V.A.10 Market Opportunity Assessment of Direct Hydrogen PEM Fuel Cells in Federal and Portable Markets

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Objectives

The overarching objectives of the project are to assist the DOE in developing fuel cell systems by analyzing the technical, economic, and market drivers of direct hydrogen polymer electrolyte membrane fuel cell (H-PEMFC) adoption. Support in Fiscal Year 2007 was focused on identifying near-term market opportunities for H-PEMFCs in the federal and portable market sectors. Project objectives were to:

- Complete market segmentation of 1–250 kW H-PEMFCs into near-term (2008) and mid-term (2012) opportunities,
- Perform lifecycle cost analysis of H-PEMFCs and competing alternatives in near-term markets,
- Develop value propositions and complete market opportunity analysis of H-PEMFCs in near-term markets, and
- Facilitate near-term market engagement in H-PEMFCs.

In 2008, Battelle is evaluating feasibility for fuel cell deployment for distributed generation in combined heat and power (CHP) applications at data centers and wastewater treatment plant markets. Support includes:

- Analyzing the market through market research to segment potential adopters, evaluating user requirements, and identifying potential early adopters,
- Evaluating the performance of fuel cell systems and competing alternatives,
- Performing economic and environmental benefits analysis of the application of fuel cells and competing alternatives,
- Identifying the value proposition for fuel cells, and
- Characterizing the market opportunity for fuel cells at data centers and wastewater treatment plants.

Technical Barriers

Battelle focuses on understanding the relationships among market-specific user requirements, current H-PEMFC performance and cost, and the technical barriers from the Fuel Cells section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan [1]. Key barriers to market adoption are:

(A) Durability
(B) Cost

Technical Targets

Battelle is gathering early adopter user-requirement data from near-term (2008) markets; gathering information on current H-PEMFC cost and performance for comparison to those user requirements; and, based on current H-PEMFC adequacy to meet user requirements, projecting lifecycle costs, market penetration, and the corresponding annual production volume likely to be achieved in transition markets. It is anticipated that the analysis provided by this project will assist the DOE in developing and/or modifying technical targets for various H-PEMFC applications.

Accomplishments

- Identified near-term and mid-term markets where H-PEMFCs offer value over competing alternatives in the federal and portable market sectors.
- Worked with the U.S. Fuel Cell Council to ensure that inputs were received from industry through the course of the federal and portable market study through surveys, interviews, and Webinars.
- Performed comprehensive marketing research through primary and secondary methods to understand user requirements in various markets.

Conducted approximately 200 surveys and interviews in the government and portable markets with users, industry experts, fuel cell companies, and hydrogen suppliers.

- Applied modified H2A model to allow cost comparisons between fuel cells and alternative electricity generation.
- Developed value propositions for H-PEMFCs in two near-term federal markets and one portable market.
- Presented results at various meetings and disseminated information to candidate users.
- Performed other near-term market engagement, including developing a database of candidate users in the emergency response market segment and conducted two emergency response teleconferences with candidate users, the U.S. Fuel Cell Council, and the DOE.
- Completed approximately 120 surveys and interviews with users, industry experts, fuel cell companies, engineering companies, and utilities on the opportunity for fuel cells in the data center and wastewater treatment plant market.

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Introduction

The DOE is facilitating the identification and deployment of H-PEMFCs in near-term markets to support the growth of the fuel cell industry and development of a supplier network. The DOE recognizes that fuel cell companies and component developers need to increase fuel cell sales in the coming years in order to support the continued research and development required for technological advancements in automotive applications. Furthermore, the DOE is authorized by the Energy Policy Act of 2005, sections 782 and 783, to support the deployment of fuel cells in early government markets and to demonstrate the benefits of fuel cells as an alternative energy source to society.

Battelle is providing an assessment of the market opportunities for fuel cells and an analysis of the technical, economic, and market drivers for H-PEMFC adoption in near-term markets. Near-term markets are those segments in which H-PEMFCs can be demonstrated successfully by 2008 in the United States. Analysis of the early markets will provide insights into the requirements for product development, application, and end-user acceptability. In 2007, Battelle published a report on near-term market opportunities for H-PEMFCs in backup power and specialty vehicle applications [2]. The follow-up analysis conducted in FY 2007 examined the near-term market opportunities for H-PEMFCs in the federal and portable market.

Approach

The methodology developed for Battelle's earlier study of near-term markets for H-PEMFCs in backup power and specialty vehicles was applied to this study [2]. The methodology uses an exploratory market research process, supplemented by modeling of lifecycle costs of H-PEMFCs and competing technologies, in order to identify those markets in which H-PEMFCs offer value and better performance in areas that are valued most by the market. Data are gathered through a combination of secondary and primary research, with continuous input from industry and government stakeholders to validate and refine the assumptions and findings. Secondary and primary research are used to identify the likely applications for H-PEMFCs, market attributes, market trends, user requirements for new technology, and economics of standard and alternative systems. Secondary research includes review of published reports, peer-reviewed journal articles, magazine articles, and market research reports to identify market requirements. Primary research includes surveys and interviews with users, manufacturers, integrators, and industry experts to gather user requirements. Selection of interviewees and survey respondents is based on a judgment sample for each market segment.

To allow lifecycle cost comparison of H-PEMFC and competing technology solutions, a modified H2A model is utilized. Current H-PEMFC lifecycle costs and lifecycle costs of competing energy generation or storage technologies determined through surveys are used in the lifecycle cost analysis. Lifecycle costs are calculated on a net present value (NPV) basis over a 15-year analysis period for backup power and specialty vehicle applications, and over five years for portable applications. A discount rate of 8% and an inflation rate of 2.3% are applied. H-PEMFC lifecycle costs are calculated. In addition, single-factor sensitivity analysis is performed to show the variability in average annual cost (cash basis) of owning and operating H-PEMFC as individual factors are varied while all other factors are held constant.

Results

FY 2007

Of the 13 federal markets analyzed, eight market segments were identified as potential near-term adopters for H-PEMFCs including the Federal Aviation Administration (FAA), the Defense Logistics Agency, the National Weather Service, the Bureau of Reclamation, Customs and Border Protection, the United States Postal Service, the Department of Defense air traffic control, and the Forest Service. Twenty-four portable market segments were analyzed and only the broadcast video camera market segment was identified as a potential near-term opportunity for H-PEMFCs. Lifecycle costs of H-PEMFCs and competing alternatives and the value proposition for fuel cells were evaluated for these near-term opportunities. PEM fuel cells are competitive on a lifecycle cost basis with competing alternatives for backup power and forklift applications in the aforementioned federal markets. For TV broadcast cameras H-PEMFCs are less competitive than the battery alternatives. Furthermore, air travel restrictions on hydrogen limit the opportunity for H-PEMFCs. Findings from the lifecycle cost analysis and the market opportunity analysis for the FAA are presented in the following. Complete assessments of these markets can be found in the reports submitted to the DOE [4,5].

Federal Aviation Administration

Market Description and Requirements. 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. The FAA installs, operates, and maintains facilities that use visual and electronic aids to support air navigation. Critical air traffic control and air navigation systems include voice and data communication equipment, radar facilities, computer systems, and visual display equipment at flight service stations. The impact of power outages can be catastrophic in this market segment, because airplanes depend on the reliability of communications systems to fly and land safely. Airlines can lose up to $3 million for every 15-minute outage at a communication facility [3].

Backup power is provided to these towers through batteries at all sites and generators at remote sites. The FAA has used alternatives including H-PEMFCs. In the near term, fuel cells are best suited to provide extended backup power to technical loads at radio transmit and receive (RTR) sites, remote communications air to ground (RCAG) sites, very high frequency omnidirectional range sites, radio communications link repeater (RCLR) sites, tactical air navigation aid sites, and instrument landing systems.

All sites are configuration managed, i.e., the FAA has standardized power orders that specify the requirements for backup power including types of backup power systems that can be utilized for various applications, installation requirements, and operations and maintenance schedules. The FAA power order requires at least four hours of backup runtime for its various sites and up to 72 hours at certain sites. The FAA is considering extending backup runtime to 72 hours at some remote sites, sites with unreliable grid power, and critical sites.

All respondents surveyed and interviewed appeared to be fairly dissatisfied with batteries and indicated issues with battery lifetime and safety. Respondents identified start-up time and ease of use of batteries as very good; reliability, capital cost, and lifetime were rated less favorably. Respondents appeared to be more satisfied with generators than with batteries. Factors of concern with generators were capital costs and operations and maintenance (O&M) costs. When evaluating alternatives, respondents identified reliability, lifetime, start-up time, fuel availability, and good experience with a system in the past as very important. Respondents were very familiar with H-PEMFCs and believed that they would compete favorably with current technologies such as batteries and generators. None of the respondents believed that hydrogen as a fuel would be a cause for concern. Respondents indicated that hydrogen was safer than propane, which is located at several sites. Factors that would drive the adoption of H-PEMFCs include the cost of not having electricity, dissatisfaction with current backup power systems, lower cost than current backup power solutions, availability of funds, and track record of others using PEMFC systems.

Respondents indicated that several factors influenced capital purchase decisions, including the type of site, needs of the site, reliability of grid power, ease of use, technician satisfaction with technology, and ease of installation and maintenance. Respondents suggested that often it is unreliable commercial power that drives the capital purchase decisions for backup power.

Lifecycle Cost Analysis. Market research suggests that widespread acceptance of H-PEMFCs at the FAA is dependent on reliability and lifecycle cost of the technology compared to batteries. Current research suggests that there is potential for further adoption of H-PEMFCs based on economics and need for extended runtime, reliability, and ease of use. To provide extended backup for the technical load at the various sites, the FAA has installed longer battery strings but is concerned with the capital costs and lifetime of batteries. In a few rare cases, due to the critical need of a site for extended runtime and because users are familiar with larger generators, these systems have been installed despite the lower technical load requirements.

To determine if H-PEMFCs offer value to the various applications in this market segment, the lifecycle costs of H-PEMFCs compared to batteries and generators are examined in three different installation scenarios at an RTR site, an RCLR site, and a RCAG site (Table 1). The lifecycle cost analysis of the battery string assumes both a 3-year and 5-year battery replacement schedule. The diesel generator used in this scenario is sized at 20 kW and is a commercial generator typically used by the FAA for supporting non-technical loads including environmental loads and facility loads; in rare cases, it is used to support technical loads as backup to batteries. H-PEMFCs use batteries as ride-through and are sized at four hours for the RTR site, RCLR site, and RCAG site. These batteries are assumed to be replaced

TABLE 1. Lifecycle Cost Assumptions for Net Present Value Analysis of H-PEMFCs, Batteries, and Generators for Backup Power

Backup Runtime	kW	Fuel Replacement	Battery/ Fuel Cell Replacement	H-PEMFC Comparison	Lifecycle Assumptions
Scenario 1 – Radio Transmit and 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 PEMFC	To battery system (Outdoor Installation)	
Scenario 2 – Radio Communications Link Repeater Site					
24, 48, 72 hours	3	Annually	3- and 5-year Battery 10-year PEMFC	To battery system (Outdoor Installation)	
Scenario 3 – Remote Communications Air to Ground Site					
24, 48, 72 hours	5	Annually	3- and 5-year Battery 10-year PEMFC	To battery system and to generator system (Outdoor Installation)	

every three years. PEMFC stacks are replaced every 10 years at $1,500 per kW.

The lifecycle cost analyses for an expected operating period of 15 years in each scenario show that H-PEMFCs can compete effectively on a total cost basis with batteries in all three site scenarios for 24 hours, 48 hours, and 72 hours of backup runtime for varying capacities less than 5 kW (Tables 2, 3, 4). The lifecycle cost analyses also shows that H-PEMFCs can compete effectively with generators for varying levels of backup runtime. Based on an NPV of total lifecycle costs, H-PEMFCs are competitive with batteries under a 3-year and 5-year battery replacement schedule. In all three site scenarios, H-PEMFCs have significantly lower O&M costs than batteries. For the RTR site (scenario 1) with 600-watt capacity, the NPV of the total capital costs of batteries with 3-year and 5-year replacement for 24 hours and 48 hours of backup runtime and for 5-year replacement for 72 hours of backup runtime are lower than the NPV of the total capital costs of PEMFC systems. Similarly, for the RCLR site (scenario 2), the NPV of the total capital costs of batteries with 5-year replacement for 3 kW capacity for 24 hours of backup runtime are lower that the NPV of the total capital costs of H-PEMFCs. In all other cases, the NPV of the total capital costs of H-PEMFCs are less than that of competing alternatives.

Single-factor sensitivity analysis was performed to show the variability in average annual cost (cash basis) as individual factors varied by +/-10% while all other factors were held constant for the H-PEMFC for backup power at an RCAG site. As shown in Figure 1, fuel cell life has the greatest impact on the annual cost of owning and operating an H-PEMFC backup power system, followed by fuel cell cost, hydrogen cost, and stack life. Thus, improvements in these factors will have the greatest

TABLE 2. Cost Analysis of Backup Power for RTR Site

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

TABLE 3. Cost Analysis of Backup Power for RCLR Site

	24 Hours Backup Runtime			48 Hours Backup Runtime			72 Hours Backup Runtime		
	Battery (3-Year)	Battery (5-Year)	PEMFC	Battery (3-Year)	Battery (5-Year)	PEMFC	Battery (3-Year)	Battery (5-Year)	PEMFC
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

TABLE 4. Cost Analysis of Backup Power for RCAG Site

	24 Hours Backup Runtime			
	Battery (3-Year)	Battery (5-Year)	Generator (20 kW)	PEMFC
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 ($)	113,204	86,852	76,998	56,905
	48 Hours Backup Runtime			
	Battery (3-Year)	Battery (5-Year)	Generator (20 kW)	PEMFC
NPV of Total Capital Costs ($)	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)	PEMFC
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

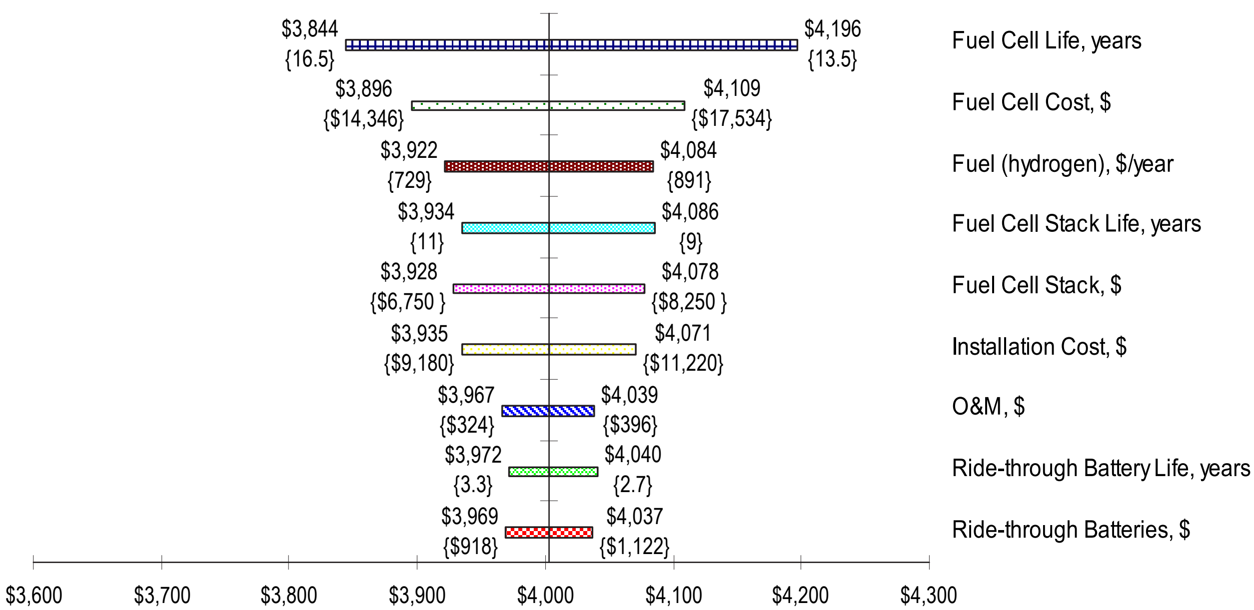

FIGURE 1. Sensitivity Analysis 5 kW H-PEMFC Providing 72 Hours of Backup Power at an RCAG Site

impact on the annual operating cost of the H-PEMFC backup power system.

Market Opportunity Assessment

The FAA appears to be a very promising early market for H-PEMFCs for backup power applications. The primary driver for adoption of alternative power sources by the FAA is increased reliability. O&M costs also were mentioned by key decision makers as an influential driver in the selection of alternative energy sources for FAA systems. Given the large number of radar and communications sites and the highly structured maintenance schedule established to ensure the proper functioning of primary and backup systems, routine maintenance results in a large burden on FAA personnel. General dissatisfaction with existing technologies, including the extensive O&M needs, has caused engineers responsible for site maintenance to evaluate H-PEMFCs as alternatives for backup power. Various user requirements for system size, backup runtime, reliability, lower O&M costs, and ease of use fit well with commercially available PEMFC systems.

H-PEMFCs offer lifecycle cost advantages over batteries for applications requiring less than 5 kW capacities for 24 hours, 48 hours, and 72 hours of backup runtime. H-PEMFCs are competitive on a total cost basis as well as offering significant savings in O&M costs as compared to batteries. In addition to significant cost savings, H-PEMFCs offer many other advantages over batteries for FAA applications. Compared to batteries, H-PEMFCs offer extended backup power, continuous runtime, stable voltage, and lower maintenance requirements. They can be monitored remotely, have longer lifetimes, and are more durable in harsh environments.

The FAA market segment offers a significant niche for PEMFC applications in the near term. Approximately 15,000 towers exist where H-PEMFCs can potentially be used to provide backup power support. To support widespread adoption, a standardized order for the application of H-PEMFCs needs to be developed. To accomplish this, a formal assessment of the reliability of installed H-PEMFCs needs to be performed and a business case that supports the economics of H-PEMFCs against competing alternatives needs to be developed. While anecdotal evidence from the existing installations shows that H-PEMFCs are highly reliable with no failures during outages, gathering statistically valid reliability data will go a long way in formalizing the adoption of H-PEMFCs as standard backup power technology for FAA applications. In addition to reliability and economic data, the availability of funds is a concern for the FAA. Currently, funding decisions are based on priority of a site; for widespread application, alternative sources of funding will be necessary.

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Data Centers

There is a critical need for reliable power and cooling to support high-powered electronic equipment used to store, manage, and process digital data. Data centers provide the infrastructure for critical operations equipment required for an organization's core business applications and operations. Markets particularly sensitive to the economic impact of unscheduled power outages include information technology, finance and banking, insurance, telecommunications, healthcare, retail, and transportation. Market research shows that metropolitan areas including New York, San Francisco, and Dallas are concerned about power consumption, power reliability, and electricity costs. Data centers surveyed show concerns about future power availability and as a result are actively implementing energy efficiency measures including investments in CHP and renewable energy sources. Purchasing decisions for alternative technologies are based on increased uptime offered by the technology as well as return on investment through increased energy efficiency and reduction in electricity costs. Currently available commercial PEMFC systems do not meet the high power and cooling needs of data centers. High-temperature fuel cell systems may have application as a part of a prime power system designed to provide high power availability, cooling, and reliability for these markets located in grid congestion areas with high electricity prices and with technical loads less than few mega watts. The primary drivers for the use of fuel cells in CHP applications include the desire to make data centers more energy efficient, an opportunity to reduce electricity costs, and the desire to reduce environmental impacts of energy production.

Wastewater Treatment Plants

The application of fuel cells to biogas generated by wastewater treatment plants utilizing anaerobic digestion offers an opportunity for turning waste to energy. Biogas can be used to generate on-site heat and electricity while reducing emissions otherwise generated by flaring waste biogas and using purchased power and natural gas. There are approximately 210 wastewater treatment plants with flows equal to or greater than 3 million gallons per day in the United States that do not use their biogas to generate on-site power or heat. Surveys of candidate users show that most users surveyed are considering using their biogas. Capital costs, operation and maintenance costs, and reliability are most important factors in considering on-site power/heat generation by wastewater treatment plants. Government incentives, availability of biogas, and track record of other fuel cell systems were cited as most important drivers for considering a fuel cell. Purchasing decisions are made based primarily on payback period and initial capital costs. Current users of biogas mostly use biogas for cogeneration and for heating digesters. Currently available commercial PEM fuel cell systems are not designed to operate on biogas as a fuel. There are approximately 24 high temperature fuel cells operating on biogas at wastewater treatment plants. Economic data derived from secondary sources shows that high-temperature fuel cells provide payback in about 3 to 8 years at locations with incentives and result in significant savings in terms of energy and emissions avoided from the grid.

Conclusions and Future Directions

H-PEMFCs currently offer value over competing alternatives in several federal markets in the near-term. To achieve widespread market penetration, successful demonstration and application of fuel cell technology to prove reliability of operation in early markets is critical. Financial assistance to support the capital purchase of fuel cells is necessary to support deployment in federal markets. Technical improvements in fuel cell life, fuel cell costs, and hydrogen storage continue to be important in making fuel cells more competitive with existing alternatives.

The future focus of this project will be to complete the evaluation of the market opportunity for fuel cells in other high-value applications like data centers and wastewater treatment markets.

FY 2008 Publications/Presentations

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2. K. Judd. Identification and Characterization of Near-Term Commercial Markets for PEM Fuel Cells in Portable Applications. Small Fuel Cells, Atlanta, GA, April 2008.
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8. K. Mahadevan, J. Sanford, and H. Stone. Interim Report on the Market Opportunity Assessment of PEM Fuel Cell Applications at the Federal Aviation Administration. Contract No. DE-FC36GO13110.

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