V.F.2 Economic and Marketing Analysis of Stationary and Near-term Markets for PEM Fuel Cell Systems

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Objectives

In 2006, objectives of the project were to:

- Prepare an interim report of the economic, technological, and market forces influencing commercialization of polymer electrolyte membrane fuel cell (PEMFC) systems.
- Identify and segment markets and applications for direct hydrogen PEMFC (HPEMFC) to 2015.
- Develop an understanding of user requirements in markets to 2015.
- With input from industry and the Department of Energy (DOE) on market selection criteria, identify promising near-term (2008) markets for HPFC.
- Analyze and compare performance and lifecycle cost of existing HPFCs and competing technologies in near-term applications.
- Develop value propositions and complete a market opportunity analysis for HPFCs in three near-term (2008) markets.

Technical Barriers

This project focuses on understanding the relationship between market-specific user requirements, current fuel cell performance and cost, and the technical barriers from the Fuel Cells section (3.4.4.2) of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan. Key barriers to market adoption are:

(A) Durability

(B) Cost

Technical Targets

This project is gathering user-requirement data from near-term (2008) markets; gathering current fuel cell cost and performance data for comparison to those user requirements; and, based on current fuel cell adequacy to meet user requirements, projecting market penetration and corresponding annual production volume likely to be achieved in near-term markets. It is anticipated that analysis provided by this project will inform DOE's planning of technical targets for various HPFC applications.

Accomplishments

- Completed interim report on the economic, technical, and market forces influencing the commercialization of polymer electrolyte fuel cell systems in the 1-250 kW range in stationary applications.
- Completed identification and segmentation of markets for HPFCs to 2015.
- Developed and vetted criteria for selecting near-term markets (to 2008) with DOE and industry.
- Received 130 completed surveys in the exploratory research of markets. These included 106 candidate users and integrators of HPFCs in transition market segments; 17 fuel cell industry members (surveyed with support from the U.S. Fuel Cell Council); and seven venture capital firms. In addition, interviews were conducted with over 50 candidate users and industry experts.
- Developed electricity generation modules for H2A model enabling cost comparisons between fuel cells and alternative electricity generation using H2A infrastructure.

Introduction

At the outset of this project, Battelle was directed to focus on developing an understanding of the economic, technological, and market forces influencing commercialization of polymer electrolyte membrane fuel cell (PEMFC) systems in the 1-250 kW size range in stationary applications.

In 2006, DOE shifted Battelle's efforts in order to focus on the goal of introducing automotive fuel cells by 2015. Battelle's revised scope was to identify and analyze near-term market opportunities for HPFCs in the 1-250 kW size range in pre-automotive applications. Priority markets for HPFCs include applications using conditions analogous to automotive operating conditions, e.g., specialty vehicle applications, or early adopter markets, e.g., backup power applications, where success could support early automotive markets.

Battelle is providing an assessment of early market opportunities for HPFCs and an analysis of the technical, economic, and market drivers for HPFC adoption in three near-term (2008) markets. Analysis of early markets will provide insights into the requirements for product development, application, and end user acceptance.

Approach

To guide the study, Battelle is utilizing a framework integrating market, economic, and technology analysis. Figure 1 provides the methodology used to identify near-term market opportunities for HPFCs. A marketing research plan was developed to identify the specific research questions, data acquisitions, and data quality guidelines. Data is 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 research includes review of published reports, peer reviewed journal articles, magazine articles, and market research reports. Primary research includes surveys, interviews, and focus groups of current and candidate users, manufacturers, suppliers, and integrators of PEMFC.

The marketing analysis determines (1) the most promising near-term applications and market segments to 2008, (2) the technical targets (user requirements) to enter specific markets, (3) performance of current technologies and user satisfaction, and (4) cost and quality of commercially-available HPFC products. The economic analysis evaluates (1) the lifecycle cost of using HPFCs as compared to other alternative technologies, (2) the value proposition for HPFCs, and (3) the market penetration of HPFC under various scenarios. A marketing database of information gathered from candidate users and integrators in various early markets has been developed and is expected to be made accessible by DOE to stakeholders.

To ensure consistency of the lifecycle analysis with the DOE H2A model, modules have been developed for the H2A model that will use much of the model's existing structure and algorithms to calculate the production and cost of electricity (rather than the cost of hydrogen). The H2A electricity production model will enable hydrogen to be used as a fuel for analysis of direct hydrogen fuel cells (or other direct hydrogen

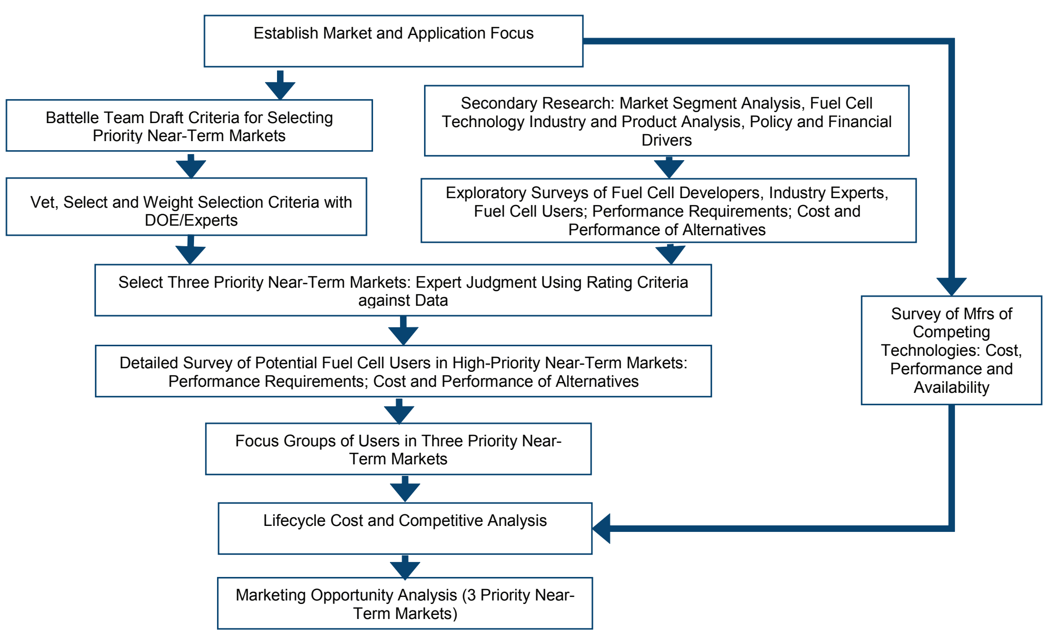

FIGURE 1. Battelle Methodology for Transition Market Analysis

generator systems). The electricity production modules are expected to be made available to stakeholders by DOE along with the existing H2A model.

Results

During the first half of the fiscal year, the interim report on the economic analysis of stationary applications for PEMFC in the 1-250 kW size range was completed under the initial scope of work. The cost analysis of the 5 kW and 50 kW system, as well as user requirements for new technologies in the telecommunications, hotel, and financial sector 5 was reported in the 2005 summary, and will not be repeated here. Presented here are the results from the lifecycle cost analysis for backup power (under the initial scope) and progress to date on analysis of near-term market opportunities for HPFCs (under the revised scope initiated in February 2006).

Lifecycle Cost Analysis in Telecommunications Applications

Net present value (NPV) of the cost of using a 5 kW HPFC was compared to cost of using batteries and, as needed, rental of a diesel generator, for remote backup applications in telecommunications. Key assumptions for the fuel cell are shown in Table 1. The key assumptions for the battery/diesel generator system are shown in Table 2. The cost assumptions reflect the 2005 conditions. The fuel cell cost to the user is assumed to be $15,000 ($3,000/kW) and batteries were assumed to cost the user $7,200. Assumptions for battery backup costs were estimates provided by Verizon or calculated by Battelle (1). At a 15 year fuel cell life (durability), shown in Table 3, batteries require more cash and yield a slightly higher cost measured as net present value (10% discount rate) over a 20 year period. Further, in

TABLE 1. Key Assumptions of the Lifecycle Analysis of the 5 kW Direct Hydrogen Backup Power System

5 kW Lifecycle Descriptor	Base Lifecycle Analysis Assumptions
Fuel Cell, $	15,000 (3,000/kW)
Installation, $	7,000
Residual Value of Fuel Cell at Close of Year 20, $	10,000
Annual Operation and Maintenance Cost (net of fuel), $	100
Annual Usage, kWh	20
Life of Fuel Cell, years	15
Ride-through Battery Life, years	5
Ride-through Battery Cost, $	400
Battery Disposal	50
Hydrogen Shelf Life, years	3
Hydrogen Cost (K Cylinder), $	38
Number of K Cylinders	7 (~9 hours at 5 kW)
Annual Tank Rental, $	21.90
Tank Delivery/Hazmat Charge, $	19.5
Discount Rate, %	10

TABLE 2. Additional Assumptions Used to Determine the Net Present Value of Batteries and Generators for Backup Power Applications

Battery/Diesel Generator Descriptor	Assumptions
Batteries, $	7,200
Installation, $	3,000
Residual Value of Batteries at Close of Year 20, $	0
Life of Batteries, years	5
Battery Charger, $	100
Charger Electric, $	84
Load Transfer Equipment, $	100
Disposal, $	100
Generator Rental, $	440
Annual Operation and Maintenance Cost, $	695

TABLE 3. Twenty-Year Lifecycle Cost Analysis Comparing 5 kW Fuel Cell Systems To Battery Systems for Backup Power Applications[a]

5 kW Fuel Cell vs. Battery Backup Power	Fuel Cell Total Cost $	Battery Total Cost $
Fuel Cell	30,000	
Installation	7,000	3,000
Fuel	1,999	0
Charger, Load Transformer and Electricity	0	2,080
Generator	0	8,800
Demurrage	3,066	0
Batteries	1,600	28,800
Disposal	100	400
Operations and Maintenance	2,000	13,900
Cash	45,765	56,980
Residual Value of System[b]	10,000	0
Net Present Value (NPV)	$25,718	$28,172

[a] Tax impacts are not included.
[b] At the end of twenty years, the fuel cell has ten years of useful life remaining; new batteries are needed.

regions where battery life is less than 5 years because of environmental conditions, fuel cells will provide a relatively more attractive net present value when compared to batteries.

Near-term Market Analysis

Using the benefit segmentation method (2), a complete segmentation of specialty vehicle and backup power markets to 2015 was performed (Table 4). Over 36 market segments were identified in the government and private sector as potential adopters of HPFC for backup power based on their need for reliable backup power, lower emissions, longer run-times, and/or ease of use. Information on market size, potential for growth, types and duration of outages, impacts from downtime, backup power systems used, operation and maintenance requirements, user requirements, user satisfaction with current technologies, and user perceptions of PFCs was gathered by surveying candidate users and integrators. To identify near-term (2008) markets for HPFC for further analysis, selection criteria were developed with inputs from DOE and industry. The selection criteria were applied to the data gathered and market segments best meeting the criteria were selected for further analysis. The selected applications include power generation for forklifts, airport tugs, and telecommunications. Because the telecommunications market sector was analyzed in fiscal year 2005, Battelle selected the next segment meeting the criteria, the emergency response segment (public sector) for further analysis. For airport tugs and forklifts, initial analysis suggests that HPFC could offer longer run-times than batteries, thus increasing productivity and reducing operation and maintenance costs. Users in these markets identified reliability, durability, fuel availability, and ease of use as most important factors in selecting alternatives to their current mode of operation (Table 5).

Conclusions and Future Directions

This first interim report includes a market analysis of the potential early adopters of stationary PEMFC, the development of economic models to predict the cost breakdown of a fuel cell system and the associated lifecycle costs for two specific applications, and the development of a methodology for assessing the relative impact of technology innovations and breakthroughs on reducing the costs of PEMFC systems. Key conclusions from the interim report are:

- Penetration of early adopter markets in the near term is critical to demonstrate performance and build consumer confidence in the technology.
- Most early adopter markets will be for backup power with the value proposition focused on reliability of the PEMFC; convincing reliability results from the field are needed.
- For PEMFC to move into stationary baseload applications, progress in the following areas is necessary:
  - Lower installed cost
  - Lifecycle costs competitive with generated electricity for baseload applications
  - Adequate durability for baseload applications (40,000 hours)
  - Successful field demonstrations of reliability, durability, and maintenance and operating costs
  - Availability of hydrogen infrastructure

TABLE 4. Transition Market Segments Analyzed

Backup Power			Specialty Vehicles
Private Markets		Government Markets	
Telecom	Water and Wastewater Treatment	Federal Agencies NASA NRC DOT DOD DHS NOAA DOE EPA GSA	Forklifts
Finance	Chemical Manufacturing		Automatic Guide Vehicles
Data Centers	Oil and Gas – Refineries		Mining Vehicles
Pharmaceuticals	Chemical Manufacturing		Tow Tractors
Healthcare	Metals Processing and Refining		Golf Carts
Grocery Stores	Computer and Electronic Products		Turf Maintenance Vehicles
Casinos	Transportation Manufacturing		Commercial Sweepers
Hotels	Utility Substations		Ice Resurfacers
Amusement Parks	Mining		Wheelchairs
Ski Parks	Airports	State Emergency Response	Motorized Bicycles/Scooters
Railways		National Parks	Unmanned Undersea Vehicles
			Unmanned Aerial Vehicles

TABLE 5. Analysis of Airport Tugs and Forklift Market Requirements

Requirements or Concerns	Airport Tugs	Forklifts
Current Mode of Operation	Electric and ICE systems	Electric and ICE systems
Maintenance Requirements	Every 150-200 hours	Every 200-250 hours
Most Important Factors for Selecting Power System	Reliability, lifetime of unit, annual operating cost, and ease of use	Reliability, lifetime of unit, fuel availability, capital cost
Performance of Current Technologies	ICE – good Batteries – very good	ICE – good Batteries – not so good
Concerns about Current Technologies	ICE – hazardous emissions Batteries – Spills and leaks; too long to refuel and recharge; inconvenient to recharge; unsafe	ICE – hazardous emissions Batteries Inconvenient to recharge; causes leaks and spills; takes to long for charging, cooling, and equalizing the batteries
Satisfaction with Current Technology	High levels of satisfaction exist for both ICE and batteries: reliability, start-up time, time between refueling, ease of use, and fuel availability; capital cost, operation and maintenance costs, and lifetime Improvement desired in costs and lifetime of system	High levels of satisfaction exist for both ICE and batteries: reliability, capital cost, lifetime, ease of use, and fuel availability, operation and maintenance costs, start-up time, time between refueling Improvement desired in costs, startup time, and run time after refueling/recharging
Have Alternatives been Considered?	Yes – including fuel cells in some cases	Yes – including fuel cells in some cases
Decision Drivers to Purchase PEM Fuel Cells	Environmental concerns, government incentives, cost incurred from downtime, dissatisfaction with current mode of operation, PEMFC track record, PEMFC efficiency	Cost incurred from downtime, efficiency of PEM fuel cells, environmental concerns, availability of government incentives, PEMFC track record, PEMFC efficiency
Key Decision Factor for Capital Purchases	Return on investment	Return on investment
Importance of Government Incentives in Purchasing	An important decision-making factor	Not a key decision-making factor

- Increasing durability is most important for lowering lifecycle costs of PEMFC.
- Power density and catalyst cost are the major drivers of stack costs at high volume.
- PEMFC efficiency is important for reducing the lifecycle costs of baseload systems; for backup systems efficiency has little or no competitive importance.

The near-term opportunities for PEMFC will be in the specialty vehicle markets and those backup markets that require reliable power to prevent high-cost or high consequence outages, such as communications. To bring this task to completion in fiscal year 2006, our next steps will include (1) completion of competitive analysis including lifecycle cost and performance of HPFCs and alternatives, (2) analysis of the value propositions in three near-term markets, and (3) analysis of market penetration rates using innovation diffusion models for HPFC in three near-term markets. Future work will be based on EERE requirements and 2006 findings.

FY 2006 Publications/Presentations

1. Stone, H.J. 2006. Market Opportunity Assessment for Direct Hydrogen PEM Fuel Cells in Transition Markets, *2006 Annual Program Review Proceedings*. The US DOE Hydrogen, Fuel Cells & Infrastructure Technologies 2006 Annual Program Review Meeting, Crystal City, VA, May 16-19, 2006.

2. Stone, Harry J. and Kathya Mahadevan. 2006. Market Opportunity Assessment for Direct Hydrogen PEM Fuel Cells in Transition Markets. The US Fuel Cell Council, Crystal City, VA, May 16, 2006.

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1. Personal communication between Harry Stone and Marty Ross, Verizon Communication April 2004.

2. Cooper, R. 2001. *Winning at New Products*. Perseus Publishing, Cambridge, Massachusetts.