacement) based on depot needs, budgetary considerations, and other priorities.
Importance of Funding Available in Purchasing	Important, as evidenced by fuel cell demonstration.

DLA: Cost Analysis Assumptions

Scenario 1	Scenario 2	Scenario 3	Scenario 4
Battery vs. PEM fuel cell	Battery vs. PEM fuel cell	Propane ICE vs. PEM fuel cell	Propane ICE vs. PEM fuel cell
Operate 8 hours/shift 1 shift per day 5 days a week	Operate 16 hours/day 2 shifts per day 5 days per week	Operate 8 hours/shift 1 shift per day 5 days a week	Operate 16 hours/day 2 shifts per day 5 days per week
No battery changeouts	Battery is changed out twice @ 30 min. each	Propane tank lasts 8 hours replaced once each day. Runtime from hydrogen is 18 hours	Propane tank lasts 8 hours replaced twice each day. Runtime from hydrogen is 18 hours
Maintenance labor cost is $30 per hour	Maintenance labor cost is $30 per hour	Maintenance labor cost is $30 per hour	Maintenance labor cost is $30 per hour
Hydrogen: $17.50/kg	Hydrogen: $12.50/kg	Hydrogen: $17.50/kg	Hydrogen: $12.50/kg
PEM fuel cell replaced every 5 years	PEM fuel cell replaced every 2, 3, or 5 years	PEM fuel cell replaced every 5 years	PEM fuel cell replaced every 2, 3, or 5 years
Battery is replaced every 3 or 5 years	Battery is replaced every 3 or 5 years	-	-

DLA Analysis: NPV Cost Analysis of Forklifts in Single Shift Operations

	Battery-Powered Forklift (3-Year*)	Battery-Powered Forklift (5-Year*)	PEM Fuel Cell-Powered Forklift (5-Year*)
Class 1 Forklift ($)	90,424	82,496	167,105
Class 2 Forklift ($)	68,271	62,325	140,410
Class 3 Forklift ($)	48,202	45,824	71,596

	Propane-Powered Sit-Down Counterbalanced Forklift	PEM Fuel Cell-Powered Sit-Down Counterbalanced Forklift (5-Year*)
NPV of Total Capital Costs ($)	17,442	70,377
NPV of Total O&M Costs ($)	133,069	80,919
NPV of Total Lifetime Costs ($)	150,511	151,296

*Battery or stack life.

DLA Analysis: Cost Analysis of Forklifts in Double Shift Operations

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NPV of Total Capital Costs	Battery-Powered Forklift (3-Year*)	Battery-Powered Forklift (5-Year*)	PEM Fuel Cell-Powered Forklift (5-Year*)	PEM Fuel Cell-Powered Forklift (3-Year*)	PEM Fuel Cell-Powered Forklift (2-Year*)
Class 1 ($)	219,052	203,194	201,187	217,045	236,958
Class 2 ($)	191,510	179,616	174,493	184,404	196,849
Class 3 ($)	161,740	156,983	88,417	94,364	101,831

	Propane-Powered Sit-Down Forklift	PEM Fuel Cell-Powered Sit-Down Forklift (5-Year*)	PEM Fuel Cell-Powered Sit-Down Forklift (3-Year*)	PEM Fuel Cell-Powered Sit-Down Forklift (2-Year*)
NPV of Total Capital Costs ($)	17,442	70,377	83,634	106,148
NPV of Total O&M Costs ($)	241,295	114,337	114,337	114,337
NPV of Total Costs of the System ($)	258,737	184,714	197,971	220,484

*Battery or stack life.

DLA: Sensitivity Analysis of PEM Fuel Cell-Powered Class 1 Forklift in Double Shift Operations

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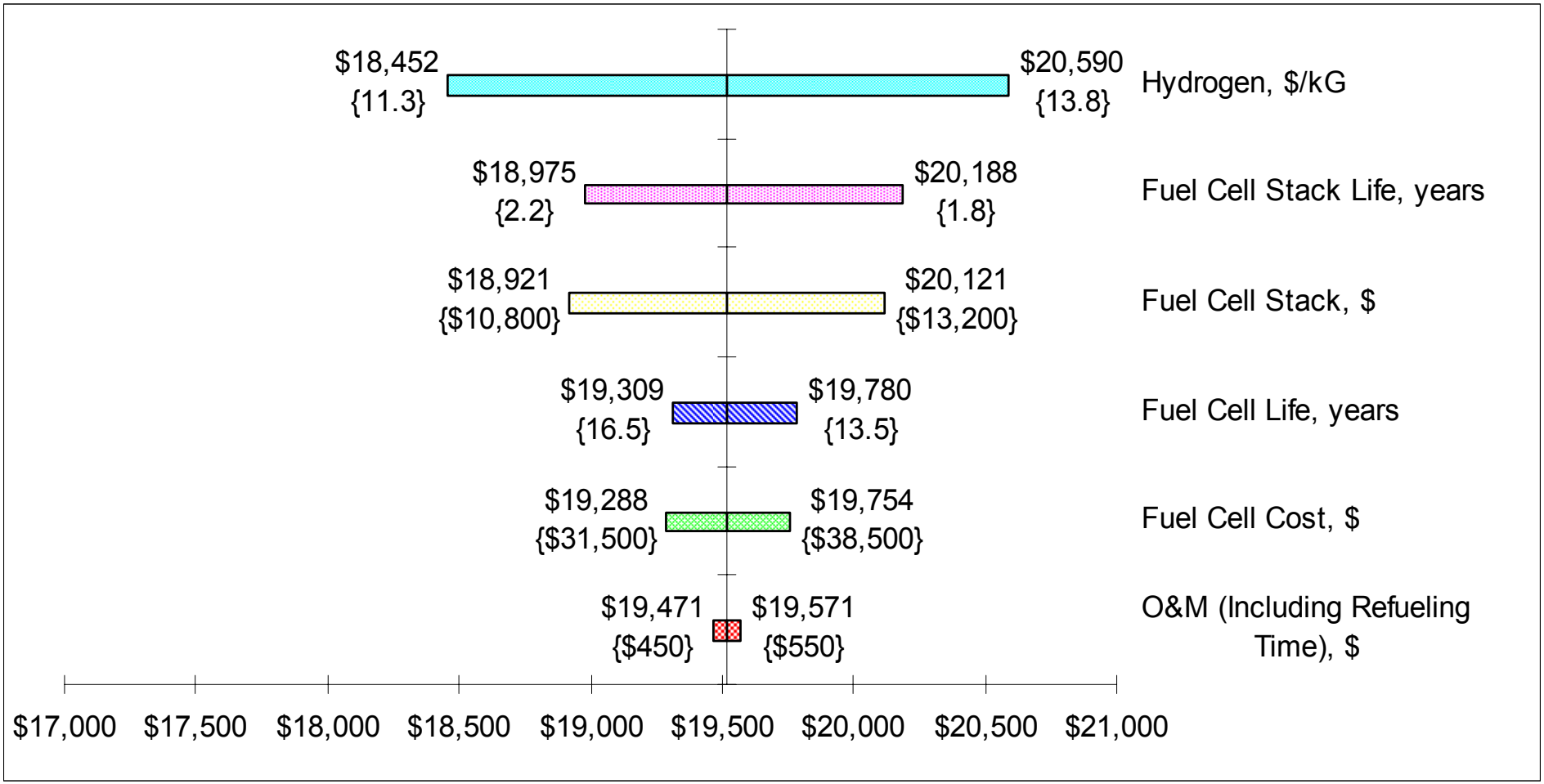
Highest Lifecycle Cost Leverage: (1) hydrogen costs, (2) fuel cell stack life, (3) fuel cell stack costs.



DLA: Value Proposition

- PEM fuel cell-powered forklifts offer lifecycle cost advantages over battery-powered forklifts and propane-powered forklifts in two-shift operations
- PEM fuel cells offer
  - Lower O&M costs
  - Lower total annual operating costs
  - Ease of refueling versus recharging batteries
  - Reduced numbers of batteries
  - No emissions
  - Increased safety
  - Increased availability
- The value of PEM fuel cell-powered forklifts is impacted by
  - Cost of hydrogen
  - Battery life
  - PEM fuel cell life
  - Operator costs
  - Hours of operation

Market Penetration in the Federal Market Sector: Backup Power Assumptions

Assumptions	
Total Market Size	19,924
Annual Replacement Percentage of Installed Base	6.7%
FAA Market Growth Rate	5%
Other Market Growth Rate	0%
Fuel Cell Purchases as Percentage of Total Annual Purchases	75%

Market Penetration in the Federal Market Sector : Backup Power Results

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Market and Application	Market Size, units	Size of PEMFC (kW)	Total Annual Purchases	Total Annual Purchases of PEMFC	Cost Per PEMFC ($)	Installation Cost ($)	Cost (million $)
FAA - Radio Towers	15,000	1	1,750	1,313	6,740	4,000	14.1
DHS - Radio Repeater Towers and Border Entry Points	200	5	200	150	15,940	18,000	5.1
NOAA – Weather Radio, Automated Surface Observing Systems	1,824	5	122	91	15,940	18,000	3.1
NOAA - Upper-Air Observations Program	800	1	53	40	6,740	4,000	0.4
USDA - Fire Incident Camps, Radio Repeater Sites	1,000	5	66	50	15,940	18,000	1.6
BoR – Communication Sites	100	5	7	5	15,940	18,000	0.2
DOD – Radio Transmitter Sites	1,000	1	67	50	6,740	4,000	0.5
Total	**19,924**		**2,265**	**1,699**			**25**

Market Penetration in the Federal Market Sector: PEM Fuel Cell-Powered Forklifts

Federal Market Segment	Forklift Type	Market Size (Units)	Annual Replacement Purchases, % of Installed Base	Annual Replacement Purchases (Units)	Adoption Rate (%)	Total Annual Purchases (Units)
DOD, Defense Logistics Agency	Class1	2,000	10	200	20	40
	Class 2	1,000	10	100	5	5
	Class 3	1,000	10	100	20	20
USPS	Class 1	5,088	20	1,018	20	204
	Class 3	5,088	20	1,018	20	204
Total		**14,176**		**2,436**		**473**

Portable Market Analysis

Professional Video Cameras: Market Analysis Summary

Market Description	Professional video cameras used for television broadcasting.
Market Size	Approximately 1,100 television broadcasting stations in the U.S. use ~ 66,000 portable power sources.
Growth Rate	Primarily a replacement market.
Current Mode of Operation	Predominantly batteries; approximately 3% penetration of fuel cells into the market.
Impact of Downtime	Loss of news story, impacts TV ratings, which impacts bottom line.
Factors Considered When Evaluating Power Systems	Reliability, ease of use, lifetime of power source, and good experience with system.
Factors That Most Influence Decision to Purchase Alternative Power Source	Reliability and weight.
Satisfaction With Current Technology	Users generally satisfied with batteries but looking for longer runtimes.
Have Alternatives Been Considered?	Yes, different types of batteries and hydrogen fuel cells (Jadoo N-Gen system).
Approach to Capital Purchase Decision Making	The purchase of batteries is not a capital purchase.
Importance of Government Incentives in Purchasing	Generally not considered.

Professional Video Cameras: Lifecycle Cost Analysis Assumptions

Ni-Cd	Ni-MH	PEM Fuel Cell
Power requirement is 65 watts.		
Total runtime is 2 hours per day, five days a week, 52 weeks a year.		
4 replacement batteries.	4 replacement batteries.	2 hydrogen canisters.
Recharge time is 2 hours.	Recharge time is 6 hours.	Recharge time is 1 hour.
Discount rate is 8%.		
Inflation rate is 2.3%.		
Assumes 5-year lifecycle.		

Professional Video Cameras: Lifecycle Cost Analysis Summary

	Li-Ion	Ni-Cd	Ni-MH	PEM Fuel Cell
NPV of Total Capital Costs of the System ($)	7,525	4,701	7,426	8,334
NPV of Total O&M Costs ($)	34	43	136	257
NPV of Total Costs of the System ($)	7,559	4,744	7,562	8,591

Professional Video Cameras: Value Proposition

- H-PEMFC advantages over batteries in video cameras include
  - longer and consistent runtimes
  - no loss of discharge capacity
  - hot swap capability
- To compete effectively in this segment, weight, reliability, and ease of use with all camera types need to be addressed.
- Air transport restrictions on movement of hydrogen limits the use of this technology.

Emergency Response Market Engagement Strategy

- Conducted two teleconferences – August 28, 2007, and February 28, 2008.
- 28 candidate users participated in the teleconference. Other participants included DOE, U.S. Fuel Cell Council, HavePower, Logan Energy.
- Information on DOE fuel cell program, including market transformation, fuel cell basics, application of fuel cells to meet user requirements, and case study discussions of successful deployments, were presented

Future Work

FY 2008 Scope of Work

- Complete market opportunity assessments for fuel cells in wastewater treatment and data center markets.
- Continue near-term market engagement through activities related to facilitating user teleconferences, presenting papers, and participating in conferences and meetings.

Project Summary

Relevance

Identify technical, economic, and market place drivers for successful development of PEM fuel cell systems.

Approach

Perform market opportunity analysis to identify early markets where PEM fuel cells are likely to successfully compete to support development and deployment of robust PEM fuel cells products.

Integrate marketing research methods (surveys, focus groups, scenario analysis, innovation diffusion modeling), technology evaluation (surveys, expert focus groups) and economic analysis (engineering cost models, lifecycle cost models) to understand market opportunities and adoption rates.

Facilitate near-term market engagement to educate candidate users on the application of fuel cell technology.

Technical Accomplishments and Progress

Identified near-term markets for PEM fuel cells in the federal and portable sector; Completed market analysis, lifecycle cost analysis, and market penetration modeling; Coordinated market engagement activities.