Identification and Characterization of Near-Term Direct Hydrogen Proton Exchange Membrane Fuel Cell Markets

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1.0 INTRODUCTION

The U.S. Department of Energy (DOE)[1] is working on the development of direct hydrogen proton exchange membrane (PEM, also referred to as polymer electrolyte membrane) fuel cell vehicles. The DOE realizes that the pathway to direct hydrogen PEM fuel cells (hereafter referred to as PEM fuel cells) in vehicles will likely include the introduction of PEM fuel cells in near-term markets with fewer technical challenges than automobiles. The DOE also 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 (R&D) required for technological advancements in automotive applications, and to sustain the interest of investors in their companies. In order to facilitate growth of the PEM fuel cell industry, build a supplier base for future automotive markets, and develop robust products, the DOE is focused on identifying near-term market opportunities for PEM fuel cells in pre-automotive applications.

The DOE commissioned Battelle to identify likely near-term pre-automotive markets for PEM fuel cells in the 1 kilowatt (kW) to 250 kW range.[2] Near-term pre-automotive markets will be those segments in which PEM fuel cells can be demonstrated successfully by 2008 in the United States. However, Department of Defense (DoD) applications for PEM fuel cells were excluded from the scope of work.

The research presented in this report identifies and characterizes near-term and mid-term markets in which PEM fuel cells can be successful. This report also assesses the market opportunity for PEM fuel cells in three near-term pre-automotive markets, including state and local emergency response agencies, forklifts in warehousing and distribution centers, and airport ground support equipment markets. Specific goals of this project were to:

- Identify and segment markets and applications for 1 to 250 kW PEM fuel cells in the near-term (2008) and mid-term (2012)
- Develop an understanding of technology and market factors, including user requirements, that will drive the adoption of PEM fuel cells in these markets and applications to 2015
- Determine the cost and quality of PEM fuel cell products that will be commercially available by 2008
- Modify the DOE's hydrogen analysis model (H2A model) to allow lifecycle cost analysis of electricity production from PEM fuel cells and competing electricity generation technologies
- Analyze and compare performance and lifecycle cost of existing PEM fuel cells and competing technologies in three near-term markets
- Estimate rates of market penetration in the three near-term markets.

This report is organized into four sections: Section 1.0 provides information on the scope of work and the methodology adopted; Section 2.0 analyzes trends from market research data in pre-automotive markets and applications to 2015; Section 3.0 analyzes the market opportunity

[1] The DOE in this report refers to the Department of Energy, Office of Energy Efficiency and Renewable Energy, Hydrogen Fuel Cells and Infrastructure Technologies Program.

[2] The scope of the study was limited to direct hydrogen PEM fuel cells to support the identification of transitional markets for direct hydrogen PEM fuel cells in automotive applications. The absence of information on direct methanol fuel cells and reformer based PEM fuel cells and applications in this study should not be interpreted in any way as an implied statement about those markets. Rather, DOE focused the scope based on assumptions about the pathway to the long-term objective of a successful PEM fuel cell automotive industry.

for PEM fuel cell in three near-term markets, and Section 4.0 presents a project summary and conclusions.

1.1 Marketing Research Design

Battelle's research approach, outlined in Figure 1-1, uses a two-phase exploratory research process, supplemented by modeling of lifecycle costs of PEM fuel cells and competing technologies, in order to identify those markets in which PEM fuel cells offer value and better performance in areas that are valued most by the market.

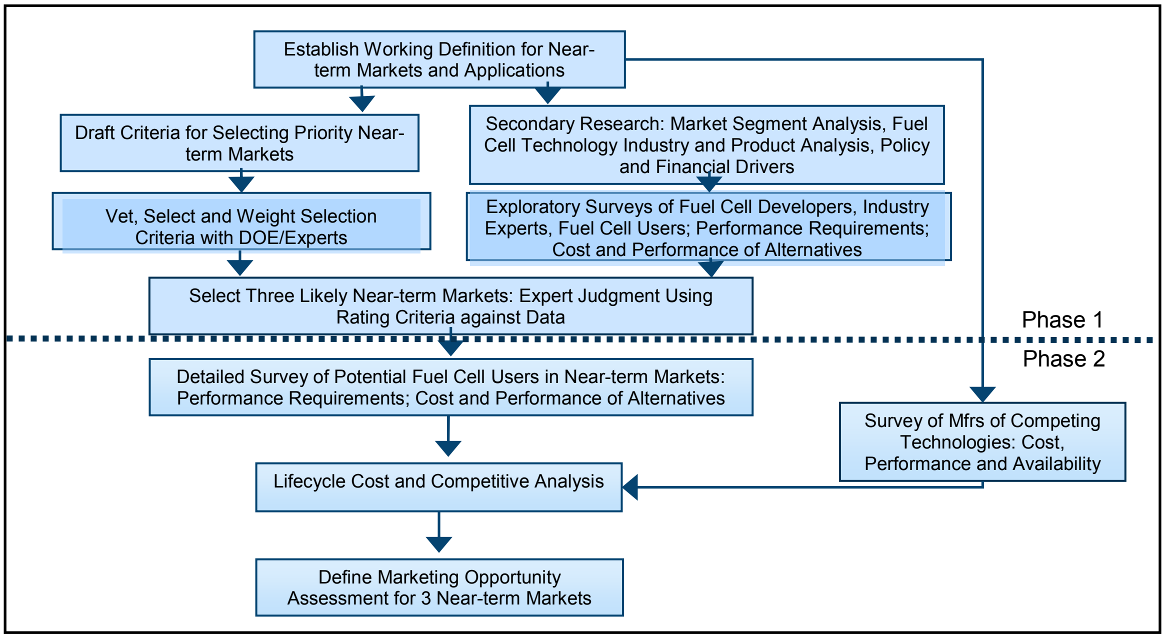

Figure 1-1. Battelle Marketing Research Approach.

1.1.1 Phase 1 Research

In the first phase, secondary research and exploratory primary research were used to establish a working definition of pre-automotive applications and markets. The definition and the approach to identifying near-term markets were discussed with the DOE. This phase resulted in broad guidance as to which applications would be evaluated to determine the potential for PEM fuel cells. Secondary research and primary research, including surveys and interviews, were used to profile and characterize the pre-automotive market segments. A total of 36 pre-automotive market segments were identified for further evaluation in backup power and specialty vehicle applications.

To prioritize near-term opportunities for PEM fuel cells, the following rating criteria were developed with input from DOE and industry. These rating criteria were applied to the findings from Phase 1 research on the 36 market segments to identify and select three markets for detailed analysis. Primary criteria were:

- PEM fuel cells offer unique value to market segment not met by competing technologies
- The product characteristics and potential benefits of PEM fuel cell product characteristics and their potential benefits fit user requirements (high priority needs)

- Market size and growth potential of the market segment are sufficient to ensure 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 will be available over the short-term.

1.1.2 Phase 2 Research

The second phase of research involved detailed analyses to determine the value proposition of PEM fuel cells in the three near-term markets including state and local departments of emergency response, forklifts in warehousing and distribution centers, and ground support equipment at airports. Analyses included an identification of user requirements for PEM fuel cells, a comparison of the lifecycle costs of PEM fuel cells against competing alternatives, and a determination of market penetration for PEM fuel cells.

Market research was utilized to develop user requirements for PEM fuel cells in the three near-term markets. Secondary sources, surveys, and follow-up telephone interviews were used to assess the ability of PEM fuel cells to meet market requirements by 2008.

A comparative lifecycle cost analysis was performed by modifying the H2A model[3] to compare cash flow and net present value (NPV) of costs using PEM fuel cells and current competing technologies. Cost data for PEM fuel cells and competing technologies collected through secondary and primary research were used to populate the modified H2A model in order to analyze lifecycle costs in the three near-term market segments.

Innovation diffusion models were used to estimate the rate of market penetration over time under alternative assumptions of government interventions. The Bass mixed-influence innovation diffusion model is the most widely used theoretical model in marketing today.[4] The Bass model was used to forecast market adoption rates based on factors such as the strength of government subsidies, mass communications (e.g., government documents, face-to-face discussions regarding experiences with a technology), and various degrees of government intervention.

1.2 Methodology

1.2.1 Secondary Research

Peer reviewed journal articles, magazine articles, and market research reports were reviewed to support market data collection. Findings from Battelle's previous work were also used to inform this analysis.[5]

To guide the definition of near-term and mid-term market segments and applications on the pathway to automotive PEM fuel cell markets, information was reviewed to identify:

- Potential near-term applications and markets for direct hydrogen PEM fuel cells
- Availability, cost, and performance of direct hydrogen PEM fuel cell products

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[3] DOE H2A Production Analysis. Available at http://www.hydrogen.energy.gov/h2a_production.html [Accessed September 2006].
[4] Rogers, E. M. 2003. Diffusion of Innovations. New York, Free Press.
[5] Battelle. 2006. Economics of Stationary PEM Fuel Cell Systems. For the Department of Energy, DOE Contract No. DE-FC36-03GO13110.

- Financial performance and general trends in the fuel cell industry
- Investment trends in hydrogen and PEM fuel cell technology
- Current and planned demonstration of direct hydrogen PEM fuel cell products
- Policy drivers for hydrogen and fuel cell technologies
- Institutional and market barriers to adoption of PEM fuel cells in the near-term.

Once these market segments were identified, secondary research was conducted to help assess:
- Specific uses for direct hydrogen PEM fuel cells within market segments
- Market segments that may be early adopters of direct hydrogen PEM fuel cells and the value proposition that would lead to early adoption
- Cost and performance requirements for PEM fuel cells in each market segment
- Companies with products into which direct hydrogen PEM fuel cells can be readily integrated
- Key drivers for the adoption of hydrogen PEM fuel cells
- Size of the market segment and growth potential.

A literature review was conducted to collect data required for a competitive analysis of PEM fuel cells and alternative technologies. Specifically, this information was used to identify:
- Characteristics of competing technologies
- Advantages and disadvantages of competing technologies
- Current and projected market applications and segments for competing technologies
- Performance of competing technologies
- Capital cost, cost of operation and maintenance, and salvage value or disposal costs for competing technologies
- Current and projected market share for competing technologies
- User satisfaction with competing technologies
- Potential technology improvements and other changes in competing technology industries
- Key drivers for competing technology adoption.

1.2.2 Surveys and Interviews

The primary research data necessary to identify PEM fuel cell markets likely to develop by 2015 and to further identify near-term markets with a high likelihood of commercial success were obtained through exploratory interviews and/or surveys with Battelle and Pacific Northwest National Laboratory (PNNL) subject matter experts, fuel cell technology developers, venture capital investors, current and/or candidate fuel cells users, and current and/or candidate specialty vehicle manufacturers (thought to be potential integrators of PEM fuel cells in their systems). A judgment sample[6] was selected from each of the aforementioned categories and interviewed.

Users were identified through internet research and review of industry databases like Hoovers and Dun and Bradstreet. Fuel cell developers, venture capital investors, and specialty vehicle manufacturers were identified from information in industry publications, market research reports,

[6] A judgment sample is a non-probability sample that is often called a purposive sample because the sample elements are handpicked to serve the research purpose.

and internet research. PEM fuel cell manufacturers and component developers were surveyed through the U.S. Fuel Cell Council.

For each market identified, current and/or candidate fuel cell technology integrators and current and/or candidate users were contacted to gather data on applications for PEM fuel cells, the current mode of use, satisfaction with current mode of use, and interest in alternatives. The exploratory research and analysis in the first phase was primarily qualitative.

A survey instrument was developed to elicit information from users in the specific market segments. Separate surveys were prepared for each application researched. The questions were developed by Battelle staff experienced with survey design and primary research methods. All surveys were pre-tested, after which refinements were made. The survey instruments used can be found in Appendix A.

A consistent approach was developed and followed for surveys and interviews. Persons implementing primary data collection were trained in using the survey instrument and interview protocol. Preliminary contact was established via an introductory telephone call and/or e-mail with details of the project and the requested information. Participants were provided with three options for response, including e-mail, fax, or telephone. If the questions were out of the respondent's scope of work, contact information for an alternate and more suitable candidate within the same organization was requested. If the respondent was knowledgeable about industry trends, in some cases short interviews were conducted to gather general trend information. If certain questions were left unanswered or incomplete, short follow-up calls and/or e-mails were used to attempt to fill the data gaps.

Precise notes were taken during telephone calls. Information received through the exploratory surveys via e-mail, fax, and telephone was input into an Access database by the persons implementing the survey. Quality assurance was conducted by a designated staff person. The staff person reviewed 10% of the completed forms against the data input into the Access database. The opportunity for response bias was minimized by limiting the number of open-ended questions subject to recording error from interviewer interpretation.

Specific data collected during the first phase is described below.

Battelle and PNNL Experts

Battelle and PNNL staff members with fuel cell experience were interviewed to identify:

- Likely PEM fuel cell markets to 2015 and likely near-term markets by 2008
- Market barriers to adoption of PEM fuel cells
- Potential early adopters of PEM fuel cells
- Strategies that DOE may employ to facilitate the critical market pathway to automotive hydrogen fuel cells.

Fuel Cell Manufacturers and Component Developers

Fuel cell technology manufacturers and component developers were contacted for input on:

- Current and projected status of commercially available PEM fuel cell technology
- Current and projected cost and performance of PEM fuel cell technology
- Near-term and mid-term markets of interest to PEM fuel cell companies

- Current and planned demonstrations for PEM fuel cells
- Strategies that DOE may employ to facilitate the critical market pathway to automotive hydrogen fuel cells.

Venture Capital Investors

Venture capital firms with energy technology portfolios participated in telephone interviews to help assess:

- Current status of the fuel cell industry and PEM fuel cell products
- Level of interest in PEM fuel cell technology
- Key areas of government support
- Requirements for successful commercialization.

Current and/or Candidate Fuel Cell Users

For the 36 market segments identified, users were contacted for information on:

- Classification data for respondents (industry, size, related SIC code)
- Frequency and impact of power system failure related to potential PEM fuel cell applications
- Specific potential uses for PEM fuel cells within the market segment
- Size (kW) and type of power system currently in use in potential PEM fuel cell applications
- Perceptions of cost of purchase, operation, maintenance, ease of use, and expected life of current systems
- Frequency of procurement of current systems
- Level and causes of dissatisfaction with current or alternative systems
- Awareness of PEM fuel cells
- Attitude toward PEM fuel cells
- Factors that would drive adoption of PEM fuel cells in the target applications.

Current and/or Candidate Fuel Cell Integrators

Specialty vehicle manufacturers were surveyed or interviewed in each specialty vehicle market to identify:

- Potential applications and markets for PEM fuel cells
- Technical requirements for integration of PEM fuel cells
- Typical operational requirements of end-user markets
- Value proposition of PEM fuel cells as a source of continuous power
- Potential barriers to the adoption of PEM fuel cells.

In Phase 2, primary data were obtained from current and/or candidate fuel cell users in the three near-term markets through surveys and interviews. The survey instrument used for the exploratory research was modified slightly to incorporate questions required to support the comparative economic analysis. The survey was pre-tested and refined. Questions in the survey were designed to elicit qualitative and quantitative information. The survey instruments can be found in Appendix A. All data obtained through surveys and interviews from both phases were input to an Access database to facilitate analysis and presentation of results. Specific data that were collected for each of the three near-term markets are:

- Frequency and duration of power outages
- Priority applications for PEM fuel cells

- Equipment used, its characteristics (e.g., power output) and specific operating conditions (e.g., hours of operation per day/quarter)
- Key factors driving the adoption of new energy technologies, including durability, lifetime, capital cost, operation and maintenance cost, emissions, and typical operating conditions of new energy technologies
- User perceptions regarding use of hydrogen
- Cost and performance of current mode of operation
- Factors driving the adoption of direct hydrogen PEM fuel cell technology in the target market segment
- Capital equipment financing and decision approaches
- Other information to inform development of strategies to facilitate PEM fuel cell technology adoption.

1.2.3 Market Research Data Analysis

Responses from current and/or candidate fuel cell users provided data that enabled development of detailed descriptions of each market segment and differences among market segments and behaviors of users in various markets. The data were input to an Access database that enabled the data to be queried.

Within the backup power market segments, data were tabulated or cross-tabulated based on the type of business to identify:

- How is backup power provided?
- What is the size of backup power systems?
- What are the durations and impacts of these outages?
- How disruptive are power outages?
- What is the number of backup power units per facility and across facilities, and what are potential opportunities for future procurement of new systems?
- How satisfied are organizations with their backup power technologies?
- What are the specific concerns regarding backup power systems?
- What are the most critical factors for selecting a backup power system?
- What are the perceptions of PEM fuel cells as backup power and the use of hydrogen as a fuel source?
- What factors would drive the adoption of PEM fuel cells?
- How are capital purchase decisions made? Are those not concerned with capital cost more concerned with return on investment, payback period, or other factors?

Across backup power market segments, data were cross-tabulated to identify:

- For each market segment, what are the frequency, duration, and impacts of power outages?
- What factors are considered by each market segment when purchasing backup power systems?
- Do certain market segments show larger market size and higher growth potential for backup power systems?
- Are certain market segments more familiar with PEM fuel cells than others?
- What factors are considered by each market segment when purchasing PEM fuel cells?
- Do market segments differ in capital purchase decision-making?

- Are certain market segments more concerned about incentives when making purchasing decisions?

Within specialty vehicle market segments, data were tabulated and cross-tabulated to identify the following:

- How is power for the specialty vehicles provided?
- What is the size of power systems?
- How often does the current power system fail to operate?
- What is the lifespan of the current power system?
- How much maintenance (frequency and duration) is required for the power system?
- How satisfied are organizations with their power technologies?
- If dissatisfied, what are the specific concerns regarding power systems?
- What are the most critical factors for selecting a power system?
- What are the perceptions of PEM fuel cells as a power system for specialty vehicles and the use of hydrogen as a fuel source?
- What factors would drive the adoption of PEM fuel cells as a power system for specialty vehicles?
- How are capital purchase decisions made? Other than capital costs, are capital decisions concerned with return on investment, payback period, or other factors?
- How would incentives impact the decision to adopt PEM fuel cells?

Across specialty vehicle market segments, data were cross-tabulated to identify the following:

- For each market segment, what is the level of dissatisfaction with current power systems for specialty vehicles?
- For each market segment, what factors drive the selection of power systems for specialty vehicles?
- Do certain market segments show larger market size and higher growth potential for PEM fuel cell systems?
- Are certain market segments more familiar with PEM fuel cells than others?
- For each market segment, what factors would influence the purchase of PEM fuel cells for specialty vehicle applications?
- How are capital purchase decisions made in each market?
- Are certain market segments more concerned about incentives when making purchasing decisions?

1.2.4 Lifecycle Cost Analysis

Secondary and primary research was used to populate the modified H2A model. The modified H2A model shows explicit assumptions, allows comparison of the costs to own and operate the alternate energy systems, and provides sensitivity analysis to various assumptions. The financial input screen to the H2A model is presented in Figure 1-2 as an example. Current PEM fuel cell costs and current costs of competing energy generation or storage technologies were used in the lifecycle analysis.

Through surveys and interviews with PEM fuel cell manufacturers, fuel cell installation engineering companies, and hydrogen suppliers, PEM fuel cell system costs, installation costs, hydrogen fuel costs, salvage value, and other operation and maintenance costs were gathered.

Secondary research was performed to gather information on characteristics, applications, benefits, and growth of electricity generation and storage technologies that will compete with PEM fuel cells in the selected near-term markets. Short surveys were implemented with manufacturers to gather quantitative information on the performance and cost of competing technologies. Information gathered by Battelle for batteries and generators in fiscal year 2005 was reviewed for completeness and updated as necessary through contact with manufacturers and technology developers.

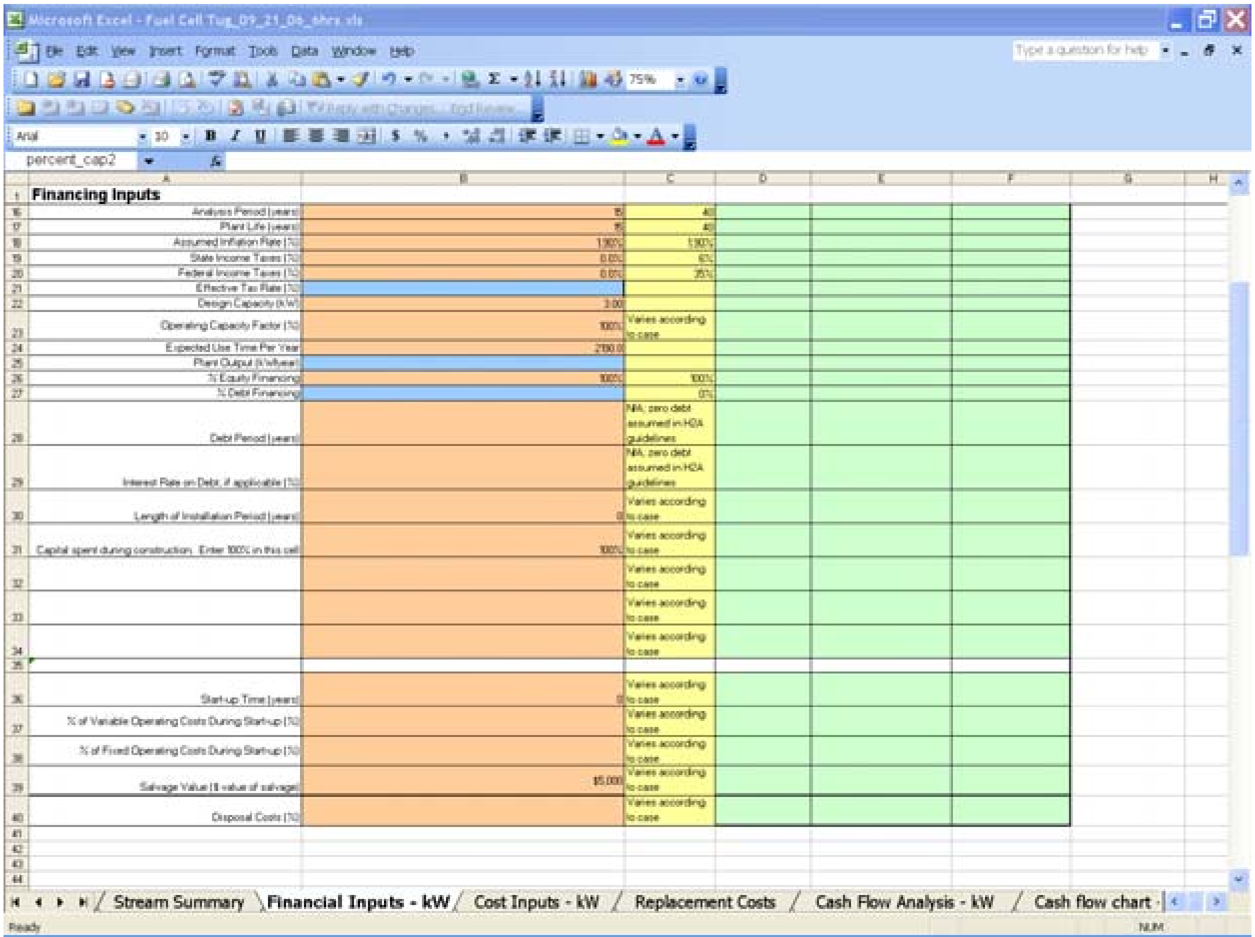

Figure 1-2. Financial Input Screen to the Modified H2A Model.

1.2.5 Market Adoption Modeling

For the three near-term market segments selected in the previous tasks, market adoption rates were estimated using a Bass innovation diffusion modeling approach.[7] The Bass innovation diffusion model is a three-parameter model for calculating the number of new adopters at a given time, *t,* and cumulative adoptions (X).[8] The parameters include the total potential adopters, m; a coefficient of innovation, p; and a coefficient of imitation, q. The parameter m is an estimate of the number of potential adopters at a given point in time. The parameter p reflects innovators that make their initial purchase without influence from the number of others who have

7 Bass, F. M. 1969. A New Product Growth for Model Consumer Durables. Management Science 15(5): 215-227.
8 Rogers, E. M. 2003. Diffusion of Innovations. New York, Free Press.

purchased. Innovators are important early in a product lifecycle, but their importance diminishes with time. Figure 1-3 shows the innovators in comparison with other early adopters of technology. The buying decisions of innovators are informed by sources external to the industry networks. The parameter *q* reflects purchases by other categories of adopters that rely on communications within their industry networks to inform their purchase decisions.

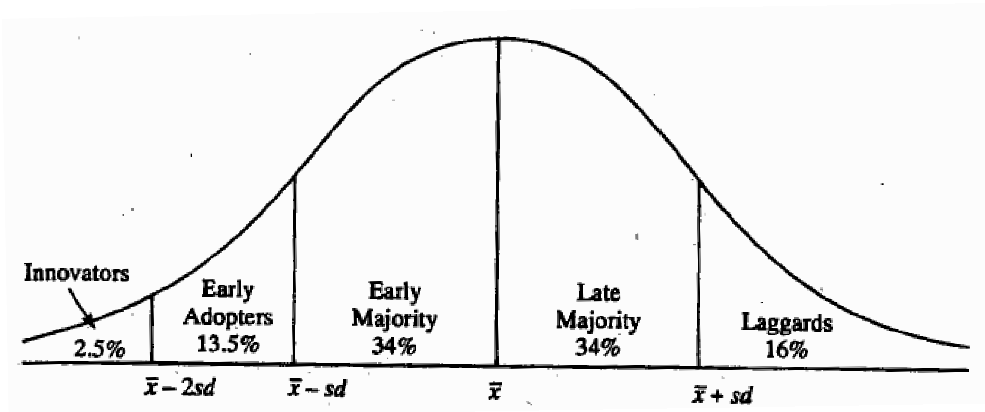

Figure 1-3. Adopter Categories Reflecting Time of Adoptions where $\bar{x}$ is the Mean Time of Adoption and SD is the Standard Deviation.[9]

The basic formula of the Bass model is[10]:

$$x(t) = p + q[(X(t-1)/m][m - X(t-1)]$$

As shown in Figure 1-4, the number of incremental (new) adopters is normally distributed over time, generating a bell-shaped curve. The number of cumulative adopters generates a logistic (S-shaped) curve.

The Bass innovation diffusion model has been demonstrated successfully to forecast product sales corresponding to empirical results. Where historical data are lacking, parameters can be estimated by using the history of analogous products and expert judgments.[11] It is recommended that environmental context, buyer behavior, market structure, marketing mix strategies, and product characteristics be considered in the selection of analogies.[12]

The approach used here combines the selection of analogies with a subsequent revision of parameters based on expert judgment. The initial analogies will consider the factors recommended by Thomas based on the survey findings.[13] Factors considered include, for example, how much relative advantage PEM fuel cell products provide compared to competing

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[9] Rogers, E. M. 2003. Diffusion of Innovations. New York, Free Press.
[10] Lilien, G., A. Rangaswamy, and C.V.D. Bulte. 2000. Diffusion Models: Managerial Applications and Software in New Product Diffusion Models. International Series in Quantitative Marketing, 9. Kluwer Academic Publishers, p. 295-336.
[11] Mahajan, V. and R. A. Peterson. 1985. Models for Innovation Diffusion. Newbury Park, CA, Sage Publications.
[12] Thomas, R. J. 1985. Estimating Market Growth for New Products: an Analogical Diffusion Models Approach. Journal of Product Innovation Management 2: 35-47.
[13] Thomas, R. J. 1985. Estimating Market Growth for New Products: an Analogical Diffusion Models Approach. Journal of Product Innovation Management 2: 35-47.

technologies and factors that may influence buying decisions. Assumptions leading to the selection of analogies were inferred from the survey findings for the three selected markets.

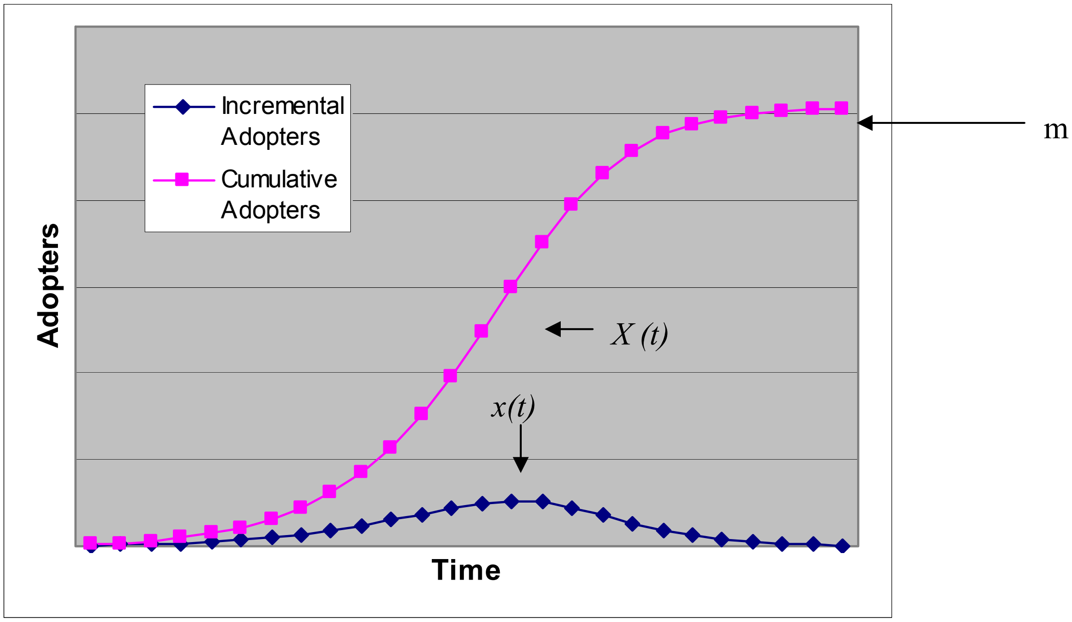

Figure 1-4. Logistic Curve of Cumulative Adopters and Normal Curve of New (Incremental) Adopters Generated by Bass Innovation Diffusion Model.

For each near-term pre-automotive market, three different cases were evaluated:

- The base case assumes that the adoption of PEM fuel cells in a market is typical for industrial products. The parameters used in the model reflect an average industrial level of innovation and imitation and generate a market penetration curve comparable to that for the adoption of the cellular telephone.
- The communication case assumes a higher than average level of innovation (50% higher *p*-value than the base case) as a result of effective communications and education by government or others outside of the target market.
- The subsidy case assumes that communications are supplemented by subsidies that lower the cost of purchasing a system. While the precise relationship between subsidy and purchasing is not known, a $1,000 per kW one-time subsidy for PEM fuel cell[14] systems for 3 to 5 years was assumed, and the corresponding cost to provide the subsidy was calculated as a point of reference.

[14] Under the Energy Policy Act (EPAct) 2005, fuel cells receive a 30% tax credit that is capped at $1,000 per kW of generating capacity.

2.0 ANALYSIS OF PRE-AUTOMOTIVE MARKETS TO 2015

2.1 Pre-Automotive Applications and Markets for PEM Fuel Cells

For the purposes of this study, pre-automotive applications and markets for PEM fuel cells are defined as those opportunities that will support the development of technology and the industry necessary for the commercialization of automotive PEM fuel cells by 2015. Pre-automotive markets for PEM fuel cells utilize components and underlying technologies similar to automotive PEM fuel cells. They include applications that have some operational characteristics similar to automotive PEM fuel cells. These might include frequent cycling, the ability to quickly respond to requests for power. Pre-automotive markets can also include markets with early adopters for stationary applications. While stationary applications have different operational characteristics than automotive applications, it is anticipated that increased demand from these markets will decrease the cost of components, help to maintain investor interest, and facilitate the development of a supplier base of PEM fuel cell technology.

2.1.1 Potential Pre-Automotive Applications

Five potential pre-automotive applications of PEM fuel cells were identified. Characteristics of these applications, some example markets, and potential advantages that PEM fuel cells may offer in these applications are described below:

- **Backup Power** – PEM fuel cells can provide standby or emergency power to ensure uninterrupted service. PEM fuel cells could be used to provide electricity that meets standard backup requirements (e.g., in blackout conditions), as well as high quality backup power requirements for industries such as financial services and telecommunications, which are willing to pay more to secure reliable service. In backup applications, efficiency is not as critical as reliability and availability of the system. PEM fuel cells in these applications provide longer runtimes than batteries. PEM fuel cells also have low operations and maintenance requirements, and have no emissions as compared to generators.

- **Grid Independent Power** – PEM fuel cells can provide continuous, stand-alone power to operations that are not connected to the grid. The fuel cell may operate on direct hydrogen from chemical processes or hydrogen supplied in canisters or tanks. For example, a fuel cell might support all the energy needs for a building at a chemical plant using hydrogen generated from the plant's production process. Power sources selected for these applications typically have high reliability, fuel availability, high efficiency, and low maintenance costs. Costs may be less important for grid independent applications than for on-grid applications. Units are expected to run for a long time, typically over 6,000 hours per year.[15] The power source is also expected to have good load-following characteristics as it is the sole source of power.

- **Specialty Vehicles –** PEM fuel cells can provide complete power for specialized equipment and vehicles such as forklifts, industrial movers, and motorized scooters, in

[15] Resource Dynamics Corporation. 2004. Distributed Generation Sourcebook.

lieu of batteries or internal combustion engines (ICEs). These applications operate in indoor and outdoor environments and are used typically to transport people or goods. PEM fuel cells in these applications are typically less than 100 kW and are expected to operate between 2,000 and 5,000 hours per year. Many specialty vehicles are expected to have long runtimes, low emissions, and easy start-up.

- **Portable Power** – PEM fuel cells can provide continuous power to meet the complete energy needs of small electronic products. PEM fuel cells may provide a substitute for conventional batteries in products such as portable phones, cameras, computers, and security devices. Product power requirements are typically less than 1 kW and are expected to operate approximately 1,000 to 5,000 hours per year.[16] Energy density, efficiency, and hydrogen storage are critical in portable applications.

- **Auxiliary Power –** PEM fuel cells can provide an alternate source of power serving specific requirements in portable, mobile on-road transportation, and off-road transportation applications. For example, they can provide electrical power to trucks, locomotives, airplanes, boats, or military vehicles when the main ICE is not operating, enabling cooling, lighting, or other auxiliary power needs to be met. PEM fuel cells for these applications can range in size from 3 to 30 kW and are expected to operate over their lifetime between 20,000 and 35,000 hours.

2.1.2 Likely Pre-Automotive Markets for PEM Fuel Cells to 2015

Based on a review of information on products in the marketplace, interviews with experts, fuel cell manufacturers, and industry stakeholders, the most promising near-term opportunities (by 2008) for PEM fuel cells operating on direct hydrogen are in specialty vehicle applications, backup power applications, and to a limited extent, in auxiliary power and portable power applications. Due to scope of the project, this report focuses on prioritizing and analyzing near-term pre-automotive markets for backup power and specialty vehicle applications.[17]

The application and development of PEM fuel cells for specialty vehicles are expected to significantly advance the development of automotive fuel cells and serve as an early market for hydrogen. Backup power applications and markets will impact the development of a supplier base by getting PEM fuel cell technology into the market and in the hands of early adopters. It is anticipated that portable power and auxiliary power applications will also develop for PEM fuel cells.

The benefit segmentation method[18] was adopted for the purpose of analyzing the applicability of PEM fuel cells to these markets. PEM fuel cell technology and its unique benefits, identified by reviewing product and application information, were matched with specific user requirements in various markets. For example, PEM fuel cells have the potential to offer customers specific benefits such as reliability, power quality, extended runtime, scalability, ease of use

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[16] DOE. 2005. Multi-Year Research, Development and Demonstration Plan: Planned Program Activities for 2003-2010. Available at http://www1.eere.energy.gov/hydrogenandfuelcells/mypp [Accessed September 2006].
[17] The scope of the project includes PEM fuel cells between 1 kW and 250 kW only and excludes Department of Defense applications.
[18] Cooper, R. 2001. Winning at New Products. Cambridge, MA, Perseus Publishing.

(plug-and-play modules), and distributed power. Extended runtime and distributed power are key decision factors for users such as telecommunications companies that operate relay towers.

Using the benefit segmentation method, the telecommunications market was defined as a unique market segment that desires a set of product benefits offered by PEM fuel cell technology. Complete market segmentation was performed using this approach for backup power and specialty vehicle markets. Through secondary and primary research, 36 market segments were identified as potential markets for PEM fuel cells to 2015 in backup power and specialty vehicle applications (Table 2-1) based on the need for lower emissions, longer runtimes, lower operation and maintenance costs, and ease of use. Of these 36 market segments, 24 are backup power market segments in the commercial, industrial, institutional, and government market sectors. Twelve market segments are specialty vehicle markets.

Table 2-1. Pre-Automotive Applications and Markets Analyzed.

Backup Power Markets				**Specialty Vehicle Markets***
Non-Government Markets			**Government Markets**	
Commercial Markets Telecom Finance Data centers Grocery stores Casinos Hotels Ski parks Amusement parks Railways Mining	Institutional Markets Water treatment Wastewater treatment Healthcare Airports Electric utilities	Industrial Markets Chemical manufacturing Oil and gas – refineries Pharmaceuticals Metals processing and refining Computer and electronic products Transportation manufacturing Food manufacturing	Federal Agencies** National Aeronautics and Space Administration (NASA) Nuclear Regulatory Commission (NRC) Department of Transportation (DOT) – Federal Aviation Administration (FAA) Department of Homeland Security (DHS) – United States Coast Guard (USCG) National Oceanic and Atmospheric Administration (NOAA) – National Weather Service (NWS) DOE Environmental Protection Agency (EPA) General Services Administration (GSA) National Park Service (NPS) Department of Interior (DOI) United States Postal Service (USPS) United States Department of Agriculture (USDA) State Agencies** State and local emergency response agencies	Forklifts Automatic guide vehicles Mining vehicles Airport ground support equipment Golf carts Turf maintenance vehicles Commercial sweepers Ice resurfacers Wheelchairs Motorized bicycles/scooters Unmanned Undersea Vehicles (UUVs) Unmanned Aerial Vehicles (UAVs)

* Specialty vehicles include industrial and recreational transportation and mobility applications.
** Counted as single market segment comprised of multiple agencies

Secondary and primary research (section 1.2.2) was conducted to identify likely applications for PEM fuel cells, market attributes, market trends, and user requirements for adopting new technologies in each of these 36 market segments. For telecom, finance, and hotels, secondary and primary research conducted in fiscal year 2005 was reviewed to identify trends for backup power. A total of 136 survey responses and 87 interviews were completed in Phase 1 and Phase

2 research. Of these 136 surveys, 83 surveys were completed by backup power users; 24 surveys were completed by specialty vehicle manufacturers, and 29 were completed by specialty vehicle users. One golf cart manufacturer provided two responses to the survey from separate departments within the company. Both responses were combined and analyzed for this manufacturer. Three specialty vehicle users (one airline company, two retail companies) and four backup power users (four emergency response agencies) answered both Phase 1 and Phase 2 surveys. If a respondent participated in more than one survey, during analysis only one response was taken into account for questions appearing in both surveys. A complete listing of respondents and their level of participation can be found in Appendix B.

The following sections analyze the likely applications for PEM fuel cells, user requirements for adopting new technologies, satisfaction with current technologies, and interest in alternatives in the backup power and specialty vehicle markets.

2.2 Analysis of Pre-Automotive Backup Power Markets for PEM Fuel Cells

This section presents qualitative and quantitative analysis of the key trends, drivers, and requirements of users for backup power in commercial, institutional, industrial, and government markets. Analyses of trends in individual segments (section 2.2.1), as well as a composite analysis of trends across backup power markets (section 2.2.2) are presented in this section. Individual backup power segment reports can be found in Appendix C. Detailed analyses of the emergency response market segment can be found in section 3.0.

2.2.1 Analysis of Individual Backup Power Market Segments

Of the 36 market segments analyzed, 24 market segments were analyzed for their potential to adopt PEM fuel cells in backup power applications in the near-term (2008). Ten commercial market segments, five institutional market segments, seven industrial market segments, and two government market segments were analyzed.

This section presents Battelle's analysis of the trends in the individual backup power market segments as determined through surveys, interviews, and secondary research. For the telecom, finance, and hotel market segments, trends are reported based on information gathered in fiscal year 2005 and a review of more recent secondary information. Table 2-2 summarizes the number of survey respondents and interviewees for each market segment and the size of the survey respondents' organizations. A complete listing of survey respondents and interviewees for Phase 1 and Phase 2 research can be found in Appendix B.

Table 2-2. Total Number and Size of Respondents for Backup Power Market Segments.

Market Segment	Number of Survey Respondents	Number of Interviewees	Size of Survey Respondent's Organization~		
			Small	Medium	Large
Telecom*	6	16	-	-	6
Finance*	9	-	2	-	7
Data Centers	2	-	1	-	1
Grocery Stores	4	9	1	-	3
Casinos	1	2	1	-	
Hotels*	8	-	2	1	5
Ski Parks	1	1	-	-	1
Amusement Parks+	-	1	-	-	-
Railways	6	-	1	1	4
Mining	1	2	-	1	
Water Treatment	3	-	3	-	-
Wastewater Treatment	4	3	4	-	-
Healthcare	5	2	-	3	2
Airports	6	3	1	5	
Electric Utilities	2	5	-	-	2
Chemical Manufacturing	2	7	-	-	2
Oil and Gas - Refineries	2	-		1	1
Pharmaceuticals+	-	1	-	-	-
Metals Processing and Refining	4	-	3	-	1
Computer and Electronic Products	4	3	3	-	1
Transportation Manufacturing	2	8	1		1
Food Manufacturing+	-	-	-	-	-
NASA	1	1			1
Department of Interior (DOI)+					
United States Postal Service (USPS)+					
NRC+	-	1	-	-	-
DOT - FHWA+					
USDA+		1			
FAA*	1	-	-	-	1
USCG	1	1	-	-	1
NOAA - National Weather Service (NWS)	1	-	-	-	1
DOE	1	2	-	-	1
EPA	3	2	2	1	-
GSA+	-	1	-	-	-
NPS	1	2	-	-	1
State and Local Emergency Response	22	11	17	2	3
Total	103	85	42	15	46

~ Small is classified as 500 employees or less, medium is classified as 500 to 3000 employees, and large is over 3000 employees; *These market segments were analyzed in fiscal year 2005. Surveys implemented with these segments were similar to those implemented in Phase 1 research; + No surveys were received from these market segments. Analysis is based on secondary research and interviewee feedback only.

2.2.1.1 Commercial Backup Power Market Segment Analysis

Table 2-3 presents Battelle's analysis of the information gathered through secondary research and through surveys of users in ten commercial market segments. Limited information was available on the potential for backup power in amusement parks (only one interviewee); as a result, the information presented in Table 2-3 for this market segment is based primarily on secondary research.

Of the ten segments analyzed, telecom and data centers are most severely impacted by power outages. In the commercial market, long outages are very disruptive and can have significant economic impact. All the segments analyzed have some level of backup power. Casinos and large data centers often have redundant grid power lines in case of outages. Reliability was identified as one of the most critical factors when selecting backup power systems by all ten commercial segments. Fuel availability, start-up time, lifetime, and ease of use of the backup power system were also identified as very important factors when selecting backup power systems by users in this segment. Initial capital costs were cited as an important factor when selecting a backup power system by all commercial segments except the railways and grocery store segments.

Commercial users are satisfied with the performance of current backup power technologies. Of the ten segments analyzed, four – grocery stores, railways, telecom, and mining – identified concerns with their current mode of operation. Maintenance concerns were identified for generator systems by two segments. The telecom market segment indicated concerns over battery life, operations and maintenance requirements of generators, and fuel availability, particularly in remote locations. Alternative backup power technologies, including fuel cells, have been considered by the telecom, data center, grocery store, and railway market segments. Commercial users familiar with PEM fuel cells in the commercial market segment identified the high capital cost of PEM fuel cells as a significant barrier to adoption. Initial capital cost was identified as a decision factor for capital purchases by five of the ten commercial market segments including casinos, data centers, ski parks, amusement parks, and finance. Primary concerns for considering alternatives in the commercial market segments were environmental concerns, regulatory requirements, the need for low maintenance systems, and the need for extended backup power at remote locations. Government incentives were not identified as a primary driver for purchasing alternatives in the data center, amusement park, finance, and telecom market segments.

Based on technology-market fit analysis, near-term opportunities for PEM fuel cells exist in the telecom and railway market segments. Users in these segments are looking for backup power alternatives to support remote communications applications. Of the two segments, the telecom market sector is a more attractive market opportunity because users are less price sensitive than the railway market segment; it is also a larger market opportunity. However, a number of barriers will have to be addressed before PEM fuel cells will be widely accepted in the telecom market segment, including a lack of reliability data on the operation of PEM fuel cells for backup power in telecom applications, guidelines for installation and operation of hydrogen fuel in high power zones, and track record of other users adopting PEM fuel cells for backup power applications.

Table 2-3. Analysis of the Potential for PEM Fuel Cells in Backup Power Applications in Commercial Market Segments*.

Market Segment	Casinos	Data Centers	Grocery Stores	Railways	Ski Parks	Amusement Parks	Hotels	Finance	Telecom	Mining
Applications	Surveillance, Emergency lighting and alarms, Sprinkler systems	Servers, Lighting, Air-conditioning, Data center-specific network switches, Telephone switching	Emergency lighting, Emergency medical system controllers, Point of sale registers, Refrigeration	Signals, Crossing guard mechanisms, Onsite communication, Emergency lighting	Lifts	Rides, Park services	Emergency lighting and alarm systems, Point of sale registers, Heating and ventilation systems, Refrigeration systems	Computer systems, Servers, Telecom systems, ATMs	Controlled environmental huts, Remote cell sites, Microwave towers, Cell sites, Hub sites, Enhancers, Repeaters, Cabinet sites, Outside plant huts, Digital loop carriers, Fiber, Private branch exchange, Public safety answering points, Remote radio centers, Portable systems, Central offices, Switching stations	Ventilation systems, Safety systems, Hoists, Communication devices, Emergency lighting and alarms, Mine pumps
Most Critical Applications	Surveillance, Emergency lighting and alarms	Servers	Refrigeration, Emergency lighting	All of the above	Lifts	Rides	Emergency lighting and alarm systems, Heating and ventilation systems, Refrigeration systems	All of the above	Hub sites, Microwave transmitter sites, Central offices	Pumps, Safety systems, Emergency lighting and alarms
Economic Impact and Other Impacts of Outages	High; Results in security breach and implementation of emergency management plans	High; Results in security breach, disruption of production, and distribution, implementation of emergency management plans	High; Results in economic loss through food spoilage, disruption in distribution, and implementation of emergency management plans	Medium; Dependent on location of outage; Impacts distribution, results in implementation of emergency management plans and potential loss of life	High; Results in implementation of emergency management plans and in customer dissatisfaction	Medium; Results in disruption of operations, implementation of emergency management plans, and in customer dissatisfaction	High; Results in disruption of operations, implementation of emergency management plans, and in customer dissatisfaction	High; Results in security breach, disruption of distribution, and implementation of emergency management plans	High; Results in security breach, disruption of production and distribution, and implementation of emergency management plans	High, Results in implementation of emergency management plans and disruption of production and distribution

Table 2-3. **Analysis of the Potential for PEM Fuel Cells in Backup Power Applications in Commercial Market Segments*.**

	Market Segment	Casinos	Data Centers	Grocery Stores	Railways	Ski Parks	Amusement Parks	Hotels	Finance	Telecom	Mining
	Types and Typical Size of Backup Systems Used	UPS; 15 - 30 kW	UPS, Generators; < 5 kW, 15 - 250 kW, > 1,000 kW	UPS, Generators; 5 - 250 kW, > 2,000 kW for warehouses	Batteries, UPS, Generators; < 5 - 150 kW	Generators; Unknown	Generators; 50 - > 500 kW	UPS, Generators; < 5 kW, 150 - 250 kW	UPS, Generators; 50 - 250 kW, > 1,000 kW	Batteries, Generators; 2 - 200 kW	Generators; > 750 kW - 2 MW
User Requirements When Selecting a Backup System	**Reliability**	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important
	Capital Cost	Very important	Very important	Important	Important	Very important	Very important	Very important	Very important	Very important	Important
	Lifetime	Very important	Very important	Important	Very important	Very important	Very important	Very important	Very important	Very important	Important
	Annual Operating Cost	Very important	Important	Important	Important	Very important	Very important	Very important	Data not available	Important	Not so important
	Emissions	Very important	Important	Important	Important	Very important	Very important	Very important	Important	Not so important	Very important
	Start-up Time	Very important	Very important	Important	Very important	Very important	Very important	Very important	Very important	Very important	Important
	Ease of Use	Very important	Very important	Important	Important	Very important	Very important	Very important	Important	Very important	Very important
	Fuel Availability	Very important	Very important	Very important	Important	Very important	Very important	Very important	Important	Very important	Very important
	Good Experience	Important	Important	Important	Very important	Very important	Very important	Very important	Important	Very important	Very important
	Most Important User Requirements	Reliability	Reliability, Start-up time, Fuel availability	Reliability, Fuel availability	Reliability, Start-up time, Lifetime	Reliability, Start-up time, Emissions	Reliability, Capital cost	Capital cost, Operating cost, High efficiency	Reliability, Capital costs, Lifetime	Reliability, Capital costs, Ease of use	Reliability, Emissions, Ease of use
	User Satisfaction with Current Technologies	Very satisfied	Very satisfied	Satisfied, with some concerns	Satisfied, with some concerns	Very satisfied	Very satisfied	Very satisfied	Very satisfied	Satisfied, with some concerns	Satisfied, with some concerns
	User Concerns with Current Technologies	No concerns	No concerns	Maintenance of generators a concern, Emissions from generators a concern	Concerns about reliability at remote location, Inability to determine charge of battery systems	No concerns	No concerns	No concerns	No concerns	Battery lifetime, Fuel availability and operations and maintenance costs at remote locations a concern	Emissions from generators are a concern, Reliability concerns also exist

Table 2-3. Analysis of the Potential for PEM Fuel Cells in Backup Power Applications in Commercial Market Segments*.

Market Segment	Casinos	Data Centers	Grocery Stores	Railways	Ski Parks	Amusement Parks	Hotels	Finance	Telecom	Mining
Performance Factors Users are Most Satisfied with – Current Technologies	Reliability, lifetime, Start-up time, Ease of use, Fuel availability	Reliability, Operations and maintenance costs, Lifetime, Annual operating cost, Emissions, Start-up time, Ease of use, Fuel availability	Lifetime, Annual operating cost, Ease of use, Fuel availability	Lifetime, Start-up time	Reliability, Operations and maintenance costs, Start-up time, Ease of use, Fuel availability	Data not available	Data not available	Data not available	Data not available	Ease of use, Operations and Maintenance costs, Fuel availability
Market Potential for Backup Power	Low	Medium to High	Medium to High – Geographically driven	High – Remote locations, subway stations	Low	Low	Low	Low	High – Remote locations	Medium to High
Interest in Alternatives for Backup Power	No interest	Limited interest	High interest	High interest	Limited interest	No interest	No interest	Limited interest	High interest	Limited interest
Awareness of PEM Fuel Cells for Backup Power	Limited to no awareness	Some level of awareness	High level of awareness	Some level of awareness	Limited to no awareness	Limited to no awareness	Limited to no awareness	Some level of awareness	High level of awareness	Some level of awareness
Key Decision Factors for Capital Purchases	Initial capital cost, Payback period, Return on investment	Initial capital cost, Business justification	Need for backup power, Return on investment, Payback period, Initial capital cost	Payback period, Initial capital cost, Return on investment	Initial capital cost, Payback period	Initial capital cost	Payback period, Return on investment, Initial capital cost	Initial capital cost, Payback period	Return on investment, Initial capital cost	Return on investment
Importance of Government Incentives in Purchasing	Important	Not so important	Very important	Important	Important	Not so important	Important	Not so important	Not so important	Important
Potential Opportunity for PEM Fuel Cells in the Near-term	Low	Low	Low	Medium	Low	Low	Low	Low	High	Low

Table 2-3. Analysis of the Potential for PEM Fuel Cells in Backup Power Applications in Commercial Market Segments*.

Market Segment	Casinos	Data Centers	Grocery Stores	Railways	Ski Parks	Amusement Parks	Hotels	Finance	Telecom	Mining
Drivers for PEM Fuel Cell Adoption	No apparent drivers	No apparent drivers	Potential environmental concerns, Need for backup power to support long outages in coastal zones	Potential environmental concerns, Need for backup power in remote locations, Mandate to provide backup power in subways	Environmental concerns, Regulatory concerns	No apparent drivers	No apparent drivers	No apparent drivers	Need for backup power in remote locations with longer runtimes and lower operations and maintenance costs	Environmental concerns, Regulatory drivers that require mining companies to install backup power
Barriers to PEM Fuel Cell Adoption	Capital costs are a decision driver, Users are satisfied with current mode of operation, Limited interest in alternatives	Capital costs are a decision driver, Users are satisfied with current mode of operation, Limited interest in alternatives, Small size of PEM fuel cell products current available in the marketplace may limit application	Track record of others using PEM fuel cells is important, PEM fuel cell size may limit application, Market segment is sensitive to fuel costs	Backup power is dependent on need, Capital costs are a concern, Track records of others using PEM fuel cells is important	Capital costs are a decision driver, Users are satisfied with current mode of operation, Limited interest in alternatives	Capital costs are a decision driver, Users are satisfied with current mode of operation, Limited interest in alternatives	Users are satisfied with their current technologies, Looking for alternatives that have high efficiency and can support their CHP needs	Capital costs are a concern, Users are satisfied with current technologies, Limited interest in alternatives	Unknown reliability of PEM fuel cells, Track record of others using PEM fuel cells is important, Need Telecordia to set guidelines for PEM fuel cell installation	Current power size of PEM fuel cells may be a limitation

*Telecom, finance, and hotels were analyzed based on surveys conducted in fiscal year 2005; No primary information was available on user requirements for amusement parks.

2.2.1.2 Institutional Backup Power Market Segment Analysis

Five institutional market segments were analyzed for the potential for adoption of PEM fuel cells in backup power applications. Table 2-4 presents Battelle's analysis of the information gathered through surveys of users in these market segments and secondary research. For the number of respondents to surveys and the number of interviewees in each of these segments, see Table 2-2.

All institutional market segments analyzed use some level of backup power; and all appear to have some backup applications that are a good fit for PEM fuel cells in the near-term, including communications systems, supervisory control and data acquisition (SCADA) systems, telecom sites, and emergency lighting. In addition to UPS systems, batteries, and generators, large users in the healthcare, airports, and electric utility markets also have redundant power lines for backup. Of the five segments analyzed, healthcare, airports, and the electric utility markets are most severely impacted by outages. Extended outages appear to be very disruptive to all three of these segments.

Reliability, start-up time, fuel availability, ease of use, and good experience with this type of system in the past were identified as the most important factors when selecting a backup power system by institutional users in the five institutional market segments. However, when making a decision to purchase a system, all users in the various institutional market segments analyzed identified initial capital cost as an important consideration. Government incentives are considered important or very important by all institutional market segments, except healthcare. Of the five institutional segments, dissatisfaction with current technologies was noted only in the airport market segment. Primary concerns are emissions from generators and the large footprint of generators. While users in the water treatment and electric utility substation market segments identified some concerns with batteries and generators, users in these segments appear to be very satisfied with current technologies. High interest in alternatives to support critical energy requirements was identified in the airport and healthcare market segments. However, it appears that this interest is primarily to support large applications (e.g., facilities, equipment). Market research suggests that only the electric utility substation market has considered PEM fuel cells as alternatives. Some users surveyed in this market segment are testing PEM fuel cells for substation backup power; however, these users are yet to be convinced of the reliability of PEM fuel cells and are considering them for battery recharging applications.

Based on the technology-market fit analysis, near-term opportunities for PEM fuel cells exist for backup power support of communications systems, SCADA systems, and emergency lighting applications. However, it is likely that none of these market segments will be adopters in the near-term. No apparent drivers were identified for the adoption of PEM fuel cells in the near-term in these market segments. Most users appear to be concerned about capital cost and reliability of backup power systems. Those users familiar with PEM fuel cells are unconvinced of their reliability. Furthermore, users are also interested in good experience with the system in the past, which may limit early adoption. No unique value for PEM fuel cells could be determined.

Table 2-4. Analysis of the Potential for PEM Fuel Cells in Backup Power Applications in Institutional Market Segments.

Market Segment		Healthcare	Airports	Wastewater Treatment	Water Treatment	Electric Utility Substations
Applications		Life support equipment, Critical life safety equipment, Communications systems, Blood bank refrigerators, Urgent care areas, Emergency lighting	Airfield lighting, Security systems, Life safety systems, Terminals - lighting and space heating and cooling, Ticket counters, Baggage systems, Fueling stations, Aircraft operations/tower, Emergency lighting, Communications centers, Emergency response stations, Electrical substations, Parking structures	Pumps, aeration blowers and mixers, Clarifier drivers, Digester blowers, Wastewater processing equipment, Traveling bridges	Plant emergency lights, SCADA systems, Communications systems, Computer operations, Water pump operations including low and high service pumps, Chemical feed systems, Mixers, Filters	Power control networks, Relay protection, Telecom sites
Most Critical Applications		Life support equipment, Critical life safety equipment	Life safety equipment, Airfield lighting, Communications centers, Security systems	All of the above	SCADA systems, Communications systems, Water pumps	All of the above
Economic Impact and Other Impacts of Outages		High; Results in implementation of emergency management plans, loss of life, and security breach	High; Results in security breach, flight delays impacting airline schedules across the country, and implementation of emergency management plans	High; Results in disruptions in production and distribution, loss of safe drinking water, and implementation of emergency management plans	High; Results in loss of safe drinking water, disruptions in production and distribution, and in extreme cases could result in lives lost where water is not available for fire protection	High; Results in implementation of emergency management plans and potential loss in distribution of power
Types and Typical Size of Backup Systems Used		Stand-by utility lines, UPS, Batteries, Generators; 5 kW - > 1,000 kW	UPS, Batteries, Generators, Stand-by utility lines; Sizes: 5kW - > 1 MW. For entire terminals > 4 MW; backup power systems on trailers ~350 kW	UPS, Generators; 5 - 30 kW, > 250 kW	UPS, Generators; 5 - 15 kW, > 250 kW	Batteries; Sizes: 15 - 30 kW, > 250 kW
User Requirements	**Reliability**	Very important	Very important	Very important	Very important	Very important
	Capital Cost	Important	Important	Important	Important	Important
	Lifetime	Important	Very important	Important	Important	Important
	Annual Operating cost	Important	Important	Important	Important	Very important
	Emissions	Important	Very important	Important	Important	Important
	Start-up Time	Very important	Very important	Very important	Very important	Very important
	Ease of Use	Very important	Very important	Very important	Very important	Very important
	Fuel Availability	Very important	Very important	Very important	Very important	Very important
	Good Experience with System in the Past	Very important	Very important	Very important	Very important	Very important

Table 2-4. Analysis of the Potential for PEM Fuel Cells in Backup Power Applications in Institutional Market Segments.

Market Segment	Healthcare	Airports	Wastewater Treatment	Water Treatment	Electric Utility Substations
Most Important User Requirements	Reliability, Start-up time, Ease of use, Fuel availability	Reliability, Start-up time, Good experience in the past	Reliability, Start-up time, Fuel availability	Reliability, Start-up time, Good experience with system in the past	Reliability, Ease of use
User Satisfaction with Current Technologies	Very satisfied	Satisfied, with some concerns	Very satisfied	Very satisfied	Very satisfied
User Concerns with Current Technologies	No concerns	Cost of system, Emissions, Space occupied by facility backup power systems, Limited ability of UPS systems to support extended outages	No concerns	Transportability of generators	Corrosion of batteries, High maintenance requirements of batteries including room ventilation, Disposal requirements for batteries
Performance Factors Users are Most Satisfied with – Current Technologies	Reliability, Start-up time	Reliability, Fuel availability, Start-up time	Reliability, Annual operating costs, Start-up time, Fuel availability	Reliability, Start-up time	Reliability, capital cost, Operations and maintenance costs, Lifetime, Annual operating cost, Start-up time, Ease of use, Fuel availability
Market Growth Potential for Backup Power	Medium	Medium	Low	Low	Low
Interest in Alternatives for Backup Power	High interest	High interest	Limited interest	Limited interest	Limited interest
Awareness of PEM Fuel Cells for Backup Power	Some level of awareness	Limited awareness among users	Limited to no awareness	Limited to no awareness	High level of awareness
Key Decision Factors for Capital Purchases	Initial capital cost, Equipment reliability	Initial capital cost, Payback period, Return on investment	Initial capital costs, Payback period, Return on investment	Initial capital cost	Initial capital cost, Payback period, Dependent on availability of funds and need for backup power
Importance of Government Incentives in Purchasing	Not so important	Very important	Important	Important	Very important
Potential Opportunity for PEM Fuel Cells in the Near-term	Low	Low	Low	Low	Low
Drivers for PEM Fuel Cell Adoption for Backup Power	No apparent drivers	No apparent drivers	No apparent drivers	No apparent drivers	No apparent drivers
Barriers to PEM Fuel Cell Adoption	Users satisfied with current mode of operation, Limited interest in small sized alternatives, Unknown reliability of PEM fuel cells, Concerns about hydrogen siting with critical equipment	Users interested in large capacity backup power, Limited interest in alternatives for smaller applications, Unknown reliability and high capital costs of PEM fuel cells a concern	Users satisfied with current mode of operation, Limited interest in alternatives, Market is sensitive to capital costs, Users look for track record of others using similar system	Users satisfied with current mode of operation, Limited interest in alternatives, Market is sensitive to capital costs, Users look for track record of others using similar system	Users satisfied with current mode of operation, Limited interest in alternatives, Unknown reliability of PEM fuel cells a concern, Market is sensitive to capital costs

2.2.1.3 Industrial Backup Power Market Segment Analysis

Seven industrial market segments were analyzed to determine the market opportunity for PEM fuel cells in the near-term. This section reports on findings in just five of seven industrial market segments (Table 2-5), due to limited primary and secondary information on the pharmaceutical and food manufacturing market segments.

Secondary information reviewed on the pharmaceutical sector suggests that users are interested in alternatives to meet their carbon reduction goals; however, limited information was available on their interest in adopting backup power alternatives. As pharmaceutical manufacturing requires highly reliable grid power, it is expected that manufacturers would have redundant power sources including the grid, large generators, and UPS systems. It is likely that, in the near-term, opportunities for PEM fuel cells will be limited to those areas where UPS systems are applied. Little information was available on opportunities for backup power in the food manufacturing sector and user interest in alternative technologies. It can be anticipated that, like other manufacturing operations sensitive to power outages, backup power for communications and SCADA systems could be potential opportunities for PEM fuel cells. The secondary and primary information gathered to support analyses of the opportunities for PEM fuel cells in all seven industrial market segments is presented in Appendix C.

Due to limitations in the size and durability of PEM fuel cells, near-term applications in industrial segments may be limited to the support of communications systems, control systems, emergency lighting and alarm systems, and other life safety systems. Users in these market segments experience outages; however, outages are typically short (< 60 seconds). Longer, more severe outages are experienced typically during weather-related events. The economic impact of extended outages is severe in this sector; as a result, most operations have a high level of redundancy. Backup power is provided through additional support from the grid, large generators, and UPS systems.

Reliability, start-up time, ease of use, and fuel availability were identified by users as the most important factors when selecting a backup system. Initial capital cost was also identified as an important factor when evaluating new systems. Users appear to be fairly satisfied with their current mode of operation. Only users in the computer and electronics manufacturing sector identified some concerns with emissions from generators and operations and maintenance requirements for batteries.

The market growth potential for small backup power systems appears to be more promising in the oil and gas refinery segment and the metal processing and refining segment than in the other industrial segments, due to regulatory drivers. However, in these market segments, there has been limited to no interest in small backup power alternatives, including PEM fuel cells. No apparent drivers or value for PEM fuel cells for backup power in the near-term could be identified. The adoption of PEM fuel cells in these market segments will depend on the ability of PEM fuel cells to compete effectively with current alternatives in terms of reliability and capital cost.

Table 2-5. Analysis of the Potential for PEM Fuel Cells in Backup Power Applications in Industrial Market Segments.

Market Segment		Chemical Manufacturing	Oil and Gas Refining	Computer and Electronic Products	Metals Processing and Mining	Transportation Equipment
Applications		Within process facilities - Control systems, Switchgear control power, Instruments, Vibration monitors, Motors, Computer systems, Emergency lighting	SCADA systems, Remote instrumentation support, Mainframe computing hardware, Emergency lighting, Corporate crisis management, Data center supporting corporate operations	Computer systems and servers, Emergency lighting, Exhaust fans, Light safety systems, SCADA systems	Process control systems, Automation and robotics control systems, Process lines	Emergency lighting, Servers, Process control for machining operations
Most Critical Applications		All of the above	SCADA systems	All of the above	All of the above	Process control for machining operations, Servers
Economic and Other Downtime Impacts		High; Critical equipment fitted with ride through for shorter interruptions; Longer disruption affects distribution and production; Results in implementation of emergency management plans	High; Any disruption is very disruptive; Results in disruptions in distribution and production and implementation of emergency management plans	High; Any type of interruption is very disruptive; Results in disruption of production and distribution and could potentially result in the implementation of emergency management plans	High; Results in equipment damage, safety concerns, and disruptions in production and distribution	Medium to High; Varies based on type of operation; Results in disruption of production and distribution
Types and Typical Size of Backup Systems Used		Batteries, UPS, Generators, Redundant feeds from electric utilities; Sizes unknown	Redundant feeds from electric utilities, Batteries, UPS, Generators; 2 kW - > 2,000 kW	UPS, Batteries, Generators; < 5kW - > 250 kW	UPS, Generators; 1 - 150 kW	UPS, Generators; < 5 kW - 500 kW
User Requirements	Reliability	Very important	Very important	Very important	Very important	Very important
	Capital Cost	Very important	Important	Very important	Important	Important
	Lifetime	Important	Important	Very important	Important	Very important
	Annual Operating Cost	Important	Important	Important	Important	Important
	Emissions	Very important	Very important	Important	Not so important	Important
	Start-up Time	Very important	Very important	Important	Very important	Very important
	Ease of Use	Very important	Important	Very important	Important	Very important
	Fuel Availability	Very important	Very important	Important	Important	Important
	Good Experience	Very important	Very important	Important	Important	Important
Most Important User Requirements		Reliability, Start-up time, Fuel Availability	Reliability, Start-up time	Reliability, Start-up time, Fuel availability	Reliability, Ease of use, Start-up time, Capital cost	Reliability, Start-up time, Capital cost

Table 2-5. Analysis of the Potential for PEM Fuel Cells in Backup Power Applications in Industrial Market Segments.

Market Segment	Chemical Manufacturing	Oil and Gas Refining	Computer and Electronic Products	Metals Processing and Mining	Transportation Equipment
User Satisfaction with Current Technologies	Very satisfied	Very satisfied	Satisfied, with some concerns	Very satisfied	Very satisfied
User Concerns with Current Backup Power Technologies	No concerns	No concerns	UPS systems - Maintenance, Generators - Emissions	No concerns	No concerns
Performance Factors Users are Most Satisfied with – Current Technologies	Reliability, Start-up time, Fuel availability, Operations and maintenance costs	Reliability, Start-up time	Reliability, Capital costs, Annual operating costs, Emissions, Start-up time, Ease of use, Fuel availability	Start-up time, Fuel availability, Reliability, Ease of use	Lifetime of unit, Fuel availability
Market Potential for Backup Power	Low	Medium	Low	Medium	Low
Interest in Alternatives for Backup Power	No interest	No interest	Limited interest	Some interest	No interest
Awareness of PEM Fuel Cells for Backup Power	Limited awareness	Limited awareness	Limited awareness	No awareness	No awareness
Key Decision Factors for Capital Purchases	Return on investment, Initial capital cost	Return on investment	Return on investment, Initial capital costs, Payback period, and Need	Initial capital cost	Return on investment, Payback analysis
Importance of Government Incentives in Purchasing	Important	Important	Not so important	Not so important	Not so important
Potential Opportunity for PEM Fuel Cells in the Near-term	Low	Low	Low	Low	Low
Drivers for PEM Fuel Cell Adoption	No apparent drivers	No apparent drivers, To a limited extent mandates for backup power could drive interest in PEM fuel cells	Environmental concerns	Environmental concerns, Regulatory concerns	No apparent drivers
Barriers to PEM Fuel Cell Adoption	Users are satisfied with current technologies, Alternatives for small backup systems are of limited interest, Track record of others using PEM fuel cells is important, PEM fuel cells are limited by size and durability	Users are satisfied with current technologies, Users are looking for larger systems to fit their requirements, PEM fuel cells are limited by size and durability	Users appear to be fairly satisfied with current technologies, Limited interest in alternatives, PEM fuel cells are limited by size and durability	Limited interest in alternatives, Users are sensitive to capital costs, Users are fairly satisfied with current technologies	Limited interest in alternatives, Users appear to be fairly satisfied with current technologies

2.2.1.4 Government Backup Power Market Segment Analysis

Two government market segments were analyzed, including the federal market and state and local emergency response market, as potential adopters of PEM fuel cells. Twelve federal sub-markets were identified for further analysis, as secondary research indicated a need for backup power in these segments that PEM fuel cells may be able to meet. The DoD is currently developing PEM fuel cells for various applications and is a likely early adopter. Due to the diverse number of applications and their sensitive nature, limited primary and secondary research was conducted in this market segment. While research was conducted, limited primary and secondary information was available on five agencies, including DOI, USPS, NRC, USDA, and GSA. No formal surveys were conducted with these agencies; interviews were conducted with three federal agencies, including NRC, USDA, and GSA. An analysis of FAA requirements was based on responses received to the surveys conducted in fiscal year 2005 and on a more recent review of secondary research. Due to this general lack of information, the potential for PEM fuel cell adoption in backup power applications is presented in Table 2-6 for only seven of the twelve federal government sub-markets analyzed.

Market research identified various drivers to adopt PEM fuel cells, including the need for extended backup power, dissatisfaction with generators and batteries, and environmental concerns, in all eight government market segments. Primary backup applications for PEM fuel cells in the near-term include radio sites, communication systems, computer networks, and emergency lighting and alarms. All of the government markets presented in Table 2-6 have remote applications that could be supported by PEM fuel cells. The impacts of outages are most significant for emergency response agencies, NOAA, the FAA, and the USCG. Outages may result in implementation of emergency management plans and potential loss of life; therefore, it is critical for these users to ensure continuous power supply at all times. In some cases, agencies are mandated to have backup power due to the criticality of their operations. Backup power is primarily provided through generators, UPS systems, and batteries.

Primary concerns for users in the government market segments when selecting a backup power system, in order of importance, are: reliability, start-up time, lifetime, fuel availability, emissions, and good experience with the system in the past. There is some level of discontent among users in the emergency response market, NOAA, NPS, USCG, and FAA, with regard to their current mode of operation for backup power. Furthermore, there is interest in alternatives in all five market segments. However, since the NPS market has limited funds for facility upgrades and considers a variety of issues when making a purchasing decision, adoption by this market in the near-term is unlikely. When the technology-market fit is examined, PEM fuel cells could offer a unique value proposition for the emergency response, NOAA, USCG, and FAA markets in the near-term; potential benefits include longer runtimes as compared to batteries, lower emissions than generators, and remote operation and monitoring capabilities. It should be noted that in all four market segments, users are sensitive to initial capital costs and that incentives will be important to facilitate purchasing. It is likely that applications for PEM fuel cells at other federal agencies like EPA, NASA, and DOE will evolve as the capital costs of PEM fuel cells become more attractive.

Table 2-6. Analysis of the Potential for PEM Fuel Cells in Backup Power Applications in Government Market Segments.

	State and Local Government	**Federal Agencies**						
Market Segment	**Emergency Response***	**NOAA (National Weather Service)**	**EPA (Facilities)**	**NASA (Facilities)**	**DOE (Facilities)**	**National Parks**	**USCG**	**FAA****
Applications	911 call centers, Dispatch telephones and computer systems, Radios, Wireless communications facilities and radio infrastructure, Security systems for jails, fire, police stations	Mission critical weather systems	Lab (includes critical analysis) equipment, Emergency operations center, Computer networks, Data centers, Emergency lighting and alarm systems	Research, operations, Data communications, Data storage	Life safety equipment, Emergency lights, Fire protection, Security, Servers and computers	Fire protection, Radio and telephone systems, Dispatch centers, Fire/rescue/law enforcement operations, Hospitality, Museums and curatorial centers, Wastewater treatment, Utility water systems, Administrative centers	Telecom systems – National distress system, Computers and servers, Navigation systems, Telephones	Air traffic control towers, Radio transmitter sites
Most Critical Applications	Remote radio sites, Dispatch radios, Computer aided systems, Telephones	All of the above	Computer networks, Critical analysis equipment	Research, Operations, Data communications	Life safety equipment	Fire protection, Radio and telephone systems, Dispatch centers, Fire/rescue/law enforcement operations, Wastewater treatment, Utility water systems	Security communication systems	Remote radio sites
Economic and Other Downtime Impacts	High; Long outages are very disruptive; Potential impacts are lives lost, security breach, and implementation of emergency management plans	High; Longer outages are very disruptive, Results in the implementation of emergency management plans and possibly in security breach	Medium to High; Outages can disrupt experiments, which may impact data	Medium to High; Impact is dependent on the type of operation supported; Results in disruptions in production and implementation of emergency management plans	Medium to High; Impact is dependent on the type of operation supported; Results in disruptions in production and can also result in implementation of emergency management plans	Low; Impact is dependent on where the outage occurs; Results in implementation of emergency management plans, loss of safe drinking water, and uncontrolled release of sewage	High; Impact is dependent on where the outage occurs; Can result in loss of life, implementation of emergency management plans, and release of sewage	High; Results in disruption of air traffic and implementation of emergency management plans

Table 2-6. Analysis of the Potential for PEM Fuel Cells in Backup Power Applications in Government Market Segments.

		State and Local Government	Federal Agencies						
Market Segment		Emergency Response*	NOAA (National Weather Service)	EPA (Facilities)	NASA (Facilities)	DOE (Facilities)	National Parks	USCG	FAA**
Types and Typical Sizes of Backup Systems Used		Batteries, UPS, Generators; Radio sites: < 5 - 60 kW, Telecom equipment and computer aided dispatch: < 5 - 30 kW, Facility backup: > 1,000 kW	UPS; 5 - 30 kW	UPS, Generators; < 5 - 250 kW, Facility backup: > 1.2 MW	UPS, Generators; < 5 - 250 kW, Facility backup: > 1MW	UPS, Generators; < 5 - 250 kW, Facility backup: > 1 MW	Generators; 5 - 150 kW	UPS, Batteries, Generators; 5 - 250 kW	UPS, Generators; 0.5 - 150 kW
User Requirements	Reliability	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important
	Capital Cost	Important	Very important	Very important	Very important	Important	Important	Very important	Important
	Lifetime	Important	Very important	Very important	Very important	Important	Very important	Very important	Very important
	Annual Operating Cost	Important	Very important	Important	Very important	Not so important	Important	Important	Very important
	Emissions	Important	Very important	Very important	Very important	Important	Very important	Very important	Important
	Start-up Time	Very important	Very important	Very important	Very important	Very important	Not so important	Very important	Very important
	Ease of Use	Important	Very important	Important	Very important	Very important	Important	Important	Very important
	Fuel Availability	Very important	Very important	Very important	Very important	Important	Important	Important	Very important
	Good Experience	Important	Very important	Important	Important	Very important	Very important	Important	Important
Most Important User Requirements		Reliability, Fuel availability, Start-up time, Ease of use	Reliability, Lifetime, Capital cost	Reliability, Lifetime	Reliability, Capital cost, Low annual operating cost, Ease of use	Reliability, Ease of use, Good experience with system in the past	Reliability, Low annual operating cost, Ease of use	Lifetime, Emissions, Start-up time	Reliability, Lifetime, Operations and maintenance costs
User Satisfaction with Current Technologies		Satisfied, with some concerns	Not so satisfied	Satisfied with UPS; Not so satisfied with PAFC and generators	Satisfied	Very satisfied	Satisfied, with some concerns	Satisfied, with some concerns	Satisfied, with some concerns

Table 2-6. Analysis of the Potential for PEM Fuel Cells in Backup Power Applications in Government Market Segments.

	State and Local Government	Federal Agencies						
Market Segment	**Emergency Response***	**NOAA (National Weather Service)**	**EPA (Facilities)**	**NASA (Facilities)**	**DOE (Facilities)**	**National Parks**	**USCG**	**FAA****
User Concerns with Current Technologies	Generators – Mechanical failure of generator, Loss of fuel, and High emissions; Batteries – Unable to determine charge	UPS systems provide only 10 minutes of backup power, Looking for alternatives to provide support for long outages	PAFC is difficult to maintain, Issues with parts availability, Dissatisfaction with durability and reliability of the system, Emissions from generators	No concerns	No concerns	Emissions, High capital costs of system	Maintenance of generators, Limited backup runtime	Generators – Emissions, High operations and maintenance costs; Batteries – Limited runtime
Performance Factors Users are Most Satisfied with – Current Technologies	Reliability, Lifetime, Start-up time, Fuel Availability	Annual operating cost, Start-up time, Emissions, Reliability	Fuel availability, Lifetime, Operations and maintenance (only UPS and generators)	Capital cost, Lifetime of unit, Start-up time	Fuel availability, Reliability, Ease of use, Lifetime	Data not available	Data not available	Data not available
Market Growth Potential for Backup Power	High	High	Low	Low	Low	Low	Medium to High	Medium to High
Interest in Alternatives for Backup Power	High interest	High interest	Low interest	Low interest	Low	High interest	High interest	High interest
Awareness of PEM Fuel Cells for Backup Power	Some level of awareness	Some level of awareness	Limited awareness	High level of awareness	Limited awareness	Some level of awareness	Limited awareness	Some level of awareness
Key Decision Factors for Capital Purchases	Initial capital cost, Payback period, Return on investment, Need for backup power	Initial capital cost, Payback period, Return on investment	Payback period	Payback period, Initial capital cost, Return on investment	Need, Funding availability, and Priority	Sustainability, Policy requirements, Initial capital costs, Return on investment	Return on investment, Energy savings, Lifetime	Return on investment, Initial capital cost
Importance of Government Incentives in Purchasing	Important	Important	Very important	Not so important	Not so important	Important	Important	Important
Potential Opportunity for PEM Fuel Cells in Backup Power Applications the Near-term	High	Medium	Low	Low	Low	Low	Medium	Medium
Drivers for PEM Fuel Cell Adoption	Environmental concerns, Regulatory	Need for longer runtime, Size requirements are a	"Green" image, User is building new facilities and	Historical use of fuel cell by the user for other	Energy efficiency	Lack of emissions from PEM fuel cells	Looking for longer runtime for certain applications	Dissatisfaction with operations and maintenance of

Table 2-6. **Analysis of the Potential for PEM Fuel Cells in Backup Power Applications in Government Market Segments.**

	State and Local Government	**Federal Agencies**						
Market Segment	**Emergency Response***	**NOAA (National Weather Service)**	**EPA (Facilities)**	**NASA (Facilities)**	**DOE (Facilities)**	**National Parks**	**USCG**	**FAA****
	requirements, Need for longer runtime, Size requirements are a good fit	good fit	is looking for alternative technologies	applications				batteries and generators, Size requirements are a good fit for PEM fuel cells
Barriers to PEM Fuel Cell Adoption	Initial capital cost is a consideration, Track record of others using PEM fuel cells is important	Capital cost of the PEM fuel cell may be a barrier, Unknown reliability of PEM fuel cells a concern	PEM fuel cells may be limited by size, Durability and capital costs of PEM fuel cells a concern	Availability of funds for non-critical facility (non-critical) expenditures, Decision to purchase is determined by total lifecycle cost of PEM fuel cells against alternatives	Availability of funds for non-critical facility (non-critical) expenditures, Limited information of PEM fuel cells	Availability of funds, Users are sensitive to initial capital cost, Users perceive that PEM fuel cells are not reliable	Power size of PEM fuel cells may limit application, Capital cost is a consideration for users in this segment, Reliability of PEM fuel cell may be a concern	Capital cost is the key financial consideration for users in this segment

*Emergency Response market includes state emergency response agencies, police stations, fire houses, and public service answering points (PSAPs).
**Individual segment analysis based on fiscal year 2005 surveys.

2.2.2 Composite Analysis of Trends in Backup Power Markets

Responses from 79 surveys and six protocol-based interviews from both phases of research are analyzed quantitatively across all backup market segments in this section. Twelve respondents in the backup power market were involved in the testing of the first version of the Phase 1 survey instrument. As a result, the analysis presented below will not include responses from these respondents on whether they had considered alternatives, whether incentives are important to them in making decisions, and if hydrogen fuel is a cause for concern.

2.2.2.1 Survey Participant Profile

Phase 1 and Phase 2 involved surveys of small, medium, and large companies. Table 2-7 identifies the size of respondents' organizations and the total number of respondents in both phases of research. For backup power, 39 respondents were from organizations with less than 500 employees; 18 respondents were from organizations with 500 to 3,000 employees, and 22 respondents were from organizations with over 3,000 employees.

Table 2-7. Number of Respondents to Phase 1 and Phase 2 Surveys by Size of Organization.

	Small	Medium	Large	Total Number of Respondents
Backup Power User	39	18	22	79
Specialty Vehicle User	4	5	17	26
Specialty Vehicle Manufacturers	12	7	5	24
Total by Size	55	30	44	129

2.2.2.2 Frequency and Duration of Outages

When asked about the frequency and duration of outages, responses were varied. Only 35 of 79 respondents identified the frequency of outages. While 14 respondents indicated that they frequently experienced outages, they were unable to provide an exact number. Figure 2-1 identifies the frequency of outages experienced by respondents. Of the 35 respondents, 21 had experienced between 1 and 5 outages in the last 12 months, six had experienced between 6 and 10 outages, and six had experienced between 10 and 15 outages. Only one respondent reported over 15 outages in the past 12 months.

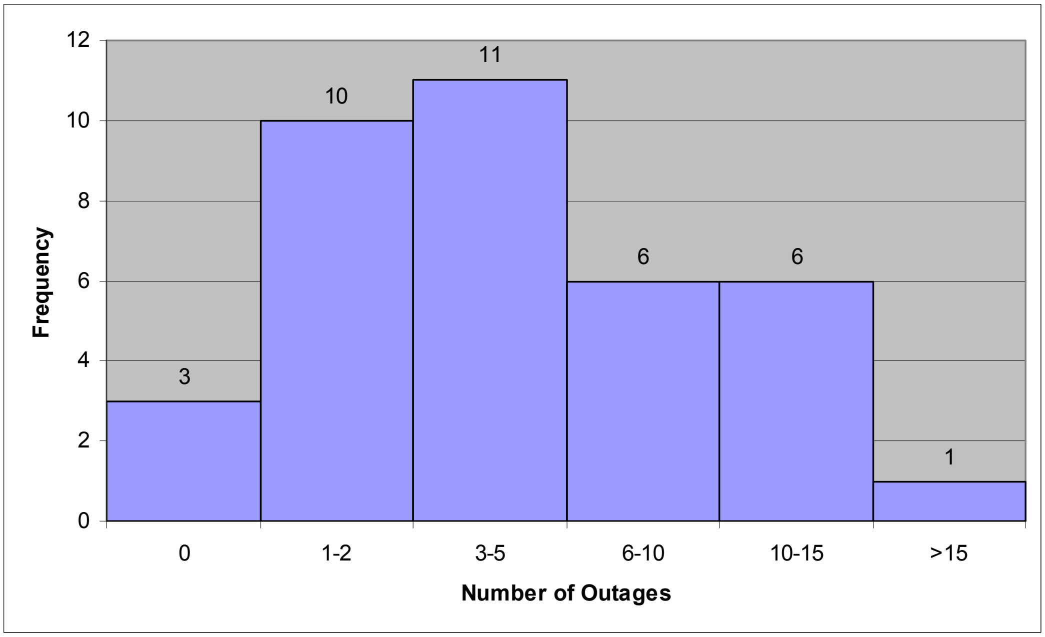

Figure 2-1. Number of Outages Experienced in the Past 12 Months.

Respondents were asked to estimate the duration of outages. Of the 79 respondents, 16 did not know the duration of outages experienced in the past 12 months. Outages less than 60 seconds were experienced 34% of the time, while outages over 5 minutes were experienced 22% of the time, outages between 5 minutes and 1 hour were experienced 22% of the time, and outages over 4 hours were experienced 13% of the time (Figure 2-2).

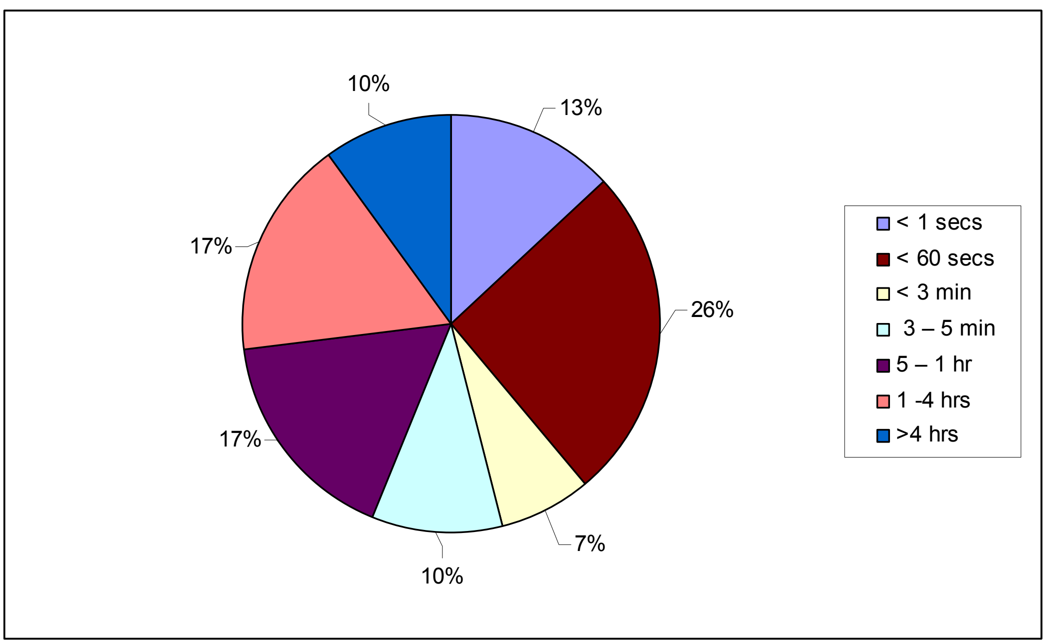

Figure 2-2. Duration of Outages Experienced in the Last 12 Months.

2.2.2.3 Current Backup Power Systems

Respondents were asked how backup power requirements are currently being met for their sensitive applications in both Phase 1 and Phase 2 surveys. Most respondents identified more than one source of backup power. Of the 79 respondents, 85% of the respondents used diesel or propane generators, 75% used UPS systems, and 46% used batteries to provide backup power. Approximately 14% of the respondents indicated that other forms of backup power were also used, including stand-by utility lines, wind power, and fuel cells (Figure 2-3).

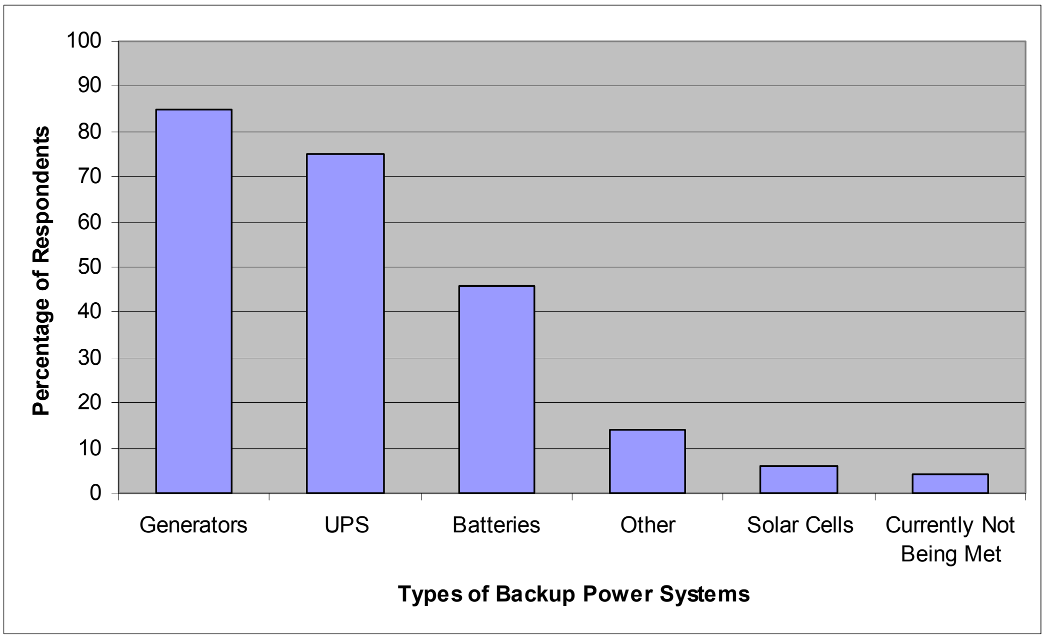

Figure 2-3. Current Sources of Backup Power.

2.2.2.4 Satisfaction with Current Systems

In the Phase 1 survey, respondents were asked to identify their level of satisfaction with their backup systems. Most users rated the performance of their system as good or very good. Of the 72 respondents in Phase 1, 57 respondents answered this question. The average response was 5.8 on a scale of 1 to 7, with 1 being not so good and 7 being very good. The mode of the distribution was 6 with a standard deviation of 0.96. Respondents were also asked if they had any specific concerns about their backup power systems; 44 respondents indicated that they did not have any concerns. Of the 28 respondents who identified concerns with current systems, 15% identified emissions as a concern (Figure 2-4).

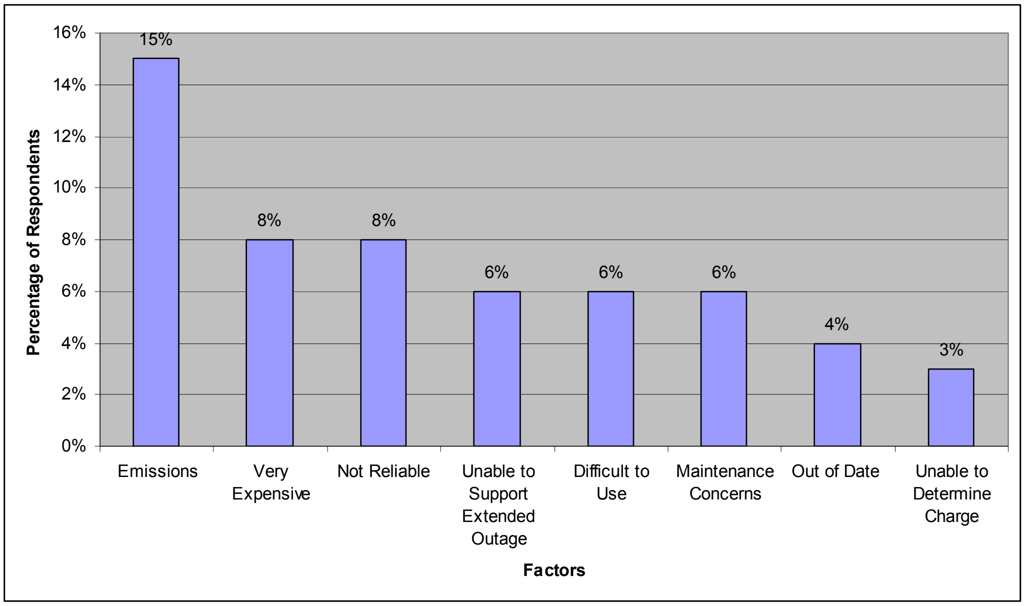

Figure 2-4. Factors of Concern with Current Backup Systems.

Users were asked to rate the performance of their backup power systems for a variety of characteristics. Of the 79 respondents, 75% of the respondents identified reliability as very good, 73% identified start-up time as very good, and 71% identified fuel availability as very good. However, of the 79 respondents, only 28% identified capital cost and 27% identified emissions as very good. Figure 2-5 shows the distribution of the ratings received for various backup system factors (on a scale of 1 to 7, 7 was very good and 1 not so good).

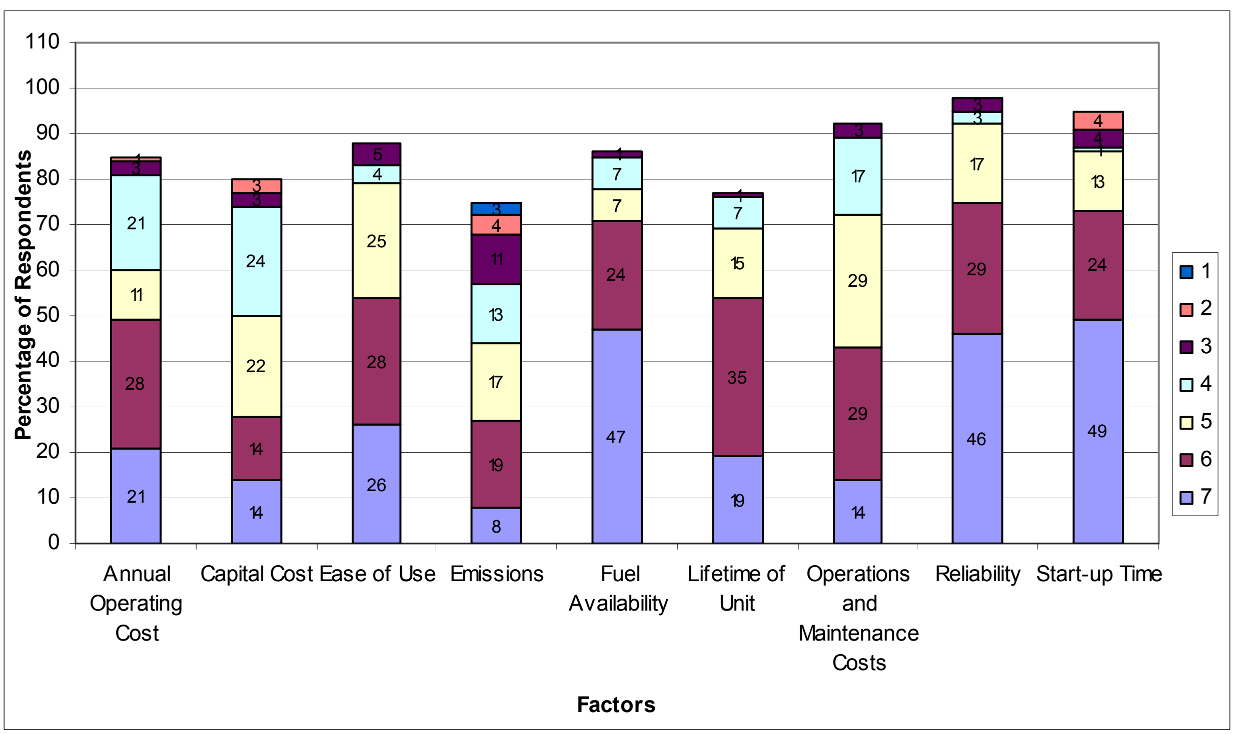

Figure 2-5. User Satisfaction with Various Backup Power System Characteristics.

2.2.2.5 Purchase Decision Factors

Users were also asked to identify the importance of various factors when selecting a backup power system (on a scale of 1 to 7, 7 was very important and 1 not so important). Of the 79 respondents, 98% identified reliability as very important, 78% identified start-up time as very important, 72% identified fuel availability as very important, 67% identified good experience with this type of system in the past as very important, 65% identified ease of use as very important, 62% identified lifetime of unit as very important, 50% identified capital cost as important, 45% identified emissions as very important, and only 39% identified annual operating cost as very important (Figure 2-6). When asked to identify three factors that would most influence their decision to purchase an alternative backup power system, users identified reliability, capital cost, and ease of use.

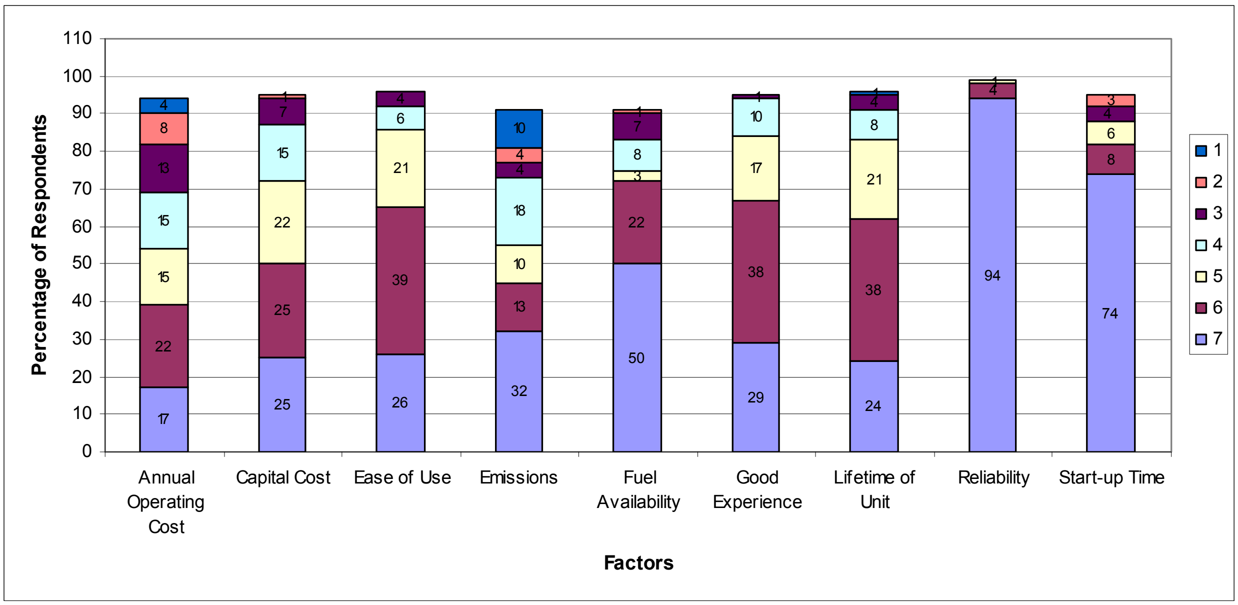

Figure 2-6. Importance of Various Factors in Selecting a Backup Power System.

2.2.2.6 Trends and Potential for Backup Power Applications

When asked if they had considered alternatives to their current sources of backup power, 30% of respondents indicated that they had considered alternatives. Of the respondents who had considered alternatives, 43% had considered fuel cells.

Users were asked if they were familiar with PEM fuel cells as a source of backup power. Of the 79 respondents, 63% were not familiar with PEM fuel cells, while 33% of the respondents were familiar with PEM fuel cells, and 4% of respondents did not answer this question. Of the respondents familiar with PEM fuel cells, 30% believed that PEM fuel cells will compete favorably with existing alternatives in the backup power market. Respondents familiar with PEM fuel cells indicated that the track record of others using PEM fuel cells and the availability of government incentives were the primary drivers for adoption, followed by environmental concerns, energy efficiency of PEM fuel cells, and the cost of not having electricity.

Of the 79 respondents, only 37 users responded to the question about whether they were concerned about hydrogen as a fuel. Just 22% of the respondents indicated that they had concerns about hydrogen as a fuel, while 59% indicated that they had no such concerns; the remaining 19% did not know enough about hydrogen to make an accurate determination.

Candidate users were asked to identify how capital purchase decisions were made in their organization for backup power. Of the 79 respondents, three users did not address this question. Respondents indicated that typically more than one factor was considered when making capital purchase decisions. Of the 79 respondents, 56% of the respondents indicated that initial capital cost was taken into consideration; 35% of the respondents indicated that return on investment was an important consideration; 35% mentioned that the payback period was an important consideration; and 11% indicated that a need for backup power would drive their purchase decisions.

Candidate users were asked if incentives are considered when making capital purchase decisions. Of the 79 respondents, 41% consider incentives when making capital purchase decisions; 28% did not consider incentives when making capital purchase decisions; 10% did not know if incentives were considered when making capital purchase decisions; 5% did not answer the question; and 16% were not asked the question.

2.3 Analysis of Specialty Vehicle Markets

This section presents qualitative and quantitative analyses of the key trends, drivers, and requirements identified by users and integrators for the adoption of PEM fuel cells in specialty vehicle markets. Analyses of trends in individual segments (section 2.3.1), as well as a composite analysis of trends across specialty vehicle markets (section 2.3.2), are presented in this section. Individual specialty vehicle market segment reports can be found in Appendix C. Detailed analyses of two specialty vehicle markets – forklifts in distribution centers and ground support equipment in airports – can be found in section 3.0.

2.3.1 Analyses of Individual Specialty Vehicle Market Segments Based on User and Integrator Responses

Of the 36 market segments analyzed, 12 market segments were analyzed for their potential to adopt PEM fuel cells in specialty vehicles in the near-term (2008). The number of respondents for each market segment and the sizes of the organizations surveyed are presented in Table 2-8. This section presents Battelle's analysis of the trends in individual specialty vehicle segments, as determined through surveys, interviews, and secondary research.

The UAV and UUV markets were examined to identify potential near-term applications. Market research indicated that early applications for UAVs and UUVs were for military applications. Limited primary information was available on user requirements, and secondary information indicated that PEM fuel cells are in development for these markets. For ice resurfacers, no primary information could be gathered on user requirements due to non-response to surveys. Secondary information indicates that there is some concern about indoor emissions from ice resurfacers and the capital costs of PEM fuel cells when integrated as a power source. For motorized bicycles and scooters, secondary research indicates that primary markets will be outside of the U.S. Furthermore, limited information was available on user requirements in the U.S. As a result, information on UAVs, UUVs, ice resurfacers, and bicycle and scooter market segments are not presented in the individual segment analysis presented in Table 2-9. Secondary information gathered on these market segments is presented in Appendix C.

Table 2-8. Total Number of Respondents and Size of Organizations Surveyed for Specialty Vehicles.

Market Segment	Number of Survey Respondents*	Number of Interviewees	Size of Survey Respondent's Organization+		
			Small	Medium	Large
Automatic Guide Vehicles	3	-	1	1	1
Mining Vehicles	5	2	2	2	1
Airport Ground Support Equipment	13	8	4	1	8
Forklifts	17	3	4	4	9
Golf Carts+	3	1		1	1
Turf Maintenance Vehicles	3	-	1	1	1
Commercial Sweepers	3	-	1	1	1
Ice Resurfacers	-	-	-	-	-
Wheelchairs	3	-	-	2	1
UAVs	1	1	1		
UUVs	-	2			
Motorized Bicycles/Scooters	-	-	-	-	-
Total	51	17	14	13	23

Small is classified as 500 employees or less, medium is classified as 500 to 3000 employees, and large is over 3000 employees; *Includes integrators. + Two responses were received from one golf cart manufacturer.

All market segments indicated concerns over their current mode of operation except the wheelchair and automatic guide vehicle markets. Of the eight specialty vehicle market segments analyzed for PEM fuel cell opportunities to 2015, four are interested in alternative technologies: airport ground support equipment, forklifts, golf carts, and turf maintenance equipment (Table 2-9). Except for the forklift market segment, users are interested in alternatives to ICE-powered vehicles to meet emission requirements and to decrease operations and maintenance requirements. In the forklift market segment, users are interested in technologies that can increase their productivity and provide alternatives to batteries. Trends in this market segment indicate that users are concerned about the maintenance and safety aspects of lead-acid batteries. Reliability is of paramount importance when selecting a specialty vehicle power source among all market segments analyzed. Other factors that are important include the lifetime of the unit, the availability and affordability of fuel, and ease of use. Except the golf cart and wheelchair market segments, all market segments consider return on investment when making capital purchase decisions. Government incentives are more important in those market segments with regulatory concerns (airports and mining). Fuel availability is a critical requirement for adoption of PEM fuel cell-powered specialty vehicles.

Table 2-9. Specialty Vehicle Market: User and Integrator Analysis Data.

Market Segment	Airport Ground Support Equipment	Forklifts	Mining Vehicles	Automatic Guide Vehicles	Golf Carts	Turf Maintenance Vehicles	Commercial Sweepers	Wheelchairs
Applications	Baggage tractors, Cargo tractors, Tow/pushback tractors, Push out tractors, Belt loaders	Material handling	Load-haul-dump vehicles, Skid-steer loaders, Shuttle cars/ramcar/shield haulers, Roof bolters, Personnel vehicles, Road graders, Drill jumbos	Materials handling vehicles in manufacturing and assembly plants	Golf courses, Individual users, Gated communities, Hospitals, Parking facilities, Warehouses, Universities, Manufacturing industry, Shuttle and tram users	Walking and Riding mowers, Golf courses, Sports fields, schools, Municipalities, Landscapers, Individual/ residential consumers	Automatic sweepers, Scrubbers, Burnishers, Blowers, Dryers, Carpet extracters, Floor moppers; Commercial use, Industrial use, Residential use	Power wheelchairs and racing wheelchairs; Limited mobility individuals and dealers (who sell products to hospitals and care providers)
Most Critical Applications	Baggage tractors, Pushback tractors, Belt loaders in Airports	Material handling (rider reach trucks and pallet reach truck applications) in distribution centers	Loaders, Haulers, Drill jumbos	Pallet trucks in manufacturing facilities like automotive assembly plants and paper manufacturing	Cars/carts in golf courses	Riding mowers used by landscaping companies	Heavy industrial applications with concerns about product contamination, Large manufacturing facilities with multiple shifts and complicated logistics	All of the above
Economics and Other Downtime Impacts	High; Results in loss in productivity and increased operation and maintenance costs	High; Results in loss in productivity, disruptions in distribution, and increased operation and maintenance costs	High; Results in loss in productivity, disruptions in distribution, increased operation and maintenance costs, and safety issues	High; Results in disruption in distribution and loss in productivity	Low; Results in customer dissatisfaction	High; Results in loss of productivity and increase in operations and maintenance costs	Medium to High; Dependent on type of operations; Results in disruption of production and decline in productivity	Low; Results in decreased individual mobility and in customer dissatisfaction
Types of Specialty Vehicles Used	Battery vehicles, ICE vehicles - gasoline, diesel, and propane	Battery vehicles, ICE vehicles - diesel and propane	Battery vehicles, ICE vehicles - diesel, gasoline, and propane	Battery systems	Battery vehicles, ICE vehicles - gasoline	ICE vehicles - gasoline and diesel	Battery vehicles, ICE vehicles - gasoline, diesel, and propane	Battery vehicles and propane ICE
User Requirements – Reliability	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important
User Requirements – Capital Cost	Very important	Important	Important	Important	Very important	Very important	Very important	Very important
User Requirements – Lifetime	Very important	Very important	Important	Very important	Very important	Very important	Very important	Very important
User Requirements – Annual Operating Cost	Very important	Very important	Important	Important	Very important	Very important	Very important	Very important

Table 2-9. **Specialty Vehicle Market: User and Integrator Analysis Data.**

	Market Segment	Airport Ground Support Equipment	Forklifts	Mining Vehicles	Automatic Guide Vehicles	Golf Carts	Turf Maintenance Vehicles	Commercial Sweepers	Wheelchairs
User Requirements	Emissions	Important	Very important	Very important	Not applicable	Very important	Very important	Very important	Very important
	Start-up Time	Important	Important	Important	Very important	Important	Important	Important	Very important
	Time Between Refueling	Important	Important	Important	Very important	Not so important	Important	Important	Not so important
	Ease of Use	Very Important	Important	Very important	Very important	Very important	Very important	Very important	Very important
	Fuel Availability	Important	Very important	Important	Not applicable	Very important	Very important	Very important	Very important
	Good Experience	Important	Very important	Very important	Very important	Very important	Very important	Very important	Important
Most Important User Requirements		Reliability, Lifetime of unit, Annual operating cost	Reliability, Lifetime of unit, Fuel availability, Capital cost	Reliability, Good experience with the system, Ease of use, Emissions	Reliability, Start-up time, Lifetime	Capital costs, Lifetime, Fuel availability	Capital costs, Emissions, Fuel Availability	Capital costs, Lifetime, Emissions	Capital costs, Ease of use, Reliability, Safety
User Satisfaction With Current Technologies		Satisfied, with some concerns	Not so satisfied	Satisfied, with some concerns	Satisfied	Satisfied, with some concerns	Not so satisfied	Satisfied, with some concerns	Satisfied
User Concerns with Current Technologies		ICE vehicles - hazardous emissions; Battery vehicles - inconvenient to recharge, takes to long to recharge, and causes hazardous spills and leaks	ICE vehicles - emissions are a concern, operations and maintenance is a concern; Battery vehicles - inconvenient to recharge, causes leaks and spills, takes too long too recharge, cool, and equalize the batteries, and lifetime is reduced with fast recharging	ICE vehicles - hazardous emissions; Battery vehicles - spills and leaks, inconvenient to recharge, and takes to long to change batteries	No concerns when sealed lead-acid batteries are used	Concerns with reliability and performance of ICE vehicles	Concerns with noise and emissions from ICE vehicles	ICE vehicles - hazardous emissions; Battery vehicles - spills and leaks, inconvenient to recharge, and requires venting	Some concerns with weight of the batteries
Market Potential for Specialty Vehicles		Medium	High	High	Low	High	High	Medium	Low-Medium
Interest in Alternatives for Specialty Vehicles		High for ICE vehicles	High for batteries and ICE vehicles in high use operations	Limited interest	No interest	Medium for replacing ICE vehicles	High for replacing diesel ICE vehicles	Limited interest	Limited interest

Table 2-9. **Specialty Vehicle Market: User and Integrator Analysis Data.**

Market Segment	Airport Ground Support Equipment	Forklifts	Mining Vehicles	Automatic Guide Vehicles	Golf Carts	Turf Maintenance Vehicles	Commercial Sweepers	Wheelchairs
Awareness of PEM Fuel Cells for Specialty Vehicles	High level of awareness	Some level of awareness	Some level of awareness	Limited to no awareness	Limited awareness	Limited awareness	Limited awareness	Limited awareness
Key Decision Factors for Capital Purchases	Return on investment, Total lifecycle costs, Total lifetime of the system	Return on investment, Payback period, Initial capital costs	Return on investment, Initial capital cost, Payback period	Return on investment	Initial capital cost	Return on investment, Initial capital cost	Initial capital costs, Return on investment	Initial capital cost
Importance of Government Incentives in Purchasing	Important	Not so important	Important	Not so important	Not so important	Not so important	Not so important	Important
Potential Opportunity for PEM Fuel Cells in the Near-term	Medium	High	Low-Medium	Low	Low	Low	Low	Low
Drivers for PEM Fuel Cell Adoption	Environmental concerns, Other regulatory drivers	Users are interested in increasing productivity, Users are interested in alternatives to batteries, Environmental concerns	Environmental concerns, Regulatory drivers	No apparent drivers	No apparent drivers, Some users are concerned about emissions	Environmental concerns, Users are looking for ways to reduce operations and maintenance costs	No apparent drivers, Some users are concerned about emissions	No apparent drivers, Some manufacturers have considered PEM fuel cells as battery rechargers
Barriers to PEM Fuel Cell Adoption	Capital costs and lifetime of PEM fuel cells may be a concern	Fuel availability, capital costs, and lifetime of PEM fuel cells may be a concern, Serviceability of PEM fuel cells also a concern	Users are unsure that PEM fuel cells are reliable and durable for heavy duty applications, Limited interest in alternatives, Users are price sensitive, Also concerns over the safety of hydrogen exist	Lack of reliability information on PEM fuel cells, Concerns about cost of PEM fuel cells, Ability to maintain and service systems	Users make their decisions to purchase based on initial capital cost, PEM fuel cells will have to be competitive with electric vehicles	Users are sensitive to capital costs, Weight restrictions for turf vehicles may limit the application of heavy hydrogen tanks, Performance has to be competitive with ICE vehicles before users will switch	PEM fuel cells are limited technically and may not be a suitable alternative in high power draw applications, Capital costs are a barrier, Performance has to be competitive with ICE vehicles	Users are sensitive to capital costs, Lack of a practical hydrogen distributing system

2.3.2 Composite Analysis of Trends in Specialty Vehicle Markets Based on User Responses and Manufacturer Responses

2.3.2.1 Specialty Vehicle User Responses

Survey Participant Profile

Responses were received from 26 specialty vehicle users. Of these users, 17 were large organizations with over 3,000 employees, five were from medium sized companies with 500 to 3,000 employees, and four were from small sized companies with less than 500 employees (Table 2-7). At the time of this composite analysis only 28 survey responses were received; as a result, responses from 28 surveys and 11 protocol-based interviews from both phases of research are analyzed across all specialty vehicle market segments in this section. The response from one large forklift user was excluded in this analysis but included in the individual segment analysis discussed in section 3.0.

Impact of Downtime

Of the 26 respondents, 8% of respondents experienced downtime events in the past 12 months lasting between 5 and 30 minutes; 15% of the respondents experienced downtime events lasting between 30 minutes and 1 hour; 38% of respondents experienced downtime events lasting between 1 and 4 hours; 31% of the respondents experienced downtime events between 4 and 8 hours; 31% of the respondents experienced downtime events lasting over 8 hours; and 12% did not know the duration of the experienced downtime incidents.

Users in the Phase 1 survey were asked to identify the impacts of downtime incidents. Of the 13 respondents, 12 indicated that downtime results in a loss of productivity through decreased movement of materials; 10 indicated that downtime increased operations and maintenance costs; and 10 reported decreases in labor productivity due to downtime incidents. Respondents indicated that downtime incidents greater than 4 hours were very disruptive to their operations. Disruptions between 30 minutes and 4 hours were not as disruptive because backup vehicles could be utilized in the interim period. If backup vehicles were not available, downtime incidents of 30 minutes could severely disrupt operations.

Specialty Vehicles Currently in Use

Respondents were asked to identify the types of specialty vehicle systems currently in use. Of the 26 respondents, 69% used electric vehicles, 38% used diesel ICE, 35% used propane ICE, and 19% used gasoline ICE. The majority of respondents used more than one type of specialty vehicle, which varied by application. For example, for heavy lifting or pushing, users of forklifts and airport tugs typically utilized ICE equipment.

User Satisfaction with Specialty Vehicles

When asked about their satisfaction with current specialty vehicles in Phase 1 research, most specialty vehicle users indicated that they were satisfied with their current mode of operation. Three of 13 respondents did not respond to this question. Specialty vehicle users were asked to rate their satisfaction on a scale of 1 to 7, with 7 being very satisfied and 1 being very dissatisfied. The average response was 5.1 with a standard deviation of 1.3. The mode of the distribution was 6. However, of these 13 respondents, eight identified concerns with the current mode of operation. The primary concerns identified were spills and leaks from batteries, the inconvenience of recharging batteries, the time required to swap out batteries, and the time required for refueling and/or recharging.

In Phase 1 and Phase 2 surveys, users were asked to rate the performance characteristics of their specialty vehicles currently in use on a scale of 1 to 7, with 1 being not so good and 7 being very good. Approximately 85% of the respondents identified fuel availability as very good; 62% identified reliability as very good; 62% identified start-up time as very good; and 61% identified operations and maintenance costs as very good. Users were less satisfied with capital cost (46%) and time between refueling (38%). Ratings of user satisfaction by performance factors are presented in Figure 2-7.

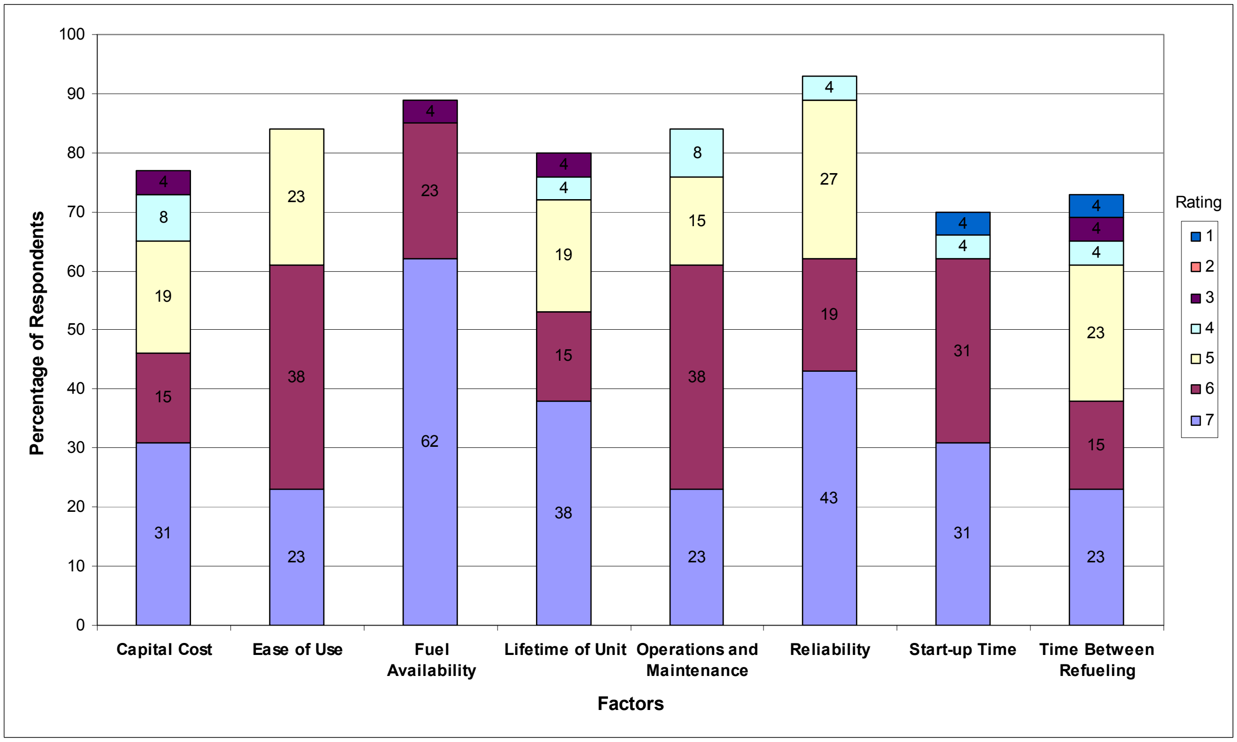

Figure 2-7. User Satisfaction with Specialty Vehicle Characteristics.

Purchase Decision Factors

Users were also asked to identify the importance of various characteristics when selecting specialty vehicles on a scale of 1 to 7, with 1 being not so important and 7 being very important. All respondents identified reliability as very important when selecting a specialty vehicle. Approximately 73% of the respondents identified the lifetime of the unit as important; 70% identified annual operating cost as important; 66% identified ease of use as very important; and 65% identified fuel availability and good experience with the system as very important. Time between refueling (42% of respondents) and start-up time (46% of respondents) were considered less important than most of the other factors identified by specialty vehicle users. The importance of various performance factors when selecting a specialty vehicle is presented in Figure 2.8.

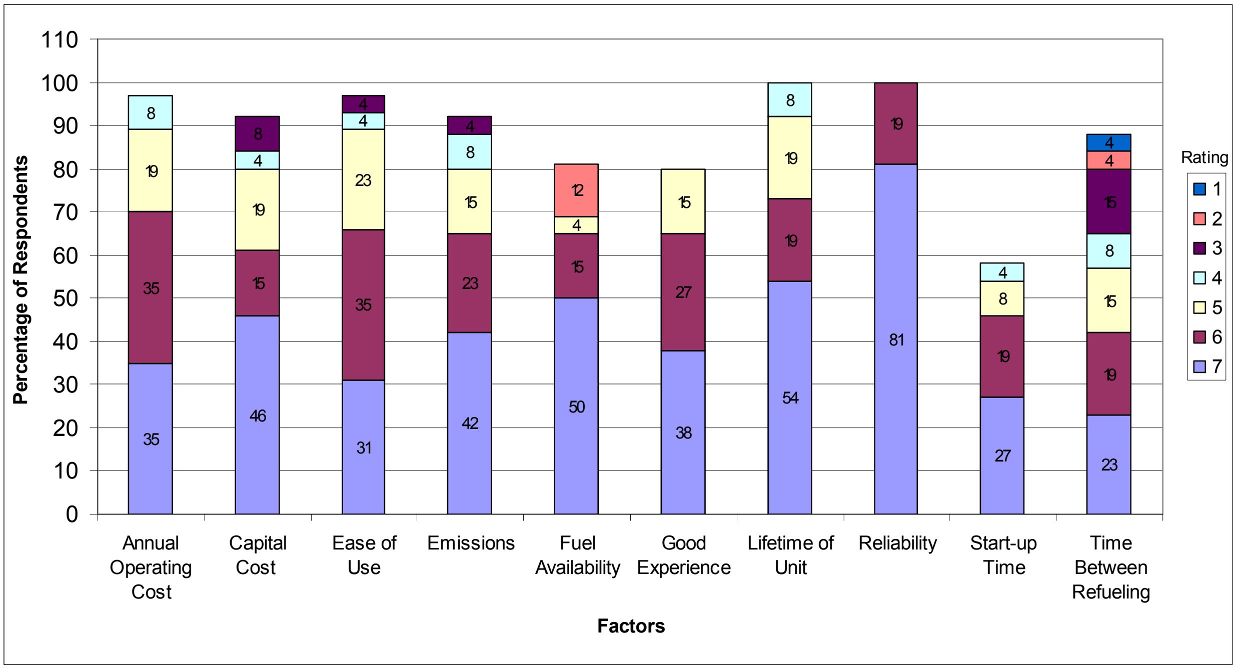

Figure 2-8. Importance of Various Characteristics When Selecting a Specialty Vehicle.

Capital purchase decisions are made based on a variety of factors. Approximately 48% of the respondents indicated that purchase decisions were based on return on investment; 20% indicated that decisions were made on initial capital cost; 20% indicated that they considered payback period. In addition, of the 26 specialty vehicle users surveyed, 48% indicated that incentives were considered, 33% indicated that incentives were not considered, and 19% did not know if incentives were considered when making purchasing decisions.

Potential for PEM Fuel Cells in Specialty Vehicles

When asked if users had considered alternatives, respondents were evenly split. Half (50%) of the respondents indicated that they had considered alternatives, while the other half had not. Airport tug users had considered alternatives such as compressed natural gas vehicles and adding more electric vehicles to their fleet. Approximately 62% of the respondents had not heard of PEM fuel cells as an alternative, while 38% had. Of the 20 users that responded, 25% thought that PEM fuel cells would compete favorably with current power sources, while 75% did not. The primary factors identified as driving the adoption of PEM fuel cells, in order of frequency, are: environmental concerns, availability of government incentives, costs incurred from downtime, track record of others using PEM fuel cells, energy efficiency of PEM fuel cells as compared to alternatives, and dissatisfaction with current mode of operation. Respondents were asked if hydrogen was a cause for concern. Of the 21 specialty vehicle users who responded to the question, 43% indicated that they were concerned about hydrogen, 33% did not know if hydrogen concerned them, 14% were not concerned, and 10% were somewhat concerned.

2.3.2.2 Specialty Vehicle Manufacturer Responses

Survey Participant Profile

Responses from 23 integrators are summarized in this section. A total of 24 survey responses were received from manufacturers of airport ground support equipment, forklifts, automatic guide vehicles, commercial sweepers, golf carts, lawn mowers, UAVs, and wheelchairs. Responses were received from 11 small companies with less than 500 employees, seven medium companies with 500 to 3,000 employees, and five large companies with more than 3,000 employees. Two responses were received from a large golf cart manufacturer. Survey questions were qualitative in nature and were designed to provide insight into manufacturers' satisfaction with current technologies and interest in alternative technologies, as well as the potential for PEM fuel cells to be used by their organizations. Respondents to the survey were product development managers, directors or managers of R&D, directors of marketing, marketing managers, or sales managers.

Most Critical Applications and Impact of Downtime

Of the eight segments analyzed, from the manufacturer's perspective, forklift users, automatic guide vehicle users, and airport ground support equipment users are most severely impacted by downtime. Downtime results in productivity losses, production and distribution disruptions, and increased operations and maintenance costs.

Satisfaction with Current Technologies

Of the manufacturers surveyed, 88% manufactured and/or distributed battery-powered vehicles, 29% manufactured and/or distributed propane ICE-powered vehicles, 42% manufactured and/or distributed diesel ICE-powered specialty vehicles, and 38% manufactured and/or distributed gasoline ICE-powered vehicles. Manufacturers indicated that safety concerns with regard to batteries are minimal, especially when appropriate handling and safety methods are used. Because users do not always follow the recommended methods, there is some concern regarding spills and leaks of acid from batteries, disposal of batteries, weight of batteries, and wastewater containment from washing of batteries. The primary concerns identified with ICE-powered vehicles were emissions. Only 13% of the manufacturers surveyed were dissatisfied with their current mode of operation. However, 50% of the respondents indicated that there was opportunity to improve and had considered alternatives.

Perceptions and Potential for PEM Fuel Cells in Specialty Vehicles

Of the 24 responses received, 71% of respondents had heard of PEM fuel cells for specialty vehicles, 42% have considered PEM fuel cells as alternatives for their applications, and 25% considered PEM fuel cells to be a viable alternative for their applications. Cost, reliability, lifetime, fuel availability, and performance when subjected to varied power draws were identified as the most important factors when considering alternatives.

Manufacturers in the forklift, airport tug, turf equipment, commercial sweeper, and automatic guide vehicle markets were among those that considered PEM fuel cells as a viable alternative to existing power sources. Manufacturers noted that while PEM fuel cells may be viable for some users, certain requirements would need to be met before widespread adoption could occur, including the availability and affordability of hydrogen fuel and storage options, service and maintenance infrastructure, a supply chain for PEM fuel cells, and more durable PEM fuel cells.

Manufacturers indicated that important drivers for the PEM fuel cell market will include: a demonstrated return on capital investment, demonstrated improvements in productivity, government incentives, and demonstrated environmental benefits. Of the manufacturers surveyed, 33% were unsure of whether hydrogen would be a cause for concern among users, while 29% indicated that it would not. Only approximately 8% of the manufacturers surveyed indicated that hydrogen may be a cause for concern.

2.4 Analysis of Most Promising Near-term and Mid-term Pre-Automotive Markets

To prioritize near-term and mid-term markets, the rating criteria developed in consultation with DOE and industry (section 1.1.1) were applied to market research data for the 36 market segments (Appendix C). These rating criteria were applied to identify a set of near-term and mid-term markets (Table 2-10) for PEM fuel cells in both backup and specialty vehicle applications. Near-term markets are those in which PEM fuel cells have a unique value proposition, based on the rating criteria, and tend to be less sensitive to cost. Mid-term markets are those in which PEM fuel cells can provide value over existing technologies if specific barriers (including capital cost) are addressed.

Table 2-10. Most Promising Near-term and Mid-term Markets.

Near-term Markets (By 2008)		Mid-term Markets (Beyond 2012)	
Backup Power	**Specialty Vehicles**	**Backup Power**	**Specialty Vehicles**
▪ Telecommunications ▪ Emergency response communications* ▪ Federal agencies – FAA, NOAA, USCG	▪ Forklifts in distribution centers* ▪ Ground support equipment in airports*	▪ Railways ▪ Electric utilities ▪ Data centers ▪ Water and wastewater utilities ▪ Financial service providers ▪ Other government agencies (backup power for buildings, police stations, fire stations) ▪ Healthcare ▪ Airports ▪ Manufacturing ▪ Grocery stores	▪ Automatic guided vehicles ▪ Turf maintenance vehicles ▪ Industrial tow tractors ▪ Mining vehicles ▪ Golf carts

*Selected for further analysis.

A detailed assessment of the value proposition for PEM fuel cells was conducted in three near-term market segments: emergency response backup power, forklifts in distribution centers, and ground support equipment in airports. While telecommunications is the most promising near-term market, this market segment was analyzed in detail in an earlier report and therefore is not included in this analysis.[19] The FAA, NOAA, and USCG also represent promising near-term

[19] Battelle. 2006. Economics of Stationary PEM Fuel Cell Systems. For the Department of Energy, DOE Contract No. DE-FC36-03GO13110.

markets in federal agencies; however, adoption in these markets is driven by the availability of funds and the mandates set under the provisions of EPAct 2005. As a result, the most likely near-term opportunities where adoption can be expected due to the value that PEM fuel cells offer were chosen for further analysis.

3.0 MARKET OPPORTUNITY ASSESSMENT OF THREE NEAR-TERM PRE-AUTOMOTIVE MARKETS

This section presents the market opportunity for PEM fuel cells in three near-term pre-automotive market segments including state and local emergency response agencies, forklifts in high-throughput distribution centers, and airport ground support equipment. For each near-term market opportunity, the value proposition of PEM fuel cells is determined through analysis of market requirements as identified through secondary research, user requirements and user satisfaction, as determined through primary research, lifecycle cost analysis of PEM fuel cells and competing alternatives, and a sensitivity analysis of various factors on the costs of owning and operating a PEM fuel cell. Analysis of the market penetration of PEM fuel cells in three cases is also presented for each near-term market segment.

3.1 PEM Fuel Cells in Backup Power Applications in State and Local Emergency Response Agencies

3.1.1 Market Attributes

3.1.1.1 Market Segment Description

The emergency response market segment is comprised of state and local agencies that are responsible for providing or coordinating emergency response services, including: fire agencies, police agencies, emergency medical services, and state emergency management agencies. Fire agencies are establishments primarily engaged in firefighting and other related fire protection activities. Police agencies are establishments primarily engaged in law enforcement, traffic safety, police, and other activities related to the enforcement of the law and preservation of order. Emergency medical service providers, including first responders, paramedics, and emergency medical technicians (EMTs), administer early (pre-hospital) treatment to those in need of urgent medical care and transport sick or injured parties to medical care facilities. State emergency management agencies are responsible for coordinating all phases of homeland security and disaster response activities within the state.

This analysis examines general backup power needs within the emergency response market segment and includes a more detailed look at one promising application for fuel cells at radio tower sites. Table 3-1 identifies the primary Standard Industrial Classification (SIC) and North American Industry Classification System (NAICS) codes associated with emergency response; these codes were used to help characterize the market and identify potential survey participants.

Within the emergency response market segment, backup power is primarily used to support 911 call centers, including the equipment required to operate computer-aided dispatch units; radio network infrastructure, including radio and microwave transmitter sites; basic facility operations; and emergency lighting.

Table 3-1. SIC and NAICS Codes Relevant to State and Local Departments of Emergency Response.

2-Digit Sic Codes	41 – Local and suburban transit and interurban highway passenger transportation 92 – Justice, public order, and safety
4-Digit SIC Codes	4119 – Local passenger transportation, nec[20] 9221 – Police protection, law enforcement 9224 – Fire protection 9229 – Public order and safety, nec
NAICS Codes	621910 – Ambulance services 922120 – Police protection 922160 – Fire protection 922190 – Other justice, public order, and safety activities

The backbone of the emergency response system is the 911 call response network – the official national emergency number in the United States and Canada. A 911 call travels over dedicated phone lines to the 911 answering point closest to the caller, and trained personnel then send the emergency help needed. The most important elements of 911 networks, and therefore the most critical applications of backup power, are the 911 call centers (including the telephones, computers, and other equipment used to handle calls) and the radio network infrastructure used by state and local emergency response agencies for communication.

Every 911 call for emergency assistance in the United States is answered by a 911 call center, also known as a Public Safety Answering Point (PSAP).[21] At the PSAP, the operator verifies the caller's location, determines the nature of the emergency, and decides which emergency response teams should be notified. Sometimes, a single primary PSAP will answer for an entire region. In most cases, the caller is then transferred to a secondary PSAP, from which help will be sent. Secondary PSAPs are sometimes located at fire dispatch offices, municipal police headquarters, hospitals, or ambulance dispatch centers. Typically, PSAPs are operated by counties but can also be run by municipalities or other governmental jurisdictions.

Radio networks enable reliable communications in emergency situations. Some radio networks are designed to support communications within a single agency. More sophisticated networks allow agencies to communicate with one another. For example, Ohio's Multi-Agency Radio Communications System (MARCS) provides mobile voice, data, vehicle location, and computer-aided dispatching services within a single computer system that is shared by multiple state agencies. MARCS allows multiple emergency response agencies to communicate with each other from anywhere in Ohio. Radio networks are comprised of several different types of electrical equipment, including radio and microwave towers, signal transmitters and receivers, and computer switching gear.

In addition to backup power for 911 call centers and radio network infrastructure, backup power is also needed by state emergency management agencies and other response organizations for emergency response field operations, which require on-site electricity generation for field phones, computers, and medical units.

[20] Not Elsewhere Classified.
[21] Mohney, D. 2004. Call Centers Prepare For The Worst. Available at http://mrtmag.com/mag/radio_call_centers_prepare/index.html [Accessed July 2006].

The impact of power outages on this market segment can be catastrophic. Emergency preparedness and response operations depend on the reliability and quality of first responders' energy supplies. If primary grid power goes down, so can 911 and state emergency communication centers, first responder stations, hospitals, control centers, traffic signals, public transportation, and vital infrastructure such as water pumping and filtration systems. For example, severe flooding in the wake of Hurricane Katrina caused power outages across the Gulf Coast, making it impossible in many areas to deliver emergency supplies and diesel fuel for backup power. The lack of electricity, lights, and communications throughout the region made emergency response missions extremely difficult. Some 911 calls went unanswered for several days because of power outages. Many hospitals and other critical emergency services were unable to rely on their backup diesel generators due to lack of fuel or mechanical failure, with fatal consequences.[22] In contrast, the fuel cell in the New York Police Department's Central Park Station kept the facility running during the big blackout of 2003.[23]

Commonly used technologies that provide backup power to emergency response agencies include generators (diesel and propane), uninterruptible power supplies (UPS), and batteries. Generators are typically used to provide support for both critical and non-critical loads. Unlike UPS systems and batteries, generators can provide backup power for extended periods of time (with adequate fuel supplies). Batteries and UPS systems are generally used as short-term backup power for telecommunications equipment and computer systems and can be used in conjunction with generators. UPS systems provide sufficient power to run the equipment for several minutes to several hours until the generators can take over. Batteries and UPS are typically used only to power critical loads.

3.1.1.2 Market Size

Current market size data for the emergency response market segment are provided below as the number of potential fuel cell adopters. Table 3-2 provides data on the primary SIC codes related to emergency response. SIC Code 4119 (local passenger transportation, nec) covers ambulance services; SIC Code 9221 (police protection, law enforcement) covers police services; SIC Code 9224 (fire protection) covers fire response services; and SIC Code 9229 (public order and safety, nec) covers state emergency management agencies. It should be noted that correctional institutions (SIC Code 9223) also serve an important role in public safety and may someday represent an opportunity for fuel cell integration; however, these institutions are not considered a potential market at this time, and therefore are not covered here. In Table 3-2, only those eight-digit SIC specialties deemed relevant to emergency response services are shown.

The size of the emergency response market is significant. As illustrated in Table 3-2, there are 5,770 ambulance services; over 3,000 state, county, and municipal police agencies; and 20,632 fire departments in the United States. An estimated 99% of the U.S. population has access to

[22] Clean Energy Group. 2005. Energy Security & Emergency Preparedness: How Clean Energy Can Deliver More Reliable Power for Critical Infrastructure and Emergency Response Missions. Available at http://www.cleanegroup.org/Reports/CEG_Clean_Energy_Security_Oct05.pdf [Accessed July 2006].
[23] UTC Power. 2006. Electrical Jam in Central Park. Project Profile P133-R082306. Available at http://www.utcpower.com/fs/com/Attachments/PP_NYPDW.pdf [Accessed December 2006].

some type of 911 service. Recent estimates of the total number of primary and secondary PSAPs in the U.S. range from 6,124 to 6,183.[24,25]

Table 3-2. Number of Emergency Response-Related Organizations.

Industries: Local Passenger Transportation, Nec (SIC Code 4119); Police Protection (SIC Code 9221); Fire Protection (SIC Code 9224); Public Order and Safety, Nec (SIC Code 9229)				
SIC Code	**SIC Description**	**No Bus.**	**Total Emps.**	**Total Sales ($)**
4119-9902	Ambulance service	5,770	145,310	6,327.6
9221-0000	Police protection	6,747	272,986	4.2
9221-0100	Police protection, interstate and federal	43	6,428	N/A[26]
9221-0101	Bureau of criminal investigation, government	620	26,239	N/A
9221-0102	State highway patrol	569	18,299	N/A
9221-0103	State police	1,006	55,373	N/A
9221-0200	Police protection, regional	139	10,073	N/A
9221-0201	County police	419	23,755	N/A
9221-0202	Marshals' office, police	351	9,001	5.4
9221-0203	Municipal police	1,620	68,866	0.2
9221-0204	Sheriffs' office	2,918	168,887	0.5
9221-0400	Police protection, level of government	46	685	N/A
9221-0401	Police protection, Federal government	33	490	N/A
9221-0402	Police protection, State government	118	5,423	0.3
9221-0403	Police protection, County government	195	13,161	N/A
9221-0404	Police protection, Local government	1,306	37,639	1.9
9224-0000	Fire protection	5,958	130,669	5.5
9224-0400	Fire protection, level of government	17	417	N/A
9224-0401	Fire protection, Federal government	7	27	0.2
9224-0402	Fire protection, State government	124	3,408	N/A
9224-0403	Fire protection, County government	175	4,046	N/A
9224-0404	Fire protection, Local government	781	15,225	0.2
9224-9901	Fire department, not including volunteer	5,685	139,685	2.2
9224-9902	Fire department, volunteer	14,947	286,415	2.2
9224-9903	Fire marshals' office, government	122	3,207	N/A
9224-9904	Fire prevention office, government	130	3,263	N/A
9229-9901	Disaster preparedness and management office, government	92	1,790	N/A
9229-9902	Emergency management office, government	528	12,262	0.2
	Total	**50,466**	**1,463,029**	**6,351**

Sales figures are in millions. Source: www.zapdata.com, accessed July 2006.

Market research indicates that hundreds of radio towers are used for emergency response in each state. Estimates made by emergency response professionals interviewed for this analysis range from 120 towers in a small but densely populated mid-Atlantic state to approximately 500 towers in a much larger and more populous state. As of 2003, the State of Washington owned and operated 296 microwave towers, backed up by emergency generators and batteries.[27] There are

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[24] National Emergency Number Association. 2006. 9-1-1 Fast Facts. Available at http://www.nena.org/911_facts/911fastfacts.htm [Accessed June 2006].

[25] Clean Energy Group. 2005. Energy Security & Emergency Preparedness: How Clean Energy Can Deliver More Reliable Power for Critical Infrastructure and Emergency Response Missions. Available at http://www.cleanegroup.org/Reports/CEG_Clean_Energy_Security_Oct05.pdf [Accessed July 2006].

[26] N/A: Not Applicable.

[27] State Interoperability Executive Committee. 2003. Inventory of State Government-Operated Public Safety Communications Systems. Available at http://isb.wa.gov/committees/siec/publications/inventoryreport1203.pdf [Accessed July 2006].

201 towers supporting Ohio's MARCS; most of these towers are backed up by emergency generators in the 20 to 25 kW range.[28] Based on these figures, the number of radio tower sites in the U.S. can be roughly estimated. Averaging figures from both a large state (500 sites) and a small state (120 sites) results in 310 towers per state; multiplying this number by 50 results in an approximate nationwide total of 15,500 radio tower sites. There is evidence that the number of radio sites will expand, at least in some areas, as demands on communication systems increase. For example, the number of towers in Maryland is expected to grow from 120 to approximately 200 in a few years.[29]

3.1.1.3 Market Trends

The use of backup power for emergency response equipment and facilities is supported by industry standards but mandated by only a small number of states. Industry organizations such as the National Emergency Number Association (NENA) have published standards recommending that PSAPs be equipped with long-term emergency power supplies and that telephones and other crucial devices be connected to UPS equipment.[30] At least two states currently mandate the use of backup power at PSAPs. New York requires all PSAPs to have an engine-driven generator, supported by a UPS system that maintains power during the transition from commercial power to the generator, as an emergency power source for all critical applications.[31] Illinois requires all PSAPs to maintain a backup power source "capable of supplying electrical power to serve the basic power requirements of the PSAP, without interruption, for a minimum of four hours" and to test the backup power source monthly.[32] It seems likely that, after the catastrophe witnessed in the Gulf Coast as a result of Hurricane Katrina, more states may adopt such regulations.

Despite the lack of a comprehensive mandate, interest in using alternative energy sources to support emergency preparedness efforts appears to be growing. As of 2005, 15 U.S. states had established clean energy funds; many of these states are supporting on-site clean energy projects at critical facilities to minimize dependence on grid power during emergencies. Clean energy technologies used in these projects include solar photovoltaics (PV), fuel cells, wind power, and advanced battery systems.[33]

Fuel cell systems have been used to provide backup (and, in one case, primary) power to emergency response equipment and facilities, as summarized below:

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[28] Personal Communication between Rachel Sell (Battelle) and Mark Patchen (Ohio Emergency Management Agency), June 2006.

[29] Personal Communication between Rachel Sell (Battelle) and Tom Miller (Maryland Institute for Emergency Medical Services System), July 2006.

[30] National Emergency Number Association. 2001. Recommended Generic Standards for E9-1-1 PSAP Equipment. NENA Technical Reference NENA-04-001 Issue 2. Available at http://www.nena.org/media/files/NENA_04-001.pdf [Accessed July 2006].

[31] Official Compilation of New York Codes, Rules, and Regulations. 2004. Minimum Standards Regarding Equipment, Facilities and Security for Public Safety Answering Points. 21 NYCRR §5203.3. Available at http://www.dos.state.ny.us/fire/911program/part5203.htm [Accessed July 2006].

[32] Illinois Administrative Code. 2004. Standards of Service Applicable to 9-1-1 Emergency Systems: Public Safety Answering Point. 83 IAC 725.505. Available at http://www.ilga.gov/commission/jcar/admincode/083/083007250E05050R.html [Accessed July 2006].

[33] Clean Energy Group. 2005. Energy Security & Emergency Preparedness: How Clean Energy Can Deliver More Reliable Power for Critical Infrastructure and Emergency Response Missions. Available at http://www.cleanegroup.org/Reports/CEG_Clean_Energy_Security_Oct05.pdf [Accessed July 2006].

- A wireless communications microwave site in Elk Neck State Park, Maryland, was one of the first sites to use a fuel cell backup power system.[34] The Elk Neck tower, which consists of a single-channel microwave repeater radio tower, supports several tenants, including the State of Maryland's enhanced 911 (E-911) Communications System. The state park is currently using two 1 kW ReliOn systems for extended backup to the site. E-911 radios are configured to run on a 48 volt (V) power system normally supplied through primary grid power. The total peak power load for this equipment configuration ranges from 200 to 450 watts (W). The integrated backup power solution aims to avoid any microwave radio downtime, since microwave communication systems are so critical. During Hurricane Isabel and in its aftermath (September 2003), the fuel cell system enabled critical radio communications over the microwave network for Maryland State Police and emergency medical response services until primary grid power was restored.

- Ohio's MARCS microwave radio towers utilize four ReliOn Independence 1000® PEM fuel cells to provide long-term, emergency backup power to Ohio's critical digital communication infrastructure. The towers are located in Butler, Otway, Tiffin, and Washington Township, Ohio.[35]

- The Washington Park Fire Station in Denver, Colorado, is using a PEM fuel cell to provide a portion of the facility's electricity and heat. [36]

3.1.2 Market Segment Analysis

The market analysis for the emergency response segment is divided into two sections. Section 3.1.2.1 summarizes the results of Phase 1, and section 3.1.2.2 summarizes the results of Phase 2. The Phase 1 survey examined a broad range of applications within the emergency response segment including 911 call centers and the associated radio infrastructure. Results of the Phase 1 analysis suggested that the most promising application of PEM fuel cells in the emergency response market segment was for radio communications towers managed by state and local emergency response agencies. The Phase 2 surveys and interviews focused specifically on requirements for backup power for radio towers maintained by these agencies. As responses in Phase 1 addressed the user requirements for the broad range of applications, they are analyzed separately and are not combined with the Phase 2 analysis.

3.1.2.1 Phase 1 Analysis

In Phase 1, approximately 150 emergency service agencies were contacted, and 15 responses were received in the form of completed surveys. In addition, four interviews were conducted with individuals familiar with the requirements for backup power in this market. Information gleaned from the surveys and interviews is summarized below.

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[34] Saathoff, S. 2004. Fuel Cells As Backup Power For State Government Communications Sites. Fuel Cell Today. Available at http://www.fuelcelltoday.com/FuelCellToday/FCTFiles/FCTArticleFiles/Article_866_Fuelcellsasbackuppower0904.pdf [Accessed July 2006].

[35] Fuel Cells 2000. 2006. Multi-Agency Radio Communications System Microwave Radio Towers. Available at http://www.fuelcells.org/db/project.php?id=833#5 [Accessed July 2006].

[36] Governor's Office of Energy Management and Conservation. 2006. Fuel Cell to Power Denver's Washington Park Fire Station. Available at http://www.energyvortex.com/pages/headlinedetails.cfm?id=527&archive=1 [Accessed July 2006].

Survey Participant Profile

Representatives of various emergency service agencies participated in the survey, including law enforcement agencies, PSAPs, public safety service agencies, and public safety communications organizations. Responses were received from ten small agencies (i.e., < 500 employees), two medium-sized agencies (i.e., 500 to 3,000 employees), and three large agencies (i.e., > 3,000 employees). Respondents to the survey were directors of state emergency service agencies, 911 coordinators/administrators, and police lieutenants.

Respondents identified several functions that are typically supplied with backup power, including 911 call centers; dispatch telephones and computer systems; radios, wireless communications facilities and radio infrastructure; emergency lighting; and security systems for jails, fire stations, and police stations. Critical functions requiring backup power, according to the responses received, include remote radio sites, dispatch radios, computers, and telephones.

Frequency of Power Outages

When asked about the total number of outages experienced by their facilities, responses varied from no outage to approximately 25 outages per year. Approximately 40% of the survey respondents experienced 1 to 5 outages in the last 12 months (Figure 3-1). When asked about the duration of power outages, most reported that outages were estimated to last between 1 second and 1 hour; two could not estimate the duration. Respondents indicated that long outages (> 1 hour) are very disruptive to emergency operations.[37] All respondents indicated that power outages severely impact their operations and can result in one or more of the following: lives lost, security breaches, implementation of emergency management plans, and disruptions in production.

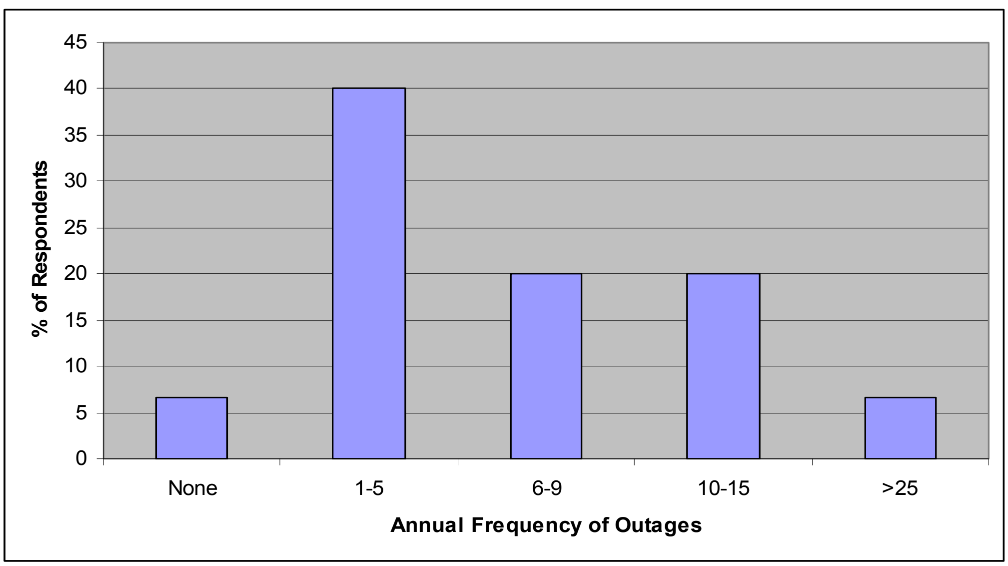

Figure 3-1. Number of Outages Experienced by Survey Respondents in the Past 12 Months (n=13).

[37] On a scale of 1 to 7, responses of 1 to 3 were classified as "not so disruptive", responses of 4 to 5 were classified as "somewhat disruptive", and responses of 6 to 7 were classified as "very disruptive".

Current Backup Power Systems

Types and sizes of systems used to provide backup power vary significantly. Figure 3-2 shows the distribution of the sizes of systems used by respondents. The generators used to provide backup power are typically 30 kW and larger, while batteries and UPS systems are smaller in size, from < 5 kW to approximately 30 kW. The total number of batteries, UPS systems, and generators used by facilities varies, based on the size of a facility and the number of dispatch centers, radios, and wireless sites it operates.

Interviewees also elaborated on their current backup power systems. One interviewee noted that their emergency communication district supports eight PSAPs, all of which use UPS systems to support their 911 radio systems and a backup generator for emergency power. These UPS units range in size from 1.8 kW to 10 kW, depending on the size of the PSAP. Most generators used at the PSAPs are larger than the UPS units. Individual PSAPs are responsible for maintaining power (and purchasing backup UPS systems and generator equipment) for their dispatch radio systems. The interviewee noted that all PSAPs generally try to adhere to NENA standards.

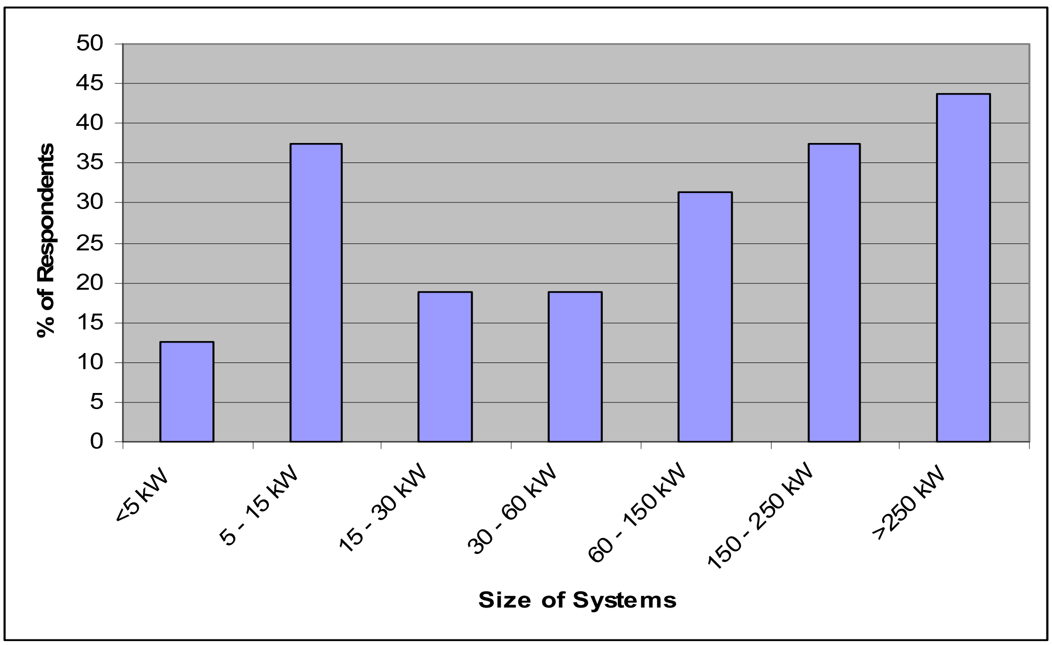

Figure 3-2. Size of Backup Power Systems in Use (n=15).

Another interviewee described the systems they have installed for their 68 PSAPs statewide. Critical applications are hooked up to a UPS system, including the computers that take emergency calls, telephone networks, radios, the consoles used by telephone operators, and supporting electronics. The interviewee added that radio towers and antennae may be located in remote locations (e.g., on mountain tops), requiring the use of generators for primary power in cases where power lines cannot be extended to the mountain.

Purchase Decision Factors

Based on responses received, the most important criteria considered when purchasing emergency response backup power systems include reliability and fuel availability. Start-up time, capital cost, ease of use, good experience with the system, and lifetime of unit were also identified as very important criteria.[38] Of the seven individuals who responded to this question, all identified reliability and fuel availability as being very important. Start-up time, capital cost, ease of use, lifetime of unit, and good experience with PEM fuel cell systems in the past were identified as important factors. Emissions and annual operating cost were relatively less important than the aforementioned factors.

Satisfaction with Current Systems

Respondents were generally pleased with the overall performance of their current backup power systems. Of the ten respondents who addressed this question, all but one described the overall performance of their system as good or very good. However, when asked if they had any concerns with their current backup power system, five respondents indicated that they had some concerns. For generators, respondents indicated that concerns included mechanical failure of the generator, loss of fuel, and high emissions. For battery-operated systems, one respondent indicated that they were unable to determine charge. When asked to rate their current backup systems against the purchase decision criteria described above (i.e., reliability, capital cost, etc.), all but one respondent indicated that their satisfaction with current technology ranged from good to very good for all factors except emissions. One respondent was disappointed by the performance of backup power systems in place for all factors.

Potential for PEM Fuel Cells in Emergency Response

Respondents indicated that there is a growing need for backup power in the emergency response market and that mandates are a key driver for backup power in public communication systems. Of the 15 surveys received, only four respondents had heard of using fuel cells for backup power. Of these four respondents, only two respondents indicated that PEM fuel cells would compete in areas with low surge draws, and two respondents indicated that, unless fuel cells' capacity was increased, fuel cells would not be able to compete in providing backup power for entire facilities. Respondents indicated that they were not concerned by the use of hydrogen as a fuel. When asked what would drive them to adopt PEM fuel cells, four respondents indicated that the cost of not having electricity and the track record of others using fuel cells would be key drivers. Two respondents had considered fuel cells as alternatives.

An interviewee who said his organization currently has a radio tower with a fuel cell for backup power compared traditional backup power sources to fuel cells. The interviewee explained that fuel cells have the benefit of being low maintenance, requiring no oil, antifreeze, or preventive maintenance. The major disadvantage of fuel cells noted was their cost, as generators are still much cheaper. The interviewee also noted that hydrogen supply can be a problem and that a better infrastructure is needed to support the storage of large volumes of hydrogen. The interviewee suggested that drivers for fuel cell use would be increased power capacity and reduced costs (e.g., a fuel cell system capable of generating 10 to 15 kW at a capital cost of ~$20,000 would be a potential catalyst for purchasing).

[38] On a scale of 1 to 7, responses of 1 to 3 were classified as "not so important", responses of 4 to 5 were classified as "somewhat important", and responses of 6 to 7 were classified as "very important".

Respondents indicated that a variety of factors are taken into account when making capital purchase decisions, including initial capital cost, period for payback, and return on investment. Respondents were split on the influence of incentives on purchase decisions, indicating that the cost of purchase often determined whether one would be swayed by incentives.

3.1.2.2 Phase 2 Analysis

The Phase 2 analysis focused on backup power requirements for radio communications towers. In Phase 2, 24 PSAPs were contacted about backup power at radio tower sites, and 11 surveys were completed. In addition, eight interviews were completed with survey participants. Four respondents in the Phase 2 analysis also answered questions in the Phase 1 analysis. As the Phase 2 analysis is presented separately from the Phase 1 analysis, survey responses from these four users are included in the section below.

Survey Participant Profile

Responses were received from three state-level emergency communications agencies and eight county-level 911 call centers. All organizations surveyed were considered small, with less than 500 employees. Respondents were typically PSAP directors or communications coordinators.

Frequency of Power Outages

Survey participants were asked about the total number of disruptive outages experienced at their radio tower sites in the past year. Answers ranged from zero to six and included: zero outages (one user); one outage (one user with eight radio tower sites); three outages (three users); four outages (one user with 48 radio tower sites); five outages (one user); and six outages (one user). Three users did not specify a number but said they experienced numerous outages related to weather (Hurricane Katrina, lightning strikes) and old infrastructure. Respondents indicated that power outages typically last anywhere from a few seconds to several days. Five users specified that outages often last 4 hours or more; three indicated that they typically last less than 3 minutes.

Users expect their backup systems to provide power until grid power can be restored. According to respondents, this period of time could range from just 4 hours to 2 weeks. One user expects their generators to run for 2 weeks, while another specified 10 days for their generators and 30 to 36 hours for batteries. Two expect their backup systems to run at least 1 week. One specified 5 to 6 days, and three others expect generators to run 2 to 3 days. Two of the respondents use only UPS system support for their radio sites and expect those systems to run for 4 hours and 8 hours.

Current Backup Power Systems

PSAP representatives were asked to describe their current backup power systems, including type of system, power output, approximate number of systems in that power range, and the estimated hours the system runs per year (including routine maintenance time). Eleven of the 12 respondents operate generators at some of their radio tower sites; eight use propane generators; five use diesel generators, and two use natural gas generators. Power output ranges for generators varied from 6 kW to 300 kW. The majority of users had power outputs between

6 kW and 100 kW. Only two respondents identified higher power output ranges. Systems less than 80 kW were typically propane-powered, while the larger systems were diesel-powered.

While some sites use combined UPS-generator systems, not all radio tower sites use backup generators. Three of 12 respondents indicated they use battery-only systems at their sites. One county PSAP relies only on UPS system support – which lasts up to 8 hours – for its remote sites; a generator is only used at the 911 dispatch center. Another PSAP relies only on UPS system support at three sites, and a generator at a fourth site. A third county PSAP uses battery systems at all 15 of its remote sites; only two or three sites that need to be climate-controlled have generators.

Others said they rely on combined UPS-generator systems at most or all of their sites. One respondent has UPS-generator systems at seven of the eight sites they operate. A second county PSAP has UPS-generator systems at nine of its ten sites; the other is located in a national forest and uses only a solar cell. One state communications center has combined UPS-generator systems at all of its 29 sites. Another state communications center uses UPS-generator systems at 200 of its 203 sites; the other three sites use fuel cell systems and a fuel cell-generator system.

Just one PSAP indicated that they do not use batteries – only ICE-powered generator systems – at their radio towers.

Backup System Maintenance

Information was collected on maintenance requirements of the participants' backup systems to help understand how fuel cells might compare.

Respondents were asked to estimate the annual hours of operation of their backup systems, including routine maintenance and actual backup operation. Responses ranged from 12 to 200 hours per year, with most operating less than 72 hours. Seven of eight respondents indicated that their systems operated between 12 and 72 hours per year. Only one respondent estimated 200 hours of runtime per year.

Labor requirements for each backup power system at radio tower sites ranged from 2 to 72 hours per year per site. Of the nine respondents that answered this question, seven reported less than 12 hours per year per site as typical labor requirements. Two organizations indicated that they enlist contractors to service their backup generator and battery systems. Other than labor, users indicated that maintenance costs can also include oil, filters, hoses, and coolant for generator systems. Batteries were cited as the primary maintenance cost associated with UPS systems. A respondent that operates one natural gas generator and four UPS systems estimated that their non-labor maintenance costs total $1,000 per year, including both ICE maintenance materials and batteries.

Nine respondents indicated that they follow the manufacturer's maintenance requirements for their backup systems. Two respondents follow another schedule; one indicated he checks the system more frequently, and another said he checks radio tower sites quarterly.

Users were also asked about the expected lifetime of their ICE generator systems, batteries, and battery chargers. Respondents expected generators to last between 10 and 20 years, with 20 years being cited by approximately half the respondents. Respondents expected battery systems to last between 2 and 10 years, with 2 years being the most common response (modal) and 5 years being the average of responses. The expected lifetime of battery chargers ranged from 5 to 20 years, with 10 years being the most common response. Nine respondents indicated that they do not require a designated space for battery charging. Just one indicated that a designated space was required and estimated the size of this space to be 50 square feet.

Purchase Decision Factors

Users were presented with a list of decision factors they might consider when evaluating a backup power system for radio tower sites, and asked which factors they considered very important.[39] All respondents identified reliability as very important, and 82% cited fuel availability as very important. Lifetime of the unit, start-up time, ease of use, and good past experience with this type of system were cited as very important by 73% of respondents, followed by capital cost (36%), annual operating cost (18%), emissions (18%), and interest in using novel, cutting-edge technology (9%). These results are summarized in Figure 3-3.

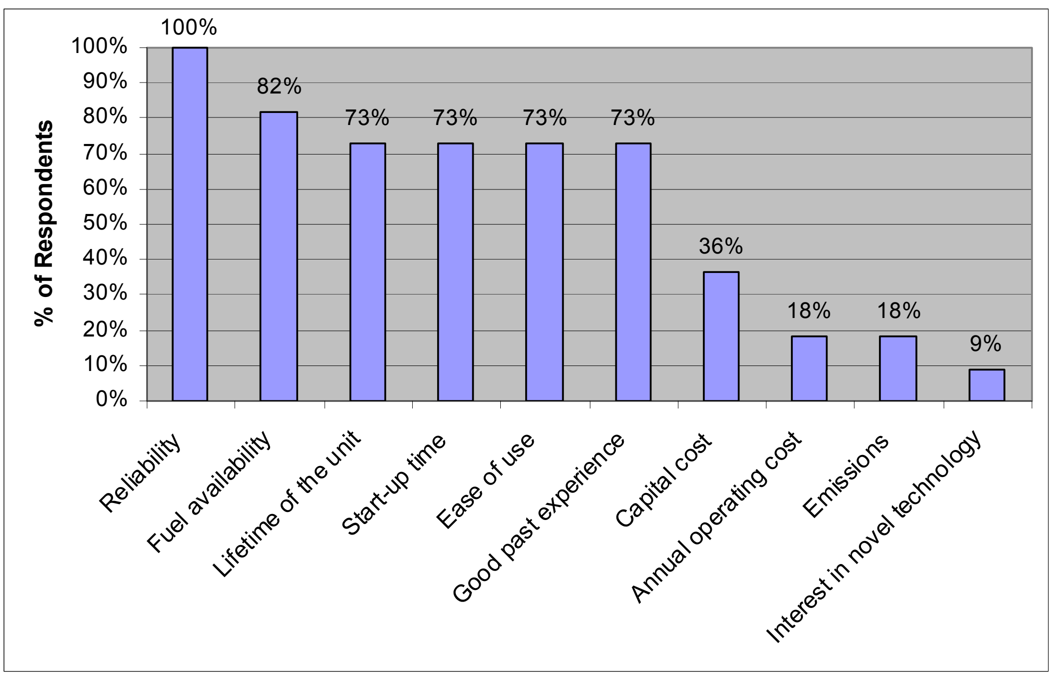

Figure 3-3. Decision Factors Identified as Very Important in Evaluating Backup Power Systems (n=11).

When users were asked which three factors, of those listed in the chart above, would most influence their decision to purchase a backup system for radio towers powered by an alternative technology, reliability and capital cost were the most important. Ninety percent of respondents to the question identified reliability as one of the three most important factors. It is interesting to

[39] On a scale of 1 to 7, responses of 1 to 3 were classified as “not so important”, responses of 4 to 5 were classified as “somewhat important”, and responses of 6 to 7 were classified as “very important”.

note that in Figure 3-3 above, capital cost was considered a very important factor by just 36% of users evaluating backup power systems. However, capital cost was identified by 70% of these respondents as one of the three most important factors influencing alternative technology purchase decisions, as noted in Figure 3-4. This may suggest that while performance factors such as lifetime and start-up time will help get a new technology on a "short list" for evaluation, reliability and capital cost will ultimately drive the purchase decision. The third most commonly cited factor was lifetime of the unit, which 40% of survey respondents indicated would most influence their decision to purchase an alternative backup power technology. Other factors cited included: start-up time; ease of use; good past experience; fuel availability; annual operating cost; and emissions. These results are summarized in Figure 3-4.

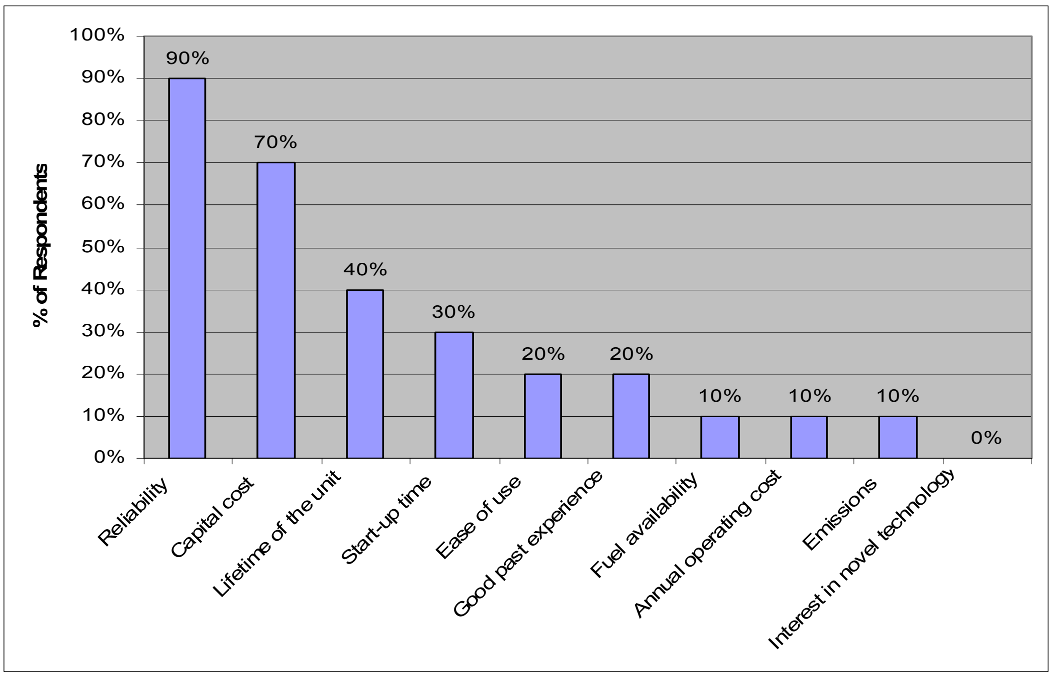

Figure 3-4. Factors that Most Influence Backup Power System Purchase Decisions (n=10).

Satisfaction with Current System

Users were asked to rate their level of satisfaction with their current backup power systems for radio towers, based on a set of characteristics provided. The proportion of respondents who believe their current systems' performance is "very good"[40] for each characteristic are presented in Figure 4-5 below. Respondents appear to be most satisfied with the lifetime (82%) and reliability (73%) of their current systems. It is important to note that reliability and lifetime of the system are also factors identified as very important by the greatest number of users (Figure 3-3), suggesting that current systems are performing well in the areas that matter most to users.

[40] On a scale of 1 to 7, responses of 1 to 3 were classified as "not so good", responses of 4 to 5 were classified as "good", and responses of 6 and 7 were classified as "very good".

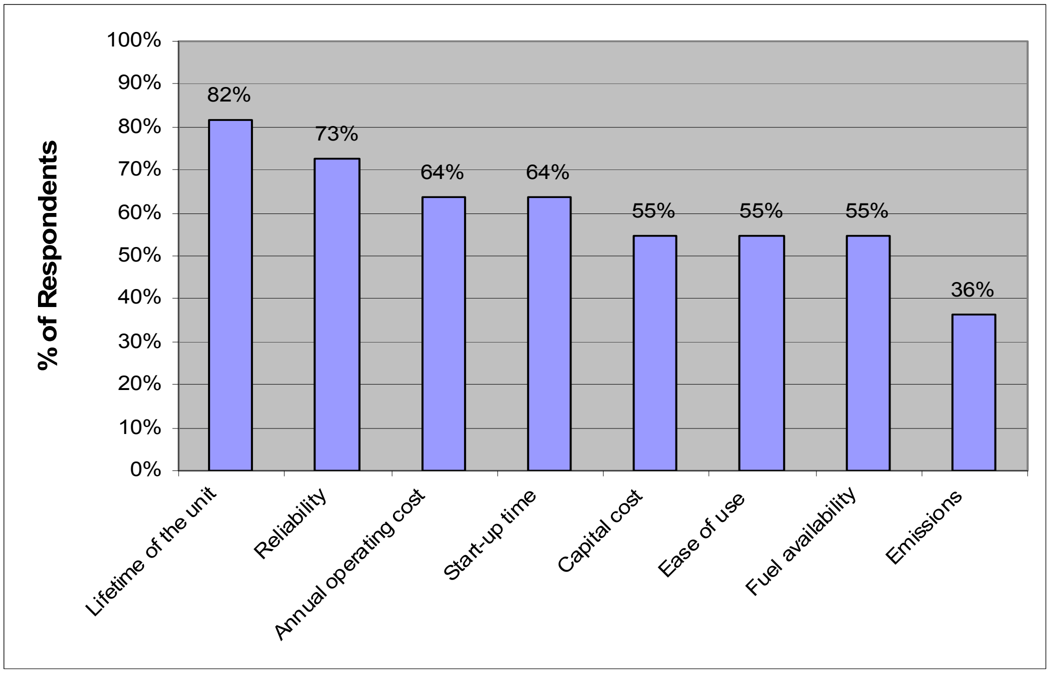

Figure 3-5. Characteristics of Current Systems that Users Identified as Very Good (n=11).

<u>Potential for PEM Fuel Cells in Emergency Response Radio Towers</u>

In follow-up interviews, users were asked about their familiarity with PEM fuel cells and whether they thought fuel cells were likely to compete favorably with existing backup power systems. Five users (out of eight respondents) were aware of the potential for PEM fuel cells to be used for backup power at radio tower sites, while three users had not heard of PEM fuel cells as a backup power source. One respondent believed that PEM fuel cells would compete with existing sources, particularly at new sites with a modest, constant power demand. This respondent specifically liked that there are no moving parts and that fuel cells can run for extended periods. Another user thought that fuel cells would compete with larger systems (e.g., a 100 kW unit) but not with his smaller propane generators. A third user believed that current technologies suffice and fuel cells are not needed at this time. One of the current users of PEM fuel cell backup systems believed that PEM systems would be adopted more widely if costs came down and the power density increased (larger kW output, smaller footprint).

With the exception of the two organizations that currently have fuel cell systems installed, most of the interviewees had not considered alternatives to their current backup power systems. One reported they considered only diesel and natural gas options and decided on diesel because of fuel availability. Similarly, a state agency representative stated that the agency had considered replacing their diesel generator with a propane generator, but were concerned about fuel availability and the higher cost of fuel. One county had evaluated turbines because they can burn a variety of fuels, have few moving parts, and require little maintenance. One respondent had evaluated a 1 kW fuel cell system as a battery replacement at a 911 call center. While this user thinks fuel cells are an excellent choice, the organization decided against using them because of cost (the state was financing the system, so there were cost limitations) and serviceability (it may be difficult to find a fuel cell technician in rural areas).

Survey participants were asked about potential concerns over the use of hydrogen as a fuel for backup power systems. While emergency responders may want to learn more about hydrogen as a fuel source, there did not appear to be a great level of concern among emergency response survey participants. Of the 11 respondents to this question, four individuals indicated that they were not so concerned, four were moderately concerned, and three individuals indicated they did not know enough about hydrogen to specify a level of concern.

In follow-up interviews respondents were asked what factors would convince them to procure a fuel cell-powered backup system. Two county PSAPs indicated that dissatisfaction with their current mode of operation may persuade them to procure a fuel cell, although one admitted he did not know enough about fuel cells to respond with certainty. Another respondent said that longer runtimes (i.e., a system that could run for days without interruption) would convince his organization to procure a fuel cell system.

Five interviewees addressed the issue of how capital purchase decisions for backup power systems are made within their organizations. Four respondents indicated that their organizations tend to emphasize initial capital costs. As governmental organizations, the ability to make capital expenditures depends on fiscal year budget allocations. Two respondents indicated that their agencies pay for capital equipment out of current budgets or with grants from state and federal agencies. One county said they use both cash reserves and loans at times. This respondent indicated that a loan guarantee program might influence the county's decision to purchase a fuel cell system. However, because loans are not typical for this type of capital investment, a loan guarantee program is not considered a useful incentive for this sector. No respondents reported that their organizations conduct a formal return-on-investment analysis.

Users surveyed were asked whether they considered the availability of government incentives when making capital purchase decisions. Three users indicated that they do consider incentives, and two responded that they do not, although others mentioned that they seek grant funding at times for such investments.

3.1.2.3 Market Research Summary Analysis

There is a critical need for backup power in the emergency response segment, because the impact of power outages can be catastrophic. Continuous power is particularly important for 911 call centers and radio towers. While some form of backup power is typically used at radio tower sites, an effort by some states to mandate backup power for emergency response communications may be a harbinger of growth in this market as other states follow.[41] Several key observations can be noted from user surveys, interviews, and secondary research with respect to backup power requirements, usage patterns, customer satisfaction with current systems, and users' understanding of PEM fuel cells:

- A variety of backup power capacities are used by emergency response agencies, with capacities for radio tower sites ranging from > 5 kW to 300 kW. Larger systems are

[41] Congressional Research Service. 2005. An Emergency Communications Safety Net: Integrating 911 and Other Service. CRS Report to the Congress. Available at http://www.fas.org/sgp/crs/homesec/RL32939.pdf [Accessed December 11, 2006].

typically used only when the system supports both a technical (radio tower, computer aided dispatch) and non-technical (lights, air-conditioning, facility power) mission.

- Currently, the state and local government entities that manage emergency response radio towers rely on propane and diesel generators, UPS systems, and batteries for backup power; and most rely on combined battery-generator systems. At PSAPs, batteries and UPS systems are used to meet backup power needs less than 30 kW. Generators are typically used for backup power greater than 30 kW. Propane generators are typically used for small power capacities (up to 60 kW), and diesel generators are used for large power capacity.
- Most organizations surveyed operate their backup power systems for less than 72 hours per year. Respondents expect UPS systems and battery systems to run 4 to 8 hours and generator systems to be able to run from 2 days to more than a week.
- Typical maintenance for backup power systems is less than 12 hours per year per site. Users typically follow the manufacturer's recommended maintenance schedules.
- Respondents are satisfied with the performance of current backup power systems, particularly with system lifetime and reliability. Respondents reported some concerns with generators, including emissions, mechanical failures, and high annual operating costs.
- The factors that would most influence respondents' decisions to purchase radio tower backup power systems powered by an alternative technology are reliability, capital cost, and lifetime of the unit.
- Awareness of PEM fuel cells is limited in this market.
- Emergency response organizations emphasize initial capital costs over longer-term return on investments when making capital purchase decisions.
- Financial incentives and grants that can reduce initial capital costs are considered by this market segment when making purchasing decisions.

3.1.3 Cost Analysis of PEM Fuel Cells

Our market research suggests that widespread market acceptance of PEM fuel cells is dependent on reliability and cost of the technology as compared to established alternatives. Although our market research suggests that users are generally satisfied with the status quo, there is potential for adoption of alternative technologies that provide lower emissions, longer runtimes, and are easy to use and maintain. Currently, batteries and battery-generator systems are the backup solutions of choice for radio tower sites in the emergency response market segment. Criticality of the site determines whether batteries or battery-generator systems are used. The type of backup system used varies by radio transmitter site and is highly dependent on power requirements (e.g., size of site, power draw, and voltage needs), type of installation (e.g., interior or exterior), and required backup time.

To determine if PEM fuel cells are a cost competitive alternative for this market, the lifecycle cost of PEM fuel cells, batteries, and generators typically used to provide backup power at radio sites are analyzed. Three different installation scenarios based on backup size and capacity are examined. The scenarios are based on candidate user input on typical applications of backup power at their sites. In these scenarios it is assumed that PEM fuel cells supply power to only critical applications at the radio tower sites.

This analysis examines the discounted NPV of using PEM fuel cells compared to batteries and generators using assumptions consistent with the H2A model.[42] Hydrogen fuel is assumed to be provided through pressurized canisters. For all three scenarios, a discount rate of 8% and an inflation rate of 1.9% are applied. No disposal costs are assumed for any of the technologies. It is assumed that disposal costs are rolled into the initial capital cost of the system. Lifecycle costs of PEM fuel cells with and without incentives specified in EPAct 2005 are analyzed.[43] The battery replacement schedules utilized in the analysis are 3 and 5 years, based on user responses to surveys. Section 3.1.3.1 provides the assumptions used in the three scenarios, and section 3.1.3.2 provides the lifecycle cost comparisons.

3.1.3.1 Lifecycle Cost Analysis Assumptions by Scenario

Scenario 1 assumes that the radio transmitter site is a new installation and requires 48 to 52 hours of backup power per year at 5 kW. This scenario compares the NPV of PEM fuel cells to battery-generator systems for a 15-year period with a 3-year and 5-year replacement cycle for batteries. Users have indicated that, in such an installation, batteries are designed to provide 4 hours of backup time, and the diesel generator is designed to provide 48 hours of backup time. To facilitate comparative analysis for this installation, the PEM fuel cell system includes enough fuel to provide 52 hours of backup time at 5 kW, essentially replacing the battery-diesel generator system. The PEM fuel cell system in this installation uses batteries to provide an hour of ride-through. The PEM fuel cell system in this installation uses an outdoor enclosure. In this scenario, it is assumed that the site experiences frequent extended outages (52 hours per year), and as a result, the generator and PEM fuel cell are refueled annually. No residual value for the installed technologies is assumed at the end of 15 years.

Scenario 2 compares the cost of a PEM fuel cell to a battery-generator system at a new remote radio transmitter site that requires extended runtime due to its critical nature (Table 3-3). The site has power requirements of 5 kW and is an exterior installation requiring up to 1 week of backup time. User input indicates that, at such an installation, batteries provide 8 hours of backup time, and the diesel generator provides 168 hours of backup time at 5 kW. For this installation, the PEM fuel cell includes enough fuel to provide 176 hours of backup time at 5 kW. It is assumed that the PEM fuel cell at this site requires an outdoor enclosure. The PEM fuel cell system in this installation uses batteries sized to provide 1 hour of ride-through. It is also assumed that the radio site rarely experiences extended outages, and as a result, the fuel in the generator and PEM fuel cell are replaced every 5 years. A system lifetime of 15 years is assumed for both the PEM fuel cell and the generator. No residual value for the installed technologies is assumed in this scenario. The NPV of PEM fuel cells is compared to battery-generator systems over the 15-year lifetime of the systems with a 3- and 5-year replacement cycle for batteries.

Scenario 3 analyzes the lifecycle cost of a PEM fuel cell compared to a battery-generator system at a new radio transmitter site that requires 3 days of backup power at 3 kW. Some users have indicated that, until reliability of PEM fuel cells is completely proven, they would not consider them as replacements to diesel generators. Other users have indicated that batteries are

[42] DOE Hydrogen Program: DOE H2A Analysis. DOE H2A Analysis. www.hydrogen.energy.gov/h2a_analysis.html [Accessed August 2006].
[43] Under EPAct 2005, fuel cells receive a 30% tax credit that is capped at $1,000 per kW of generating capacity.

problematic, and they would welcome reliable alternatives to batteries. As a result, in Scenario 3, lifecycle costs are evaluated for replacing a battery-generator system, a battery-only system, and a generator-only system with a PEM fuel cell. In this scenario, batteries, sized to 1.6 kW, provide power for 8 hours during an outage for technical loads (radio transmitter only). The generators, sized to 3 kW, provide power for 72 hours during an outage for technical and non-technical loads (facility power, air conditioning, and lights). Expected annual usage is approximately 12.8 kWh for the batteries and 216 kWh for the diesel generator. One PEM fuel cell is designed to carry both the technical and non-technical loads with hydrogen fuel for 72 hours at 3 kW to facilitate comparison with the battery-generator system and the generator-only system. The second PEM fuel cell is designed to carry only technical loads for 8 hours at 2 kW and is compared with the battery-only system. For this scenario, it is assumed that this is an interior installation and no enclosures are necessary. The PEM fuel cell system in this installation uses batteries sized to provide 30 minutes of ride-through. It is assumed that the site undergoes frequent outages, and as a result, the fuel is replaced in the diesel generator and PEM fuel cell on an annual basis. This analysis assumes a 15-year payback period with a 5-year replacement cycle for batteries. No residual value for the installed technologies is assumed in this scenario.

Table 3-3 identifies the cost assumptions used in all three scenarios.

Table 3.3. Lifecycle Cost Analysis Assumptions by Scenario.

	Scenario 1			Scenario 2			Scenario 3			
	Batteries	Diesel Generator	PEM Fuel Cell	Batteries	Diesel Gen.	PEM Fuel Cell	Batteries	Diesel Generator	PEM Fuel Cell (Replacing Bat-Gen. System)	PEM Fuel Cell (Replacing Battery Only)
Size (kW)	5	5	5	5	5	5	1.6	3	3	2
Lifetime (yrs)	3 or 5	15	15	3 or 5	15	15	5	15	15	15
Backup Time (hrs)	4	48	52	8	168	176	8	72	72	8
Usage (kWh/Yr)	20	240	260	40	840	880	12.8	216	216	16
Unit Cost ($)	7,000[1]	10,000	15,000	14,000	10,000	15,000	4,480	8,000	9,000	6,000
Engineering Installation Costs ($)	6,500[2]	4,000[3]	5,000[4]	6,500[2]	4,000[3]	5,000[4]	2,080[2]	2,400[3]	4,000[4]	4,000[4]
Non-Engineering Installation Costs ($)	3,000[5]	4,400[5]	17,075[1,4,5]	3,000[5]	4,400[5]	17,075[1,4,5]	2,000[5]	4,400[5]	2,075[1,5]	1,550[1,5]
Battery Charger ($)	2,000	-	-	2,000	-	-	2,000	-	-	-
Transfer Switch ($)	-	2,400	-	-	2,400	-	-	2,400	-	-
Fuel Tank ($)	-	2,000	-	-	2,000	-	-	1,200	-	-
Moon Pad ($)	-	-	1,200[5]	-	-	1,200[5]	-	-	1,200[5]	1,200[5]
Battery Ride-Through ($)	-	-	875[1]	-	-	875[1]	-	-	525[1]	350[1]
Outdoor Enclosure ($)	1,000	-	15,000[4]	1,000	-	15,000[4]	-	-	-	-
Maintenance Costs ($/yr)	560[6]	1260[7]	140[8]	560[6]	1260[7]	140[8]	560[6]	1260[7]	140[8]	140[8]
Fuel Usage	None[12]	1.4 gal/hr	75 slpm	None[12]	1.4 gal/hr	75 slpm	None[12]	1.4 gal/hr	45 slpm	30 slpm
Cost of Fuel ($/yr)	None	202[9]	495[10]	None	706[9]	1,650[10]	-	302[9]	405[10]	30
Tank Rental ($/yr)	-	-	1782[11]	-	-	5,940[11]	-	-	1458[11]	108

[1] Battery cost is based on $0.35 watt-hour. USACE ERDC CERL. 2004. Initial Report ReliOn Inc Backup Power for Mission Critical Loads.
[2] Assumes engineering services installation cost of $1300/kW. Data obtained from Battelle market research surveys.
[3] Assumes engineering services installation cost of $800/kW. Data obtained from Battelle market research surveys.
[4] Industry communication, September 2006.
[5] Personal communication between Kathya Mahadevan (Battelle) and George Milne (HavePower), September 2006 .
[6] Routine maintenance – Assumes 2 hours a quarter at $70/hr. Data obtained from Battelle surveys.
[7] Routine maintenance – Assumes 2 hours per quarter at $70/hr. Data obtained from Battelle market research surveys. Oil filter changes and tune-ups annually $700. Personal communication between Kathya Mahadevan (Battelle) and George Milne (HavePower), September 2006.
[8] Routine maintenance – Assumes 1 visit a year for 2 hours a year at $70/hr. Data obtained from Battelle market research surveys.
[9] Assumes $3 per gallon of diesel. Diesel generator provides 72 hours of backup in Scenario 3.
[10] Assumes 1 cylinder at 261 ft^3provides 8 kWh of runtime. Cost per cylinder is $15. Personal communication between Kathya Mahadevan (Battelle) and John Osickey (ReliOn), September 2006.
[11] Assumes tank rental of $4.5 per month per tank. Personal communication between Kathya Mahadevan (Battelle) and Kevin Coyne (Praxair), September 2006.
[12] Negligible amount of electricity is used to recharge batteries.

3.1.3.2 Lifecycle Cost Analysis Results by Scenario

Results for Scenario 1 (52 hours of Backup Power)

In scenario 1, the 15-year analysis period with a 3-year and 5-year battery replacement cycle indicates that PEM fuel cells are competitive on a NPV basis with the incumbent solution both with and without tax incentives (Table 3-4).

The NPV of total capital costs for PEM fuel cells is lower than the NPV of total capital costs of the incumbent solution in both battery replacement schedules. The NPV of the capital costs of a battery-generator system with a 3-year battery replacement schedule is 20.2% greater than the NPV of the capital costs of PEM fuel cells without incentives. This difference is reduced to 9% with the 5-year battery replacement schedule between the NPV of the two systems.

The operation and maintenance costs, including the cost of fuel, are 16% lower for the battery-generator system than PEM fuel cells for both battery replacement schedules. In this analysis, battery replacement is assumed to be a capital cost expense, while fuel is considered a maintenance cost.

Over the 15-year lifetime of the systems, the NPV of the total costs of the PEM fuel cell system without incentives is approximately 9% lower than the NPV of the total costs of the battery-generator system in a 3-year battery replacement schedule. With incentives, in the 3-year battery replacement schedule, the NPV of the total cost of PEM fuel cells is 16% less than the NPV of the total cost of the incumbent solution. The 5-year battery replacement schedule results in the NPV of the total costs of the battery-generator system being slightly lower than the NPV of the total costs of the PEM fuel cell without incentives. Incentives in this scenario (with 5-year battery replacement schedule) make the NPV of the total costs of PEM fuel cells more attractive over the 15-year analysis period by 7%.

Table 3-4. Scenario 1: 5 kW for 52 hours - NPV of PEM Fuel Cells and Battery-Generator System over 15-Year Analysis Period with a 3-Year and 5-Year Battery Replacement Schedule.

3-Year Battery Replacement Schedule			
	Battery-Generator System	**PEM Fuel Cell without Tax Incentive**	**PEM Fuel Cell with Tax Incentive**
NPV of Total Capital Costs ($)	50,337	40,158	35,441
NPV of Fixed O&M Costs ($) (Including Cost of Fuel)	19,656	23,496	23,496
NPV of Total Cost of System ($)	69,860	63,521	58,804
5-Year Battery Replacement Schedule			
	Battery-Generator System	**PEM Fuel Cell without Tax Incentive**	**PEM Fuel Cell with Tax Incentive**
NPV of Total Capital Costs ($)	41,560	37,964	32,247
NPV of Fixed O&M Costs ($) (Including Cost of Fuel)	19,656	23,496	23,496
NPV of Total Cost of System ($)	61,082	61,326	56,609

Results for Scenario 2 (176 hours of Backup Power)

Over the 15-year analysis period with both battery replacement schedules in scenario 2, PEM fuel cells are not competitive with the incumbent solution based on the NPV of the total cost of the system (Table 3-5). However, in this scenario, PEM fuel cells do require less capital investment than the incumbent solution (based on the NPV of the total capital costs).

With a 3-year battery replacement schedule and without incentives, PEM fuel cells are approximately 9% more expensive than the battery-generator system based on NPV of the total cost of the system. With incentives, the difference between the NPV of the total cost of the two systems is reduced to approximately 5%. With a 3-year battery replacement schedule and incentives, the NPV of total capital cost of PEM fuel cells is 49% less than the NPV of total capital cost of the incumbent solution.

With the 5-year battery replacement schedule, NPV of the total cost of the PEM fuel cell is approximately 25% (without incentives) to 21% (with incentives) higher than the NPV of the total cost of the battery and generator system. PEM fuel cells require less capital investment than do batteries and generators, by approximately 29% (without incentives) to 37% (with incentives), with a 5-year battery replacement schedule.

In scenario 2, the cost of hydrogen storage severely impacts the operation and maintenance costs of PEM fuel cells. Hydrogen fuel tank rental and storage costs for 176 hours of runtime account for 98% of the annual operation and maintenance costs for PEM fuel cells in this scenario.

Table 3-5. Scenario 2: 5 kW for 176 hours - NPV of PEM Fuel Cells and Battery-Generator System over 15-Year Analysis Period with a 3-Year and 5-Year Battery Replacement Schedule.

3-Year Battery Replacement Schedule			
	Battery-Generator System	**PEM Fuel Cell without Tax Incentive**	**PEM Fuel Cell with Tax Incentive**
NPV of Total Capital Costs ($)	75,887	43,750	39,032
NPV of Fixed O&M Costs ($) (Including Cost of Fuel)	17,692	59,104	59,104
NPV of Total Cost of System ($)	93,129	102,403	97,686
5-Year Battery Replacement Schedule			
	Battery-Generator System	**PEM Fuel Cell without Tax Incentive**	**PEM Fuel Cell with Tax Incentive**
NPV of Total Capital Costs ($)	58,333	41,556	36,838
NPV of Fixed O&M Costs ($) (Including Cost of Fuel)	17,692	59,104	59,104
NPV of Total Cost of System ($)	75,575	100,209	95,491

Results for Scenario 3 (72 hours of Backup Power Generation)

Incentives in this scenario impact the capital cost investment required and make PEM fuel cells significantly more attractive than the battery-generator system, battery-only system, and a new installation generator-only system.

In scenario 3, the 15-year payback analysis with a 5-year battery replacement schedule shows that PEM fuel cells require less capital investment and operation and maintenance costs than the battery-generator system (Table 3-6). Without incentives, the NPV of the total cost of the PEM fuel cell system is 28% less than the battery-generator system.

When compared to the generator-only system, PEM fuel cells require more capital investment and operation and maintenance investment over the 15-year analysis period. The NPV of the total cost of PEM fuel cells is $33,901, as compared to $28,283 for newly installed generators and $24,886 for replacement generators (Table 3-6).

Table 3-6. Scenario 3: 3 kW for 72 hours - NPV of PEM Fuel Cells, Battery-Generator System, and Generator-Only System over 15-Year Analysis Period with a 5-Year Battery Replacement Schedule.

	Battery-Generator System	Generator (New Installation)	Generator Replacement (No Installation Costs)	PEM Fuel Cell without Tax Incentive	PEM Fuel Cell with Tax Incentive
NPV of Total Capital Costs ($)	26,800	13,209	9,813	14,540	12,653
NPV of Fixed O&M Costs ($) (Including Cost of Fuel)	20,628	15,184	15,184	19,471	19,471
NPV of Total Cost of System ($)	47,318	28,283	24,886	33,901	32,014

Over the 15-year analysis period, PEM fuel cells are less expensive than batteries alone, both with and without incentives (Table 3-7). The NPV value of the total cost of the PEM fuel cell system is less than the battery-only system by 26% (without incentives) and 36% (with incentives) over the 15-year analysis period with a 5-year battery replacement schedule. As compared to the battery-only system, PEM fuel cells require approximately 50% less operation and maintenance investment.

Table 3-7. Scenario 3: 2 kW for 8 hours - NPV of PEM Fuel Cells and Battery-Only System over 15-Year Analysis Period with a 5-Year Battery Replacement Schedule.

	Battery	PEM Fuel Cell without Tax Incentive	PEM Fuel Cell with Tax Incentive
NPV of Total Capital Costs ($)	13,600	11,329	9,442
NPV of Fixed O&M Costs ($) (Including Cost of Fuel)	5,444	2,702	2,702
NPV of Total Cost of System ($)	19,037	14,023	12,136

3.1.3.3 Lifecycle Cost Summary

The lifecycle cost analyses above show that PEM fuel cells can compete effectively with current technologies – both battery-generator systems and battery-only systems – when shorter runtimes are required (i.e., 8 to 72 hours). When runtimes of 176 hours are required, the high cost of hydrogen storage tank rental and use makes PEM fuel cells less attractive than the alternatives from a lifecycle cost perspective. The results are summarized in Table 3-8. PEM fuel cells are more competitive in a 3-year battery replacement schedule than a 5-year battery replacement schedule. Tax incentives for PEM fuel cells significantly impact the lifecycle costs of PEM fuel cells, making them more attractive than the incumbent solutions for shorter runtimes.

Table 3-8. Comparison of NPV for Total Cost of System: 8-Hour, 52-Hour, 72-Hour, and 176-Hour Runtime Scenarios.

	3-Year Battery Replacement			5-Year Battery Replacement							
	Battery-Gen.*	PEMFC[+] without Tax Incentive	PEMFC with Incentive	Battery-Gen.	PEMFC without Tax Incentive	PEMFC with Tax Incentive	Gen. New Installation	Gen. Repl. Existing Installation	Battery-only	PEMFC without Tax Incentive	PEMFC with Tax Incentive
8-hour Runtime									19,037	14,023	12,136
52-hour Runtime	69,860	63,521	58,804	61,082	61,326	56,609					
72-hour Runtime				47,318	33,901	32,014	28,283	24,886			
176-hour Runtime	93,129	102,403	97,686	75,575	100,209	95,491					

*Gen. is generator, [+] PEMFC is PEM fuel cell

3.1.4 Sensitivity Analysis

3.1.4.1 Sensitivity Analysis Modeling Analysis Methodology

Single-factor sensitivity analysis was performed to show the variability in average annual system cost as individual factors are varied while all other factors are held constant. The base values for each factor are the same as the values used in the scenario 1 lifecycle cost analysis shown in Table 3-3. Here, each factor was allowed to vary by +/-10% of the base assumption. The results of the sensitivity analysis are presented in a tornado diagram (Figure 3-6). The factor that shows the greatest cost leverage is graphed at the top, with other factors arrayed below it in descending order of cost leverage. Two numbers are shown at each end of the horizontal bar graph for each factor. The upper number is the average cost per year of owning and operating the PEM fuel cell if this factor is varied by 10% from base assumptions, holding all other factors at base assumptions. In brackets under the average cost figure is the value of the factor when varied by 10%.

The factors varied in the PEM fuel cell backup power cost sensitivity analysis are shown in Table 3-9. For example, the base value assumed for the life of the ride-through batteries was 5.0 years; the high value (+10%) is 5.5 years, and the low value (-10%) is 4.5 years. In the sensitivity analysis, the average annual cash outlay for use of a PEM fuel cell was calculated using Equation 1. Hydrogen cost, tank cost, and operation and maintenance (O&M) costs are annual averages. Installation costs include engineering and non-engineering costs, moon pad (installation pad), and outdoor enclosure listed in Table 3-3 for scenario 1.

$$\overline{C} = \frac{(FuelCell\,Cost + Installation\,Cost)}{FuelCell\,Life} + \frac{BatteryCost}{Battery\,Life} + Hydrogen\,Cost + Tank\,Cost + O\,\&\,M\,Cost \qquad \text{Equation 1}$$

Table 3-9. Cost Assumptions for PEM Fuel Cell Backup Power Sensitivity Analysis: +/-10% Base Assumption.

	Base Value	-10% of Base Value	+10% of Base Value
O&M Cost, $	140	126	154
Ride-through Batteries, $	875	788	963
Ride-through Battery Life, years	5.0	4.5	5.5
Fuel (hydrogen), $/year	495	446	545
Fuel Cell Cost, $	15,000	13,500	16,500
Installation Cost, $	38,275	34,448	42,103
Hydrogen Tank Rental, $/year	1,782	1,604	1,960
Fuel Cell Life, years	15	13.5	16.5

3.1.4.2 Sensitivity Analysis Results

The results of the sensitivity analysis are shown in Figure 3-6. For a PEM fuel cell used in backup applications, improving the fuel cell life has the largest impact on the average annual cost.

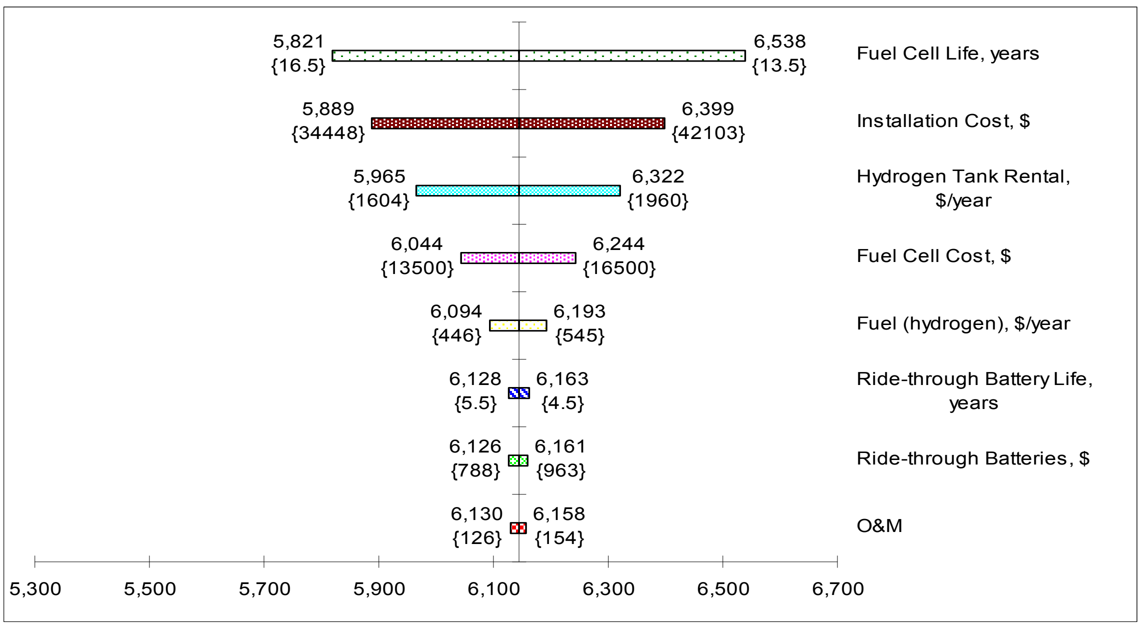

Figure 3-6. Sensitivity Analysis of Average Annual Cost of Owning and Operating a PEM Fuel Cell Backup Power System.

Installation cost is the second largest cost driver of the cost of owning and operating a PEM fuel cell. Hydrogen tank rental and fuel cell cost are the third and fourth largest cost drivers. The cost of hydrogen, batteries (and battery life), and operation and maintenance costs have a smaller leverage on the cost of owning and operating the PEM fuel cell system. In the scenario where longer periods of backup electricity are required (176 hours, rather than 48 hours), the cost of hydrogen tank rental becomes a more important cost driver.

3.1.5 Market Penetration Analysis

3.1.5.1 Market Penetration Assumptions

The market penetration potential of PEM fuel cells (adoptions and sales) when key cost and performance criteria are met as compared to competing alternatives, is presented in this section.

Extrapolating from published data and user interviews, it is estimated that there are about 15,000 registered emergency response radio towers in the U.S. today. However, the total number of emergency response communication towers, including unregistered towers, may be as high as 60,000. Based on survey data and existing regulations, it is anticipated that all emergency response communication towers have, or will acquire, backup power sufficient for 48 hours or longer. To meet this requirement, it is anticipated that batteries will be supplemented with other equipment for power generation. As a basis for the market penetration analysis, the research team conservatively used 15,000 registered towers to estimate annual purchases of backup power systems.

Three separate cases were assumed for the market penetration analysis. In the base case, no government actions are taken. In the communication case, the government provides some form of outreach or information to the market on the value of PEM fuel cells. In the subsidy case, the government subsidizes purchases of PEM fuel cells at a cost of $1,000 per kW. Table 3-10 summarizes the assumptions that were used for these three cases. For all three cases, it was assumed that a diesel backup system and PEM fuel cells each need to be replaced after 15 years. It is further assumed that the purchase of backup systems is evenly distributed over time. Therefore, backup power for 1,000 towers was purchased in the first year of PEM fuel cell introduction (15,000 towers/15 years). It is assumed that PEM fuel cells will penetrate approximately 40% of this market (400 towers).

For all three cases, it was assumed that the PEM fuel cells were 5 kW systems at a cost of $15,000 ($3,000/kW). It is expected that, as sales increase, the cost of production will decrease. It is further expected that, as PEM fuel cells begin penetrating the market, competing ICE generators will lower their prices to prevent erosion of market share. Both the lower production costs and the response of competing industries will likely to drive down price. Therefore, it was assumed that the price of PEM fuel cells will decrease 5% per year for 10 years. The price is assumed to be stable (given constant dollars) after that time.

For all three cases, it was assumed that the value of PEM fuel cells to the market will be significantly greater than competing technologies. Because of this higher value, market penetration will occur initially. This is an optimistic but plausible assumption because of the lower maintenance costs and higher reliability that PEM fuel cells are expected to provide.

Table 3-10. Assumptions for PEM Fuel Cell Adoption for Backup Power Applications at Emergency Response Radio Towers*.

Assumption	Base Case	Communication Case	Subsidy Case
Market Growth Rate	8.7% for five years; 6% falling by 1% every two years; stable at 2%	8.7% for five years; 6% falling by 1% every two years; stable at 2%	8.7% for five years; 6% falling by 1% every two years; stable at 2%
Government Actions	None	Communications	Subsidize purchase at $1,000/kW
Values of p and q	$p = 0.008$ $q = 0.423$	$p = 0.012$ $q = 0.423$	$p = 0.070$ $q = 0.423$
Total U.S. Emergency Response Communication Towers with 48 Hour Backup Power	15,000	15,000	15,000
Initial Number of Communication Towers Purchasing Backup Power Annually	1000	1000	1000
Initial Annual Number of Communication Towers Purchasing Fuel Cell Backup Annually, *m*	40% of total market; 400	40% of total market; 400	40% of total market; 400
Average Initial Cost of 5 kW System for each Tower ($)	15,000	15,000	15,000
Rate of Price Reduction	5% per year for 10 years; stable thereafter	5% per year for 10 years; stable thereafter	5% per year for 10 years; stable thereafter
Final Share of Backup Power	100%	100%	100%
Life of Fuel Cells and Diesel Generators	15 years	15 years	15 years

*Assumes that PEM fuel cells are cost competitive and offer superior performance compared to competing alternatives.

3.1.5.2 Market Penetration Results

The models show that the subsidy case achieves the greatest market penetration. The price of PEM fuel cells is assumed to be driven down by competitive pressures. Based on previous estimates of the change in fuel cell cost with increasing volumes,[44] only the subsidy case achieves fast enough growth for the price to exceed cost.

The models show that, in the base and communication cases (Figures 3-7 through 3-10), the first years in which 500 units will be sold annually, are 14 years and 13 years, respectively, after commercial introduction. In the subsidized case (Figures 3-11 and 3-12), 500 units are sold annually much earlier, eight years after commercial introduction. Further, the models show that, in the base and communication cases, the first years in which $5 million in sales are achieved will again be 13 years and 12 years, respectively, after commercial introduction. In the subsidized case, $5 million in sales occurs much earlier, in seven years. Assuming that a $1,000 per kW subsidy for 5 years is used to spur early purchases of PEM fuel cells, the cost to government would be about $3.35 million.

[44] Battelle. 2006. Economics of Stationary PEM Fuel Cell Systems. For the Department of Energy, DOE Contract No. DE-FC36-03GO13110.

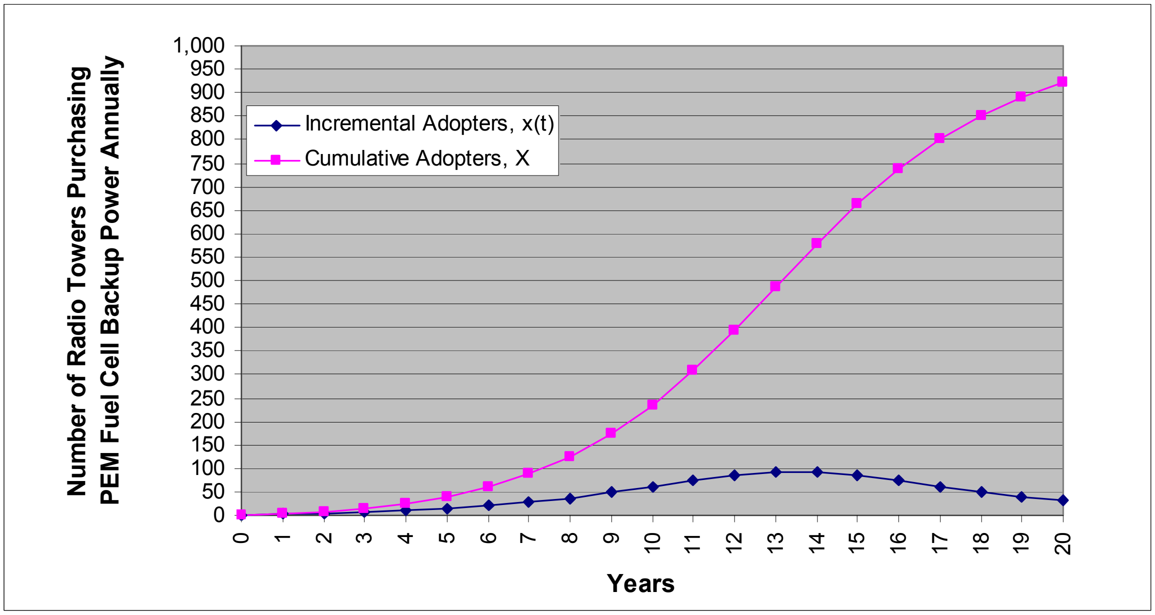

Figure 3-7. Adoptions of PEM Fuel Cell Backup Power for Emergency Response Communication Towers in the Base Case.

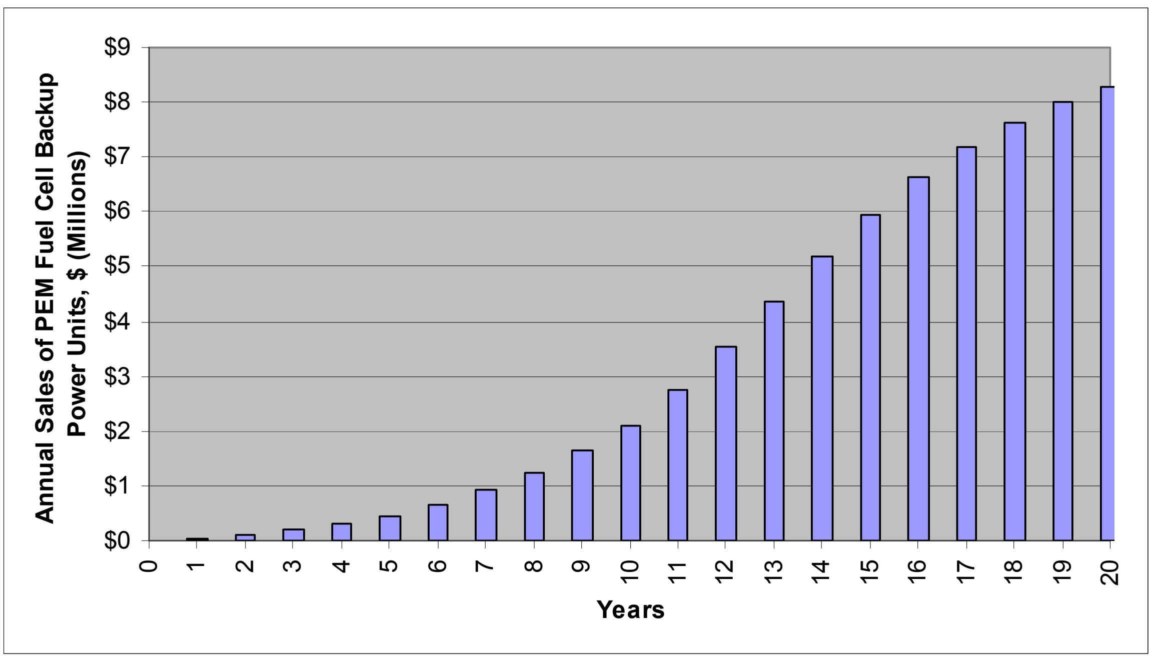

Figure 3-8. Sales of PEM Fuel Cell Backup Power for Emergency Response Communication Towers in the Base Case.

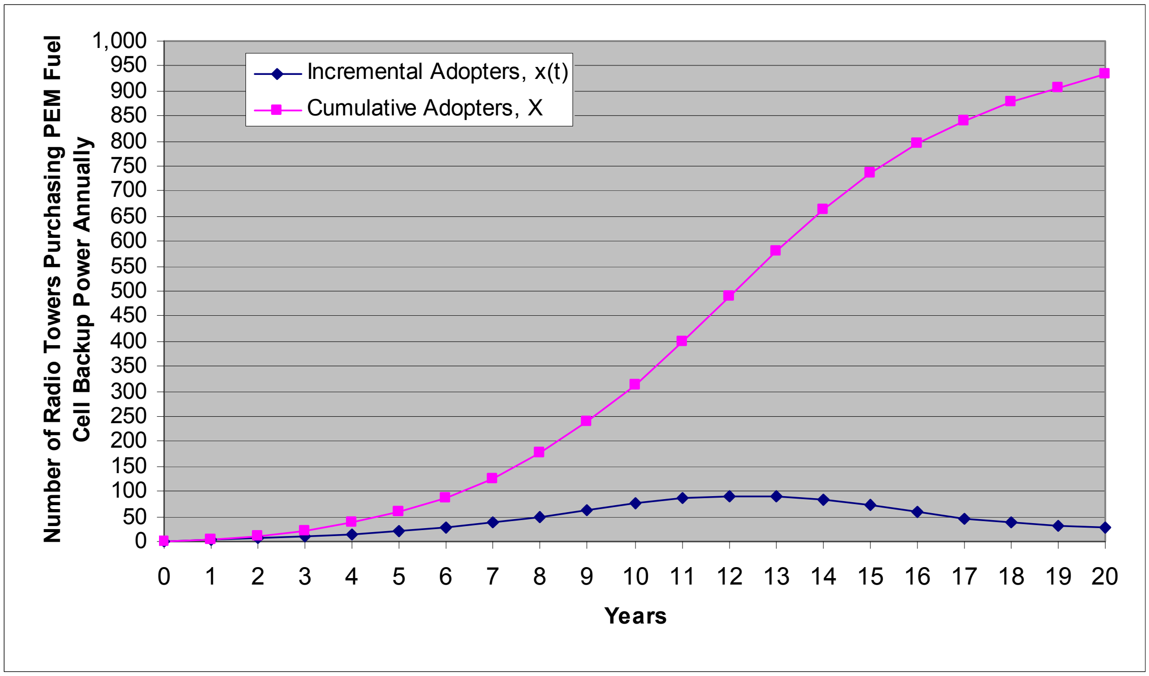

Figure 3-9. **Adoptions of PEM Fuel Cell Backup Power for Emergency Response Communication Towers in the Communication Case.**

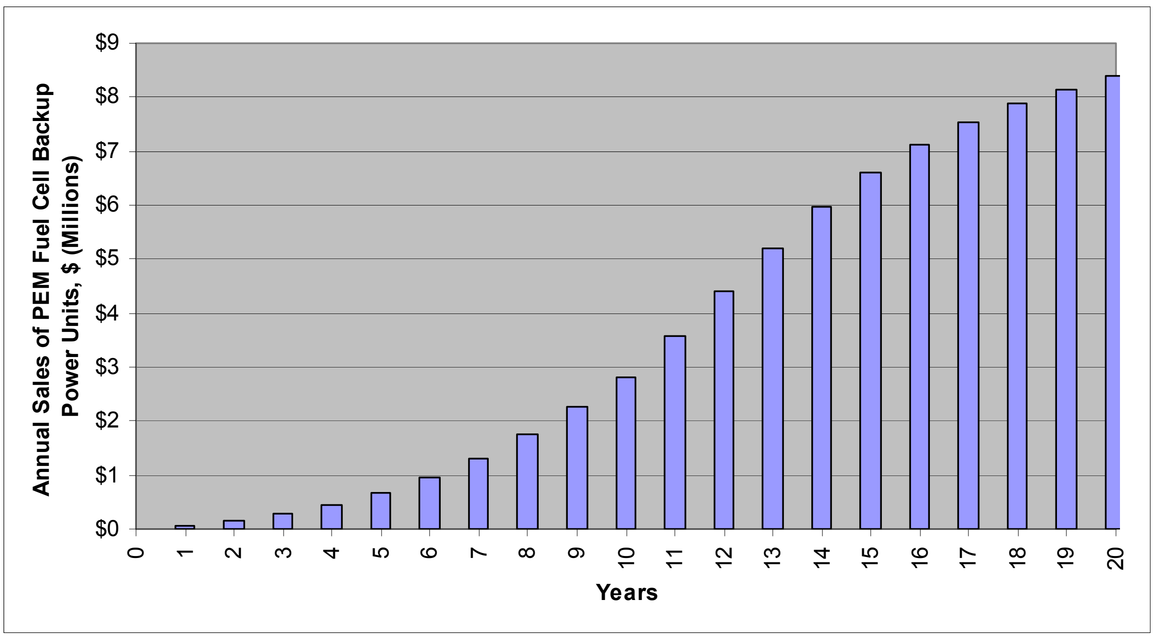

Figure 3-10. **Sales of PEM Fuel Cell Backup Power for Emergency Response Communication Towers in the Communication Case.**

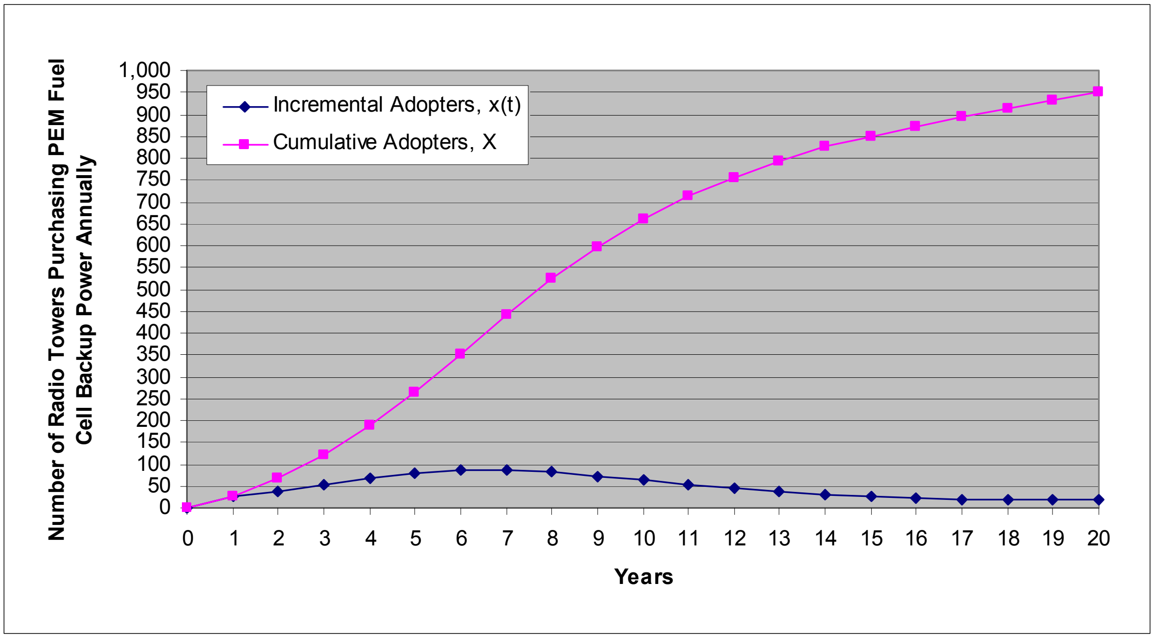

Figure 3-11. Adoptions of PEM Fuel Cell Backup Power for Emergency Response Communication Towers in the Subsidy Case.

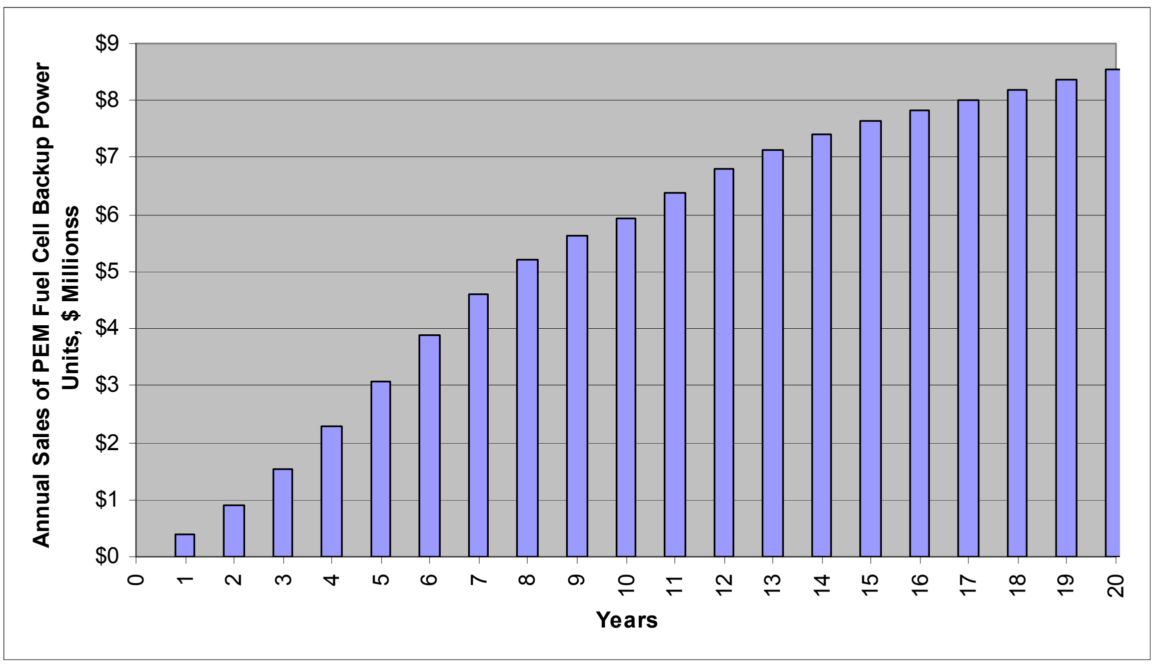

Figure 3-12. Sales of PEM Fuel Cell Backup Power for Emergency Response Communication Towers in the Subsidy Case.

Table 3-11 provides a summary of the sales and market share data presented for each of the three cases described above.

Table 3-11. Summary of PEM Fuel Cell Penetration Assuming Alternative Cases.

	5 Years After Commercial Introduction			10 Years After Commercial Introduction			15 Years After Commercial Introduction			20 Years After Commercial Introduction		
	Base Case	Communication Case	Subsidy Case	Base Case	Communication Case	Subsidy Case	Base Case	Communication Case	Subsidy Case	Base Case	Communication Case	Subsidy Case
Annual Sales (Units)	40	58	266	234	314	659	664	735	851	922	933	951
Annual Sales ($ millions)	<.5	<1	3	2.10	2.82	5.91	5.96	6.6	7.64	8.28	8.38	8.54
Market Share (%)	3	4	17	12	16	34	30	33	38	37	38	38

3.1.6 Value Proposition for PEM Fuel Cells

The emergency response market segment appears to represent a promising early niche for PEM fuel cells as a backup power source at some radio tower sites. It is expected that improvements in the application of PEM fuel cells in the telecommunications sector will drive the adoption of PEM fuel cells at radio tower sites in the emergency response market segment. Emergency response radio towers represent an adequately sized market, and growth is expected in the number of towers using backup power in the next few years as more states consider mandating backup power at PSAPs and radio tower sites. Various user requirements (for system size, reliability, ease of use, durability, and start-up time at smaller radio sites with backup requirements of 8 to 72 hours) fit well with the performance of PEM fuel cells relative to alternatives. Furthermore, fuel cells have been demonstrated successfully as a source of backup power for emergency response radio tower sites in at least three locations. It is anticipated that PEM fuel cells will penetrate other applications in the emergency response segment as the technology matures.

PEM fuel cells offer many advantages over incumbent technologies. Compared to batteries, PEM fuel cells offer longer, continuous runtime and are more durable in harsh environments. Compared to generators, PEM fuel cells have lower maintenance requirements, since they have fewer moving parts; can be monitored remotely, reducing actual maintenance time; and have lower emissions.

PEM fuel cells also offer potential cost advantages over competing technologies under some conditions in this market segment. The lifecycle cost analysis shows that PEM fuel cells are cost competitive with current technologies – both battery-generator systems and battery-only systems – when shorter runtimes are required (i.e., the equivalent of 1 to 3 days). A key opportunity for PEM fuel cells will be for backup power to radio tower sites in harsh environments, which can shorten the lifetime of batteries. PEM fuel cells offer a lifecycle cost advantage over battery-generator systems when battery lifetime is shorter, and are similar in cost to battery-generator systems when batteries are replaced on a 5-year schedule. The value proposition for PEM fuel cells deteriorates relative to incumbent technologies when extended runtimes are required (i.e., the equivalent of 7 days). Under these conditions, the high cost of hydrogen storage and use drives up the lifecycle cost of PEM fuel cells.

Financial incentives, demonstration projects, and fuel availability will be critical in order for PEM fuel cells to exploit these advantages and compete effectively with current backup power technologies for radio towers. Market penetration modeling illustrates that near-term adoption increases with government subsidies that reduce the capital cost of the fuel cell, such as those enacted under EPAct 2005. Incentives may be even more important in this sector than others, given the emphasis users place on capital cost in making purchase decisions. Reliability testing and demonstration projects will also be key to adoption, as reliability is another high priority purchase decision factor. Users in this market segment will need to see data that prove PEM fuel cells to be as reliable or more reliable than incumbent technologies before they adopt. Fuel availability is a final issue that will need to be addressed if PEM fuel cells are to succeed in this market. Users will need to be assured that hydrogen can be supplied in appropriate quantities and stored in a cost-effective manner.

3.2 PEM Fuel Cells in Forklifts at High Throughput Distribution Centers

3.2.1 Market Attributes

3.2.1.1 Market Segment Description

Forklifts are a type of material handling equipment, used by various industries, to move materials to, through, and from production processes in receiving, storage, packing, and shipping. By mechanizing materials handling, forklifts increase productivity and reduce production costs. Table 3-12 identifies the SIC and NAICS codes for manufacturing of forklifts. These codes were utilized to guide market research.

Table 3-12. SIC and NAICS Codes for Forklift Manufacturing.

2-Digit SIC Code	35 – Industrial and commercial machinery and computer equipment
4-Digit SIC Code	3537 – Industrial trucks and tractors
NAICS Code	333924 – Industrial trucks, tractors, mobile straddle carriers and stacker machinery

Forklift trucks are available in many variations and load capacities. They can be powered by batteries or ICEs fueled by gasoline, propane, or diesel. The Industrial Truck Association (ITA) has defined seven classes of forklift trucks:

- Class 1 – battery-powered motor trucks with cushion or pneumatic (air filled) tires. Class 1 forklifts include four sub-categories, or lift codes, which are:
    - Lift Code 1 – counter balanced rider type, stand-up
    - Lift Code 4 – three-wheel battery-powered, sit-down
    - Lift Code 5 – counter balanced rider, cushion tire, sit-down
    - Lift Code 6 – counter balanced rider, sit-down rider (includes pneumatic tire models)
- Class 2 – battery-powered motor narrow aisle trucks with solid tires

- Class 3 – battery-powered hand trucks or hand-rider trucks with solid tires
- Class 4 – ICE-powered sit-down rider forklifts with cushion tires, generally suitable for indoor use on hard surfaces
- Class 5 – ICE-powered sit-down rider forklifts with pneumatic tires, typically used outdoors, on rough surfaces or significant inclines
- Class 6 – battery- or ICE-powered ride-on units with the ability to tow at least 1,000 pounds (lbs); this class is designed to tow cargo rather than lift it
- Class 7 – rough terrain forklift trucks with pneumatic tires; these are almost exclusively powered by diesel ICE and are used outdoors.

Battery-powered forklifts (Class 1, 2, and 3) are typically used in indoor materials handling applications that do not require large lift capacities. In some instances, battery-powered forklifts are selected primarily for worker safety. These applications include confined spaces, cold storage, and food retail (primarily grocery stores).[45] Class 1, 2, and 3 forklifts are typically used in multi-shift operations by warehousing, distribution centers, third-party logistics suppliers, shipping and receiving, and manufacturing. Class 4, 5, and 6 trucks are typically used in construction, agriculture, manufacturing, large warehousing, recycling, beverage and bottling, trucking, and garden supply operations. They are also used in the manufacturing and processing operations of paper and allied products; lumber and wood products; building supplies; stone, clay, and glass products; and primary metal products. Class 1 forklifts can be used in similar applications to Class 4 or Class 5 forklifts. Typically, Class 2 and Class 3 forklifts are used in those applications where ICE-powered forklifts are not practical, such as indoor environments and narrow aisles.

Although battery-powered forklifts are designed for indoor operations, a number of manufacturers are offering equipment features, such as different types of tires, which enable battery-powered models to be used in a wider variety of environments. Class 1 battery-powered forklifts are available in a wide variety of lift capacities from 3,000 lbs to over 20,000 lbs. Most Class 1 forklifts sold in the U.S. today are in the 3,000 to 6,000 lb lift capacity range. There does not seem to be a large penetration of Class 1 battery-powered forklifts with lift capacities greater than 6,000 lbs.[46]

Forklifts with spark-ignited engines that are also used indoors have lift capacities between 3,000 and 16,000 lbs. ICE-powered forklifts with compression ignition engines have lift capacities over 6,000 lbs and can exceed 40,000 lbs. Forklifts range from 50 HP (approximately 37 kW) to over 175 HP (approximately 130 kW).

The annual hours of usage vary significantly among different types and users of forklift trucks. The usage pattern can vary from continual use to four or five hours per shift. In 1995, the Gas Technology Institute (GTI) reported that the range of battery-powered forklift runtimes varied from 500 hours to 3,500 hours per year, with a mean of about 2,250 hours per year.[47] For ICE forklifts, the GTI reported that the average annual hours of usage are approximately 1,800 to

[45] Antelope Valley Air Quality Management District. 2006. Chapter VII. Forklifts. Available at http://www.avaqmd.ca.gov/carlm/g_forklift.pdf [Accessed March 2006].
[46] California Air Resources Board. 2006. Draft Forklift Project Criteria. Available at http://www.arb.ca.gov/msprog/moyer/fl_crit.pdf [Accessed June 2006].
[47] Gas Technology Institute. 1995. Industrial Truck Market Analysis.

1,900 hours per year. The same report found that 69% of Class 1 and 2 battery-powered forklifts operate one shift a day, 16% operate two shifts, and 15% operate three shifts. For ICE forklifts, GTI noted that 59% operate one shift and almost 40% operate two shifts. On average, it was noted that both battery- and ICE-powered forklifts operate 1.5 shifts a day, five days a week. GTI also reported that battery-powered (Class 1 or 2) forklifts on average are recharged after 11 clock (not meter) hours. Thus, battery-powered forklifts operating in multiple shifts typically use multiple battery packs and require battery change-out equipment. The average propane tank was replaced or refilled after 15 hours.

The price of forklift trucks varies according to class. New battery-powered forklifts can cost 20-40% more than ICE-powered trucks of a comparable size. A 5,000 lb walkie stacker battery-powered forklift retails for $18,000 to $25,000 plus $2,000 to $5,000 for one battery and charger. Quotes received from Crown Equipment indicate that battery-powered forklift trucks can range from approximately $8,000 for a 6,000 to 8,000 lb rider pallet truck to $75,000 for a 3,000 lb narrow aisle stock picker.[48] On the other hand, a 5,000 lb ICE-powered forklift can range from $16,000 to $28,000. A 10,000 lb diesel ICE forklift truck ranges in price from $28,000 to $45,000.[49]

Battery-powered forklift trucks have lower lifecycle costs compared to ICE-powered models. This is due to lower maintenance costs, lower fueling costs, and a longer useful life. Operating costs can range from $1 per hour for small battery-powered forklift trucks to over $20 per hour for Class 7 diesel forklift trucks. In a study conducted by the Electric Power Research Institute (EPRI), one user found that the median service life for battery-powered forklifts was 11 years, as compared to 7.5 years for ICE-powered versions.[50]

Battery-powered forklifts are typically powered by lead-acid batteries that can typically provide enough power for one 8-hour shift, which translates into 5 to 6 hours of constant usage. The primary advantages of battery-powered forklifts are that they produce zero emissions and they can be used indoors. However, the disadvantage of the battery-powered forklift is battery change-out and downtime, which impacts productivity and increases costs of operation. In a typical operation, battery change-out takes 20 to 45 minutes. Charging the battery takes 8 hours, plus 8 hours of cooling time before the battery can be used. Due to this slow charging speed, multiple shift operations must typically keep extra batteries charged and available. The battery chargers are typically located in a dry, ventilated, and temperature-controlled location, because batteries release oxygen and hydrogen during charging. Furthermore, because overcharging of the battery can often result in acid spills, it is necessary to locate battery charging operations away from other operations so that spills can be easily disposed. In locations where space is at a premium, battery charging stations can be costly.

ICE-powered trucks run on a variety of fuels including gasoline, diesel, liquid propane gas (LPG), and compressed natural gas (CNG). The main benefit of the ICE engine is the ease of refueling (< 30 seconds). While ICE-powered forklifts are cheaper to buy, the cost of

[48] Personal communication between Kathya Mahadevan (Battelle) and Rich Bair (OKI Systems). April 2006.
[49] Buyerzone.com. 2006. New and Used Forklift Pricing. Available at http://www.buyerzone.com/industrial/forklifts/buyers_guide7.html [Accessed June 2006].
[50] Southern California Edison. 2006. Electric Transportation. Available at http://www.sce.com/PowerandEnvironment/ElectricTransportationOld/Non-roadApplication/Forklifts.htm [Accessed June 2006].

maintenance is high. In addition, refueling equipment and storage equipment are an added cost. In many cases, dual fuel equipment is available to switch between LPG and diesel.

3.2.1.2 Market Size

Current data on the number of businesses manufacturing forklift trucks and other industrial trucks and tractors are provided below in Table 3-13. Within this table, only those eight-code SIC specialties deemed likely to be involved in forklift manufacturing are shown.

Table 3-13. Number of Companies Potentially Involved in Forklift Manufacturing.

Industry: Industrial Trucks and Tractors (SIC Code 3537)				
SIC Code	**SIC Description**	**No Bus.**	**Total Emps.**	**Total Sales ($)**
3537-0000	Industrial trucks and tractors	391	9,184	2,049.5
3537-0208	Forklift trucks	207	5,587	3,847.4
3537-0210	Lift trucks, industrial: fork, platform, straddle, etc.	147	8,550	6,527
3537-0211	Pallet loaders and unloaders	9	383	67.1
3537-0212	Palletizers and depalletizers	12	228	24.5
3537-0213	Stackers, power (industrial truck stackers)	1	1	0.1
3537-0215	Straddle carriers, mobile	4	10	0.7
3537-0216	Tractors, used in plants, docks, terminals, etc.: industrial	17	2,544	58.2
3537-0218	Trucks: freight, baggage, etc.: industrial, except mining	147	2,139	88.7
	Total	**935**	**28,626**	**12,663.2**

Sales figures are in millions. Source: www.zapdata.com, accessed May 2006.

Forklift trucks are used by a variety of industries, including, but not limited to, manufacturing, construction, mining, agriculture, food, retail, internet retailers, and wholesale trade. Forklifts are widely used by these industries at manufacturing sites, distribution centers, and warehousing operations to move goods within the facility or to load goods for shipping to other sites. Discrete process and service industry sectors found in construction (SIC Codes 15-17), manufacturing (SIC Codes 20-39), and service sectors (SIC Codes 40-59) are all users of forklifts.

Most of these industries have shown sales growth over the past decade, particularly for businesses involved in online sales and direct marketing through catalogs and television. Internet sales rose approximately 25% in 2005.[51] To support these increased sales, most businesses today have extensive supply chains, and the use of appropriate solutions for order picking and transporting to facilitate the movement of goods is critical to their bottom line. In 2003, total demand for material handling equipment by end users in the U.S. was approximately $16,450 million. This demand is expected to grow to $24,900 million by 2013 (Table 3-14). Of the end users listed in Table 3-14 below, nondurable goods, food and beverages, and electrical and electronic equipment end-user markets have the greatest demand for material handling equipment.

[51] Plunkett Research. 2006. Major Trends Affecting the Retail Industry.

Table 3-14. Material Handling Equipment Demand by End-User Market to 2013 in Millions of Dollars.[52]

Material Handling Equipment	Demand ($Million)				
	1993	1998	2003	2008	2013
Total Material Handling Demand by End-User*	12,325	17,865	16,450	20,350	24,900
Durable Goods Manufacturers	4,460	6,985	5,680	7,230	8,960
Primary and Fabricated Metals	304.4	410.8	634	466	516
Industrial Machinery and Equipment	196.3	282.8	255	380	485
Electrical and Electronic Equipment	407.5	583.8	570	749	965
Motor Vehicles and Parts	263.2	366.5	374	461	569
Other Durable Goods	235.4	312.1	319	357	413
Nondurable Goods Manufacturers	2,155	2,945	2,630	3,260	3,980
Food and Beverages	400.2	463.2	498	580	672
Paper Products	127.9	158.5	164	186	204
Chemical Products	229.7	277.3	299	358	429
Non Durable Goods	666.2	781	919	1,091	1,315
Other Industries	5,710	7,935	8,140	9,860	11,960

*Material handling equipment includes conventional material handling (industrial trucks, conveying equipment, hoists, cranes, and monorails) and automated handling equipment.

Total shipments of forklifts and other lift trucks in the U.S. in 2003 were valued at $3,190 million, and this figure is expected to grow by 5% per year to 2013 (Table 3-15). Battery-powered forklifts are approximately 58% of the total forklift market and are projected to retain a constant share through 2013. Shipments of battery-powered forklift trucks in 2003 were valued at approximately $1,850 million, and this figure is expected to grow 31% to $2,420 million in 2008. Battery-powered riding forklift trucks account for approximately 80% of the current and projected total battery-powered forklift market, while battery-powered narrow aisle forklift trucks account for approximately 20% of the current and projected total battery-powered forklift market.

Shipments of ICE-powered forklift trucks totaled $1,285 million in 2003, and this figure is expected to grow to $1,650 million in 2008. LPG-powered forklift trucks occupied the highest market share of ICE-powered forklift trucks shipped in 2003, with shipments valued at approximately $765 million. LPG-powered forklifts accounted for 60% of the ICE-powered forklift market in 2003, gasoline-powered trucks accounted for 16%, diesel-powered trucks accounted for 16%, and CNG-powered trucks accounted for 8%. By 2013, market share of diesel-powered trucks is projected to decline to 15% and LPG-powered trucks are expected to increase to 61% of the total ICE-powered forklift truck market (Table 3-15).

[52] The Freedonia Group, Inc. 2004. Material Handling to 2008: Equipment and Systems. Cleveland, OH, The Freedonia Group, Inc.

Table 3-15. Manufacturers' Shipments of Forklift Equipment in the United States in Millions of Dollars.[53]

Equipment	1993	1998	2003	2008	2013
Industrial Trucks and Lifts	4,195	6,030	5,770	7,290	9,140
Forklifts and Other Lift Trucks	2,320	3,425	3,190	4,130	5,230
Battery-powered Forklifts and Other Lift Trucks	1,335	1,970	1,850	2,420	3,060
Riding Trucks	1,080	1,580	1,470	1,920	2,420
Narrow Aisle Trucks	255	390	380	500	640
Internal Combustion Engine	955	1,405	1,285	1,650	2,100
LPG	545	825	765	995	1,280
Gasoline	150	230	210	265	330
Diesel	170	230	200	250	310
Natural Gas	90	120	110	140	180
Hand Lifts and Trucks	30	50	55	60	70

The ITA conducts an annual survey of its members to identify the numbers of forklift trucks shipped in the U.S. In 2004, ITA members reported that 91,194 battery-powered forklift trucks and 74,228 ICE-powered forklift trucks were shipped (Table 3-16). The exact number of forklift trucks manufactured and shipped to an end user, the type of forklift truck, and their application could not be identified, as this information is considered proprietary.

Table 3-16. U.S. Factory Shipments of Class 1, 2, 3, 4 and 5 Forklifts.*

Year	Battery-Powered Rider (Class 1 And Class 2)	Battery-Powered Hand (Class 3)	ICE-Powered (Class 4 and Class 5)	Total (Class 1 - Class 5)
2000	56,090	49,121	85,993	191,204
2001	45,980	37,210	61,507	144,697
2002	39,235	36,445	55,928	131,608
2003	40,463	36,659	63,365	140,487
2004	46,886	44,308	74,228	165,422

*Years are not comparable since this data is submitted on a yearly basis by members of the Industrial Truck Association. Membership changes are not reflected in these numbers.

Market research data were reviewed to identify the existing population of battery-powered and ICE-powered forklift trucks in the U.S. No information on the current population of battery-powered forklift trucks could be obtained. The most recent data available (1996 population estimates) identified 441,999 ICE-powered forklift trucks in use in the U.S. Of that total, 22,099 were gasoline-powered ICE forklift trucks, 376,593 were LPG-powered forklift trucks, and 43,307 were CNG-powered forklift trucks (Table 3-17). If a growth rate of 5% per year is assumed, the estimated current total population of ICE-powered forklift trucks in the U.S. is approximately 755,967 trucks in 2006.

The top seven forklift truck manufacturers are Toyota Industries Corporation, Linde, Jungheinrich Deutschland, NACCO Corporation, Mitsubishi Heavy Industries, Crown

[53] The Freedonia Group, Inc. 2004. Material Handling to 2008: Equipment and Systems. Cleveland, OH, The Freedonia Group, Inc.

Equipment Corporation, and Komatsu Forklift. Examples of potential large end users in the U.S. include: Wal-Mart, Costco, Target, Kroger, Coca-Cola, Anheuser-Busch, PepsiCo, Home Depot, Lowes, Ford Motor Company, General Motors, Honda, and Toyota.

Table 3-17. Total Population of ICE Forklift Trucks in the United States in 1996.[54]

Equipment Description	Minimum Horsepower	Maximum Horsepower	Average Horsepower	Total Population
Gasoline 4 Stroke Forklifts	25	40	36.12	1,645
Gasoline 4 Stroke Forklifts	40	50	45.16	5,876
Gasoline 4 Stroke Forklifts	50	75	62.77	9,466
Gasoline 4 Stroke Forklifts	75	100	89.03	691
Gasoline 4 Stroke Forklifts	100	175	144.7	4,399
Gasoline 4 Stroke Forklifts	175	300	215.8	22
LPG-Forklifts	25	40	33.44	31,264
LPG-Forklifts	40	50	45.43	68,337
LPG-Forklifts	50	75	58.18	179,857
LPG-Forklifts	75	100	79.83	13,136
LPG-Forklifts	100	175	131.5	83,590
LPG-Forklifts	175	300	215.8	409
CNG-Forklifts	40	50	48	43,307
Total Population				**441,999**

3.2.1.3 Market Trends

Companies are focused on increasing productivity and decreasing the costs associated with their supply chains. At distribution centers and warehouses, operation and maintenance of forklifts are a significant cost. For battery-powered forklifts, fast charging has emerged as a potential solution for recharging batteries to increase productivity in heavy-use applications. Fast charging is typically recommended for three-shift operations. Fast chargers can automatically detect the level of discharge of the battery and supply only the amount of power required to restore it to full power. Forklift trucks can be recharged during breaks, lunch, shift changes, and at night. With fast chargers, batteries can be brought to 80% charge in less than two hours, do not need equalizing time, and can be used immediately. Complete recharge and equalizing of charge for batteries is necessary only once a week with fast chargers. Fast chargers are compatible with existing batteries, and the same charger can be used to charge multiple voltage batteries (24V, 36V, 48V). Though fast charging requires high initial investment, it decreases the need for extra batteries, as well as the time needed to change batteries, and decreases warehouse space requirements for battery storage. While lifecycle costs of batteries are estimated to be 20% lower with fast charging units, the lifetime of batteries is reduced. Fast charging also improves worker safety because lift truck operators are not handling heavy batteries. Fast charging is considered to be more suitable for continuous applications with well-managed schedules and workforces. Ford Motor Company has contracted with PosiCharge

[54] EPA, 2005. Non-Road Engine Population Estimates. EPA-420-R-05-022. Available at http://www.epa.gov/OMS/models/nonrdmdl/nonrdmdl2005/420r05022.pdf#search=%22Non-Road%20Engine%20Population%20Estimates.%20EPA420-R-05-022.%22 [Accessed June 2006].

to install fast charging in all of its North American plants.[55] With fast chargers, Nestle has been able to shave 15% off the costs associated with the old battery changing scenario.[56]

PEM fuel cell-powered forklifts have also emerged as potential alternatives to battery- and ICE-powered forklifts. PEM fuel cell forklifts require minimal time for refueling and have significantly less maintenance than battery-powered forklifts, whose batteries must be regularly charged, refilled with water, and replaced. In addition, the fuel cell system ensures constant power delivery and performance, eliminating the reduction in voltage output that occurs as batteries discharge. These and other features make fuel cell-powered forklifts potentially well-suited to conditions in multi-shift operations. Fuel cell-powered forklifts also have advantages over ICE-powered forklifts, including zero emissions, quiet operation, and longer runtimes between refueling. A study exploring the economics of converting an entire warehouse from batteries to fuel cells indicates that sites with high labor rates and multiple shifts are good initial targets of the technology. The process of delivering hydrogen to the fuel cell system and long stack life must be demonstrated for fuel cell technology to be commercially successful.[57]

An annual business trends survey conducted by the ITA indicates that manufacturers are split on whether fuel cells will make up a significant share of the forklift market in the next two to five years. The survey indicates that manufacturers think that more forklift trucks will begin to use fast charging technology in the next five years.[58]

Several tests have begun to demonstrate the feasibility of fuel cell-powered forklifts. Hydrogenics Corporation recently completed forklift demonstrations at GM of Canada's car assembly plant in Oshawa and FedEx Canada's logistics hub at Toronto International Airport. Lead-acid batteries in two Hyster Class 1 5,500 lb sit-rider forklifts provided by NACCO Materials Handling Group were replaced with HyPM 10 fuel cell packs. The HyPM 10 incorporates a 10 kW fuel cell power module for base load requirements and energy storing ultracapacitors to handle peak loads and long-duration transients, and to capture braking energy. In this demonstration, PEM electrolyzers were used to refuel the forklifts. The fuel cell deployment at GM's Oshawa Car Assembly Plant ran for 3 months and logged over 900 hours of operation.[59]

Recently, Cellex Power completed a first round of testing of direct hydrogen PEM fuel cell forklifts at Wal-Mart stores in Bentonville, Arkansas. The fuel cell-powered pallet trucks ran approximately 1.2 to 1.5 times longer than lead-acid batteries and could be refueled in about 1 minute. Wal-Mart plans to support the commercialization process of the Cellex fuel cell power system for battery-powered forklifts and has agreed to a second round of testing. Four Crown

[55] Kempfer. L. 2006. Fast Chargers Power-up Lift Trucks. Material Handling Management. Available at http://mhmonline.com/viewStory.asp?sID=%7B49839030-D53D-4594-8E5C-36E3C4419485%7D&S=1 [Accessed June 2006].
[56] Andel, T. 2004. Not All Lift Trucks Are Created Equal. Logistics Today. Available at http://www.logisticstoday.com/sNO/6460/iID/20887/LT/displayStory.asp [Accessed June 2006].
[57] Medwin, S. 2005. Application of Fuel Cells to Forklift Trucks. Industrial Utility Vehicle Magazine. Volume 7, Issue 5. Available at http://www.specialtyvehiclesonline.com/images/Raymond_FC.pdf#search=%22Application%20of%20Fuel%20Cells%20to%20Forklift%20Trucks%22 [Accessed September 2006].
[58] Carinci, A. 2005. Results of the 2005 Business Trends Survey. ITA Fall Meeting. Available at http://www.indtrk.org/docs/2005BusinessTrends.ppt [Accessed June 2006].
[59] McKinnon, M. 2005. Forklifts Hoist Fuel Cells to Commercial Applications: Hydrogen-Powered Industrial Vehicles Lead the Way to Mass Market. Available at http://www.fuelcell-magazine.com/eprints/free/hydrogenicsoct05.pdf [Accessed June 2006].

PE4000 series forklifts will be retrofitted by Cellex Power.[60] For fuel cells in forklifts, the predicted payback period is 3 to 4 years for both the fuel cell-based forklift and the hydrogen infrastructure. The expected savings are $5,000 per year per truck according to Cellex Power. These savings are comprised of the avoidance of several costs: the hard costs associated with battery changing, the extra maintenance costs associated with maintaining batteries, reduced productivity caused by drivers having to stop and drive over to a battery changing station, and the voltage drop that comes during the last half-hour of battery life.

Companies are also seeking alternative solutions to ICE-powered forklifts due to the problem of emissions from ICE-powered forklifts. In 2004, EPA adopted emission standards for non-road spark ignition (SI) engines above 25 HP/19 kW, including forklifts, airport service equipment, generators, compressors, welders, aerial lifts, and ice grooming machines. Beginning in 2007, manufacturers will be required to use optimized engines, including new diagnostic systems, to meet more stringent standards that call for a 90% reduction in NO_x, hydrocarbon, and carbon monoxide emissions.[61] More recently, the California Air Resources Board (CARB) has proposed to adopt more stringent emissions standards and test procedures for large spark-ignition engines (> 19 kW), including forklifts, sweepers/scrubbers, industrial tow tractors, and ground support equipment.[62] CARB proposes the adoption of EPA's 2007 model-year emission standard and a more stringent 2010 model-year emissions standard. CARB has also proposed stricter emission standards for fleets in use that would require them to reduce their emissions by retrofit or by replacement of engines or equipment with cleaner models by 2009. The proposal provides exemptions for lift trucks that cannot be retrofitted in the agricultural sector and for owners of three lift trucks or less.

3.2.2 Market Segment Analysis

The market analysis for forklift applications in distribution and warehousing is divided into two sections. Section 3.2.2.1 analyzes responses from Phase 1 surveys of manufacturers of forklifts. These surveys were conducted to determine the market opportunities for PEM fuel cells from the manufacturers' perspective. It is anticipated that these manufacturers will also serve as potential integrators of fuel cells into their products. Section 3.2.2.2 analyzes the responses received from users of forklifts in the food, beverage, and retail market sector conducted during Phase 1 and Phase 2. This analysis summarizes user requirements for forklift vehicles reported by survey respondents.

3.2.2.1 Manufacturer Response Analysis

In Phase 1, 11 forklift manufacturers were contacted and four responses were received. Information gleaned from the surveys is summarized below.

[60] Forkliftaction.com. 2005. Fuel Cells on Crown Forklifts Pass Wal-Mart Test. Newsletter #221. Available at http://www.forkliftaction.com/news/story_2521.htm [Accessed June 2006].
[61] EPA. 2002. Regulatory Announcement: Emission Standards for Non-Road Engines. EPA-420-F-02-037. Available at http://www.epa.gov/otaq/regs/nonroad/2002/f02037.pdf#search=%22Regulatory%20Announcement%3A%20Emission%20Standards%20For%20Non-Road%20Engines%22 [Accessed June 2006].
[62] California Air Resources Board. 2006. Staff Report: New Emissions Standards, Fleet Requirements, and Test Procedures for Forklifts, and Other Industrial Equipment. Available at http://www.arb.ca.gov/regact/lore2006/isor.pdf [Accessed June 2006].

Survey Participant Profile

Of the manufacturers that responded, two were medium-sized forklift manufacturers (i.e., 500 to 3,000 employees), and two were small forklift manufacturers (i.e., < 500 employees). Job titles of respondents ranged from director of product strategy to manager of research and development to account manager. Manufacturers reported that they were involved in the manufacture of a variety of battery- and ICE-powered material handling equipment for various applications. Two manufacturers produced battery-powered forklifts only, and two manufacturers produced both battery- and ICE-powered forklifts. ICE-powered forklifts manufactured by respondents included diesel, propane, gasoline, and dual fuel types.

Applications

Respondents indicated that their products were used in a variety of markets, including warehousing, distribution centers, manufacturing, and assembly plants. Forklift users include grocery stores, third-party logistics providers, retail department stores, E-commerce retailers, home improvement and hardware stores, medical and pharmaceutical manufacturing, computer and electronics manufacturing, and paper and publishing. All respondents identified warehouses and distribution centers as the market segments most severely impacted by forklift downtime.

Satisfaction with Current Technologies

Respondents were asked to determine the impact of forklift downtime; all respondents identified that forklift downtime results in decreased operation, loss in productivity through decreased movement of materials, decreased labor productivity, and increased operation and maintenance costs.

Manufacturers were asked to assess their satisfaction with batteries and ICE currently integrated in their products. Three of four respondents indicated that they were happy with their current mode of operation (batteries and/or ICE). Of these respondents, two indicated that they were always looking for opportunities to decrease the total cost of operation, through improvements in productivity, reliability, maintenance cost, and fuel cost. One respondent indicated that, while they commonly use batteries, most of their users are dissatisfied with batteries. Batteries are heavy and dirty; charge cycles are difficult to track; if not watered regularly, the life of the battery is impacted; fast charging also results in reduced life of the battery; and continuous maintenance is required to extend the life of the battery. Manufacturers identified other issues of concern with the current mode of operation as indicated by their users, including hazardous acid spills from overcharging batteries, size and weight of batteries, wastewater containment from washing batteries down, battery disposal, vented gases from batteries, and exhaust emissions from ICEs.

Operations and Maintenance of Current Technologies

Manufacturers were asked about the typical maintenance schedules recommended to users. Respondents indicated that users are provided with an operation and maintenance checklist to ensure that a product remains in proper working order during its lifetime. Detailed maintenance checks are performed every 200 to 250 hours. For battery forklifts, users are required to follow a checklist on a daily basis to ensure that the product is in working order.

Potential for PEM Fuel Cells

Three of four respondents were aware of PEM fuel cells as an alternative to battery- and ICE-powered forklifts. All three respondents are currently evaluating fuel cells in forklifts. One respondent indicated that his company has also considered other alternatives including ICE-electric hybrids, ultracapacitor-lead-acid battery hybrids, and advanced ICE technology. Respondents indicated that paper studies, analysis of maturity and availability of products, competitive intelligence, user input, and reliability data from installation and testing of the product are considered when evaluating alternatives. One respondent emphasized that, to select an alternative, it is important that the product have good total cost of ownership, high reliability, and high performance compared to current technologies. One respondent indicated that suppliers with good engineering capabilities were also a critical factor in selecting the right alternative. Only one of the three respondents who were aware of PEM fuel cells considered PEM fuel cells a viable alternative today.

Barriers to successful integration of PEM fuel cells in forklifts, as identified by two respondents, include capital cost, stack life, infrastructure for hydrogen delivery, and local regulations for handling hydrogen. Key drivers to successful adoption of fuel cell forklifts by users, as identified by manufacturers, include demonstrated return on capital investment, improvements in productivity, and associated cost savings. Respondents did not believe that environmental concerns were a big driver. Respondents indicated that use of hydrogen as a fuel may concern customers but indicated that appropriate education would alleviate those concerns.

3.2.2.2 User Response Analysis

In Phase 1 and Phase 2, 28 forklift users were contacted and 13 responded. Five responses were received in the Phase 1 survey, and ten responses were received in the Phase 2 survey. Two users responded to both the Phase 1 and Phase 2 surveys. Three in-depth interviews were conducted with respondents of Phase 2 surveys. For respondents who answered both Phase 1 and Phase 2 surveys, only one response was taken into account for the various common questions. Information gathered from these surveys and interviews is summarized below.

Survey Participant Profile

Of the 13 forklift users who responded, nine were large organizations, two were medium-sized organizations, and two were small organizations. Title of respondents ranged from distribution center manager, logistics vice president, to distribution center manager. Responses were received from users in discount retailing, retail distribution, food manufacturing and distribution, and online merchandise distribution. Types of forklifts used varied among respondents, including pallet trucks, sit-down riders, stockpickers, tuggers, and utility carts. All respondents indicated that they used some form of pallet forklifts. Of the respondents, ten indicated that they use battery-powered forklifts, while eight indicated that they use propane forklifts.

Applications

Survey respondents were asked to identify the types of forklifts used in a typical facility, the typical applications for these vehicles, and the frequency of use. Reach trucks, stand-up and sit-down riders, pallet jacks, and stockpickers were all used to facilitate materials handling in warehouses, distribution centers, and retail centers. The most common makes of forklifts the respondents reported using were: Crown, Yale, Hyster, Raymond, Nissan, Allis Chalmers, and Ottawa.

Battery-Powered Vehicles

Of the 13 respondents who indicated that they operate battery-powered vehicles, 11 indicated that battery-powered vehicles for materials handling typically ran for 2 to 3 shifts, operating 15 to 24 hours per day. Four respondents indicated that they ran vehicles 1 to 2 shifts per day, operating for 2 to 8 hours. The number of vehicles varied by facility; smaller facilities, such as retail outlets, typically maintained 1 to 8 vehicles; larger distribution centers would maintain as many as 250 vehicles.

Six of nine respondents indicated that forklift batteries are changed at least once per shift; of these, one respondent indicated that batteries sometimes are changed two times per shift, depending on use. Three of nine respondents indicated that they did not need to change or recharge batteries because they used smart chargers that keep batteries charged and running at peak capacity for an entire shift, and that it was rare to spend more than 15 minutes a week on battery maintenance. Times to change and charge batteries varied greatly and were dependent upon the application. Responses for battery change-out times ranged from 10 minutes to 1 hour per day.

Battery lifetime ranged from 4 to 9 years. Five of nine respondents indicated that battery life was approximately 5 to 7 years. For battery chargers, respondents indicated that charger lifetime was 5 to 15 years. Respondents did not indicate concern over the cost to dispose of batteries; old batteries were either traded with new batteries under contracts with specialty vehicle service providers, or disposed of without cost.

ICE-Powered Vehicles

Respondents used LPG-powered ICE vehicles primarily for heavy materials handling. Of the eight respondents who used propane trucks, four respondents indicated that refueling takes minimal time. Propane tanks are pre-filled and switched out when empty. One noted that refueling occurred 2 to 3 times per day, for a total of 15 minutes per day. Required maintenance varied; respondents reported maintenance times of 1 to 4 hours per month. For three respondents, costs for maintenance (excluding labor) per truck ranged from $10 to $25 per month.

Downtime/Unscheduled Maintenance

Respondents indicated that all applications of forklift trucks were impacted by product downtime. Applications which are the most severely impacted are those served by reach trucks (which move items from hard- to easy-to-reach locations, and have no substitutes). All respondents stated that downtime could result in loss of productivity through decreased movement of materials, decreased labor productivity, and increased operation and maintenance costs. Regarding the level of disruption caused by product downtime, respondents indicated that longer periods of downtime (greater than 4 hours) were very disruptive to their operations.

Downtime due to maintenance was described as being extremely variable, depending on the cause of the vehicle problem, and could range from 1 hour to a few days. One respondent provided examples of typical repair jobs and times: brakes (4 hours), transmission (8 hours), engine (30 hours), and water pump (4 hours). Nine respondents indicated that they follow (or exceed) the manufacturer's recommended schedule for maintenance.

Downtime incidents varied significantly among the user respondents and were highly dependent upon the operator and maintenance schedules. Large distribution centers may experience two to three downtime incidents per battery-powered forklift and four downtime incidents per ICE-powered forklift per year. One respondent who operated a fleet of 374 battery-powered forklifts estimated that 1,004 labor hours were impacted by product downtime in the past 12 months. For this application, based on the average wage of $14 per hour (as provided by respondents), annual lost productivity was valued at approximately $14,000.

Battery-powered vehicle users noted that battery change-out operations lead to vehicle downtime and lost productivity. Respondents indicated that they have spare batteries and battery changing equipment to minimize downtime and lost productivity. For one-shift operations, users cited no impact of batteries, as batteries last for a full shift and can be charged at night to avoid vehicle downtime. Space requirements for battery change-out and charging were variable. Space requirements ranged from 19 ft^2 per forklift to 122 ft^2 per forklift depending upon the type of operation. The average space requirements for a retail distribution center were approximately 24 ft^2 per forklift.

Purchase Decision Factors

The percentage of users rating various factors as very important is shown in Figure 3-13.[63] Reliability, ease of use, and lifetime of unit were most frequently cited as very important factors when selecting forklifts. While very important to some users, capital costs and emissions were less frequently cited by users compared to reliability, ease of use, and lifetime of the unit.

[63] On a scale of 1 to 7, responses of 1 to 3 were classified as "not so important", responses of 4 to 5 were classified as "somewhat important", and responses of 6 to 7 were classified as "very important".

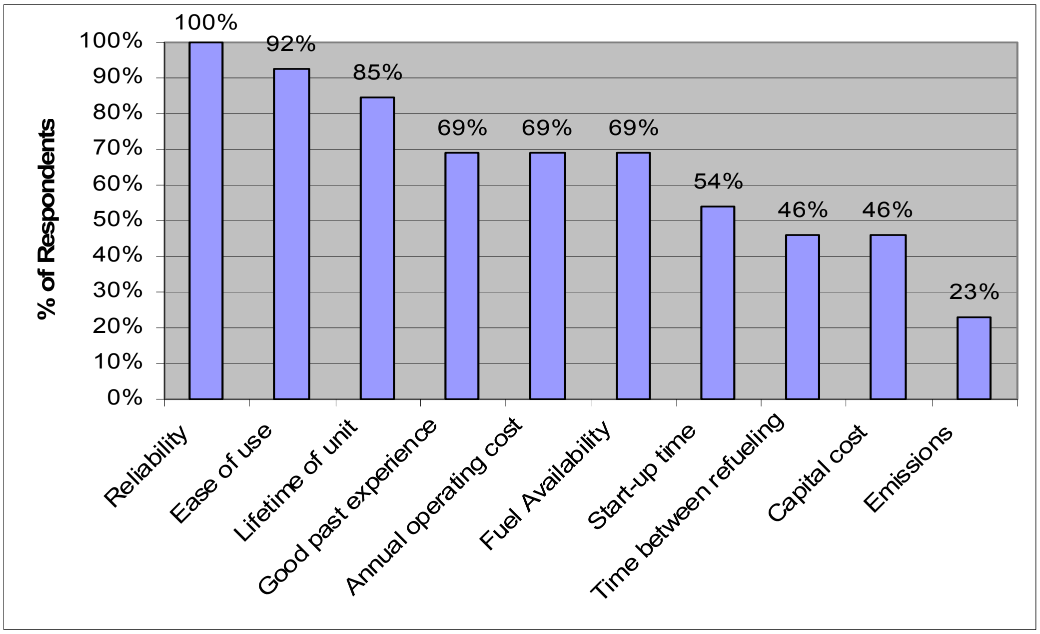

Figure 3-13. Factors That Most Influence Purchase Decisions (n=13).

When users were asked which three factors from the list above would most influence their decision to purchase a specialty vehicle powered by an alternative technology, a majority of the respondents identified reliability (72%), followed by capital cost (43%), fuel availability (29%), and lifetime of the unit (29%).

<u>*Satisfaction with Current Vehicles*</u>

In Phase 1 surveys, users were asked to rate the performance of their current forklifts. Two of five respondents indicated they were dissatisfied with the current performance of their forklifts. Concerns regarding performance of battery-powered forklifts included: batteries take too long to recharge, batteries are inconvenient to recharge and swap out, and batteries can produce hazardous emissions.

In Phase 1 and Phase 2, users were asked to rate their level of satisfaction with their current forklifts against the same set of characteristics they considered when selecting material handling products. Fuel availability (77%) followed by ease of use (69%), lifetime of unit (69%), and reliability (62%) were most frequently cited by users as "very good"[64] (Figure 3-14).

[64] On a scale of 1 to 7, responses of 1 to 3 were classified as "not so good", responses of 4 to 5 were classified as "good", and responses of 6 and 7 were classified as "very good".

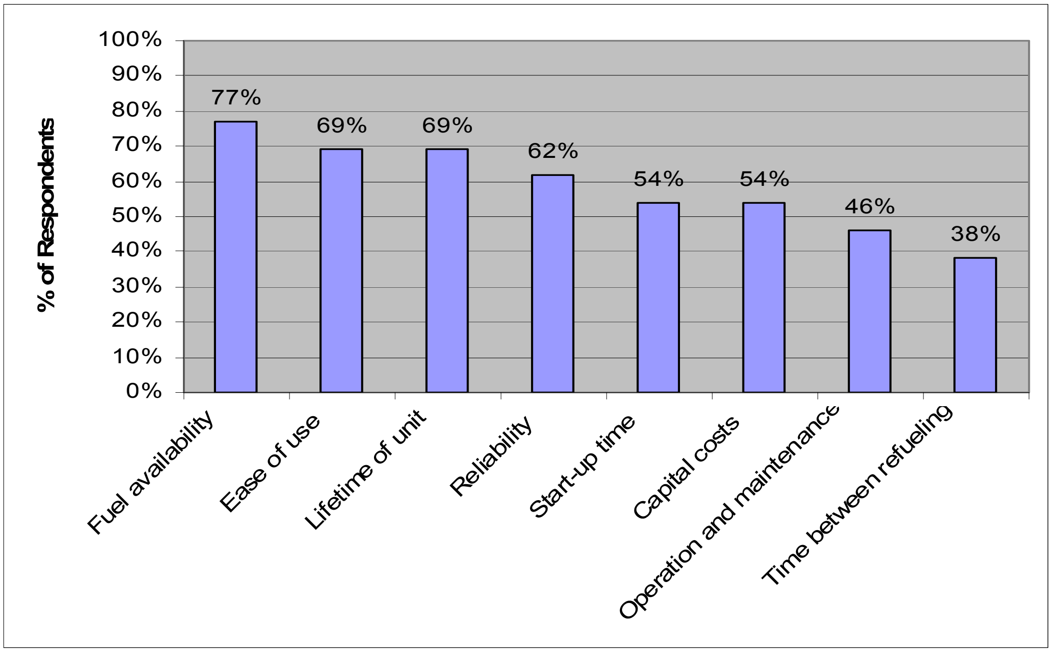

Figure 3-14. Characteristics of Current Systems That Users Identified as Very Good (n=13).

Potential for PEM Fuel Cells in Forklifts

In the Phase 1 survey, five users were asked about the trends and potential for PEM fuel cells in their marketplace. Four of five respondents to the Phase 1 survey anticipated a growing need for forklifts in their market. Three of the five respondents in Phase 1 had heard of PEM fuel cells and were currently evaluating alternative systems, including better battery systems, hydrogen fuel cells, and fast charging systems. All three respondents thought that PEM fuel cells would compete favorably with existing systems. One of these three respondents was concerned with the high initial capital cost of fuel cells, hydrogen fuel availability, and safety. Purchase decision drivers for PEM fuel cells, as identified by these three users, included costs incurred from downtime, efficiency of PEM fuel cells, environmental concerns, availability of government incentives, and the track record of others using PEM fuel cell vehicles.

Users were asked if the use of hydrogen as a fuel would concern them. Of the 12 respondents, four indicated that it would; two indicated that it would not; two indicated that it might be of concern; and two did not know enough to comment. Half of the eight users surveyed indicated that they consider government incentives when making purchase decisions. Respondents indicated that capital purchase decisions were made primarily on the basis of return on investment and payback period, although initial capital cost was also a consideration.

3.2.2.3 Market Research Summary

This section summarizes the information gathered through secondary and primary research on market trends and user requirements for forklifts in retail distribution and warehousing operations.

- The market for forklifts was $3.2 billion in 2003 and is projected to grow to $5.2 billion in 2013. Current and projected market share of battery-powered forklifts is approximately 58% of the total forklift market.
- Users of battery-powered forklifts are concerned about increasing productivity of operations by reducing the number of battery change-outs and increasing the lifetime of batteries. Air emissions regulations, particularly in California, may drive the conversion from ICE-powered to lower-emission forklifts.
- Fast charging systems and fuel cells are emerging alternatives to standard battery-powered and ICE-powered forklifts.
- Fast charging battery systems eliminate many of the disadvantages of standard battery-powered forklifts (i.e., long charging and cool-down time and the need for extra batteries) and are most suitable for multi-shift operations that work on predictable schedules and have a trained workforce. Fast charging also decreases the life of the battery and requires high initial capital investment.
- Compared to ICE-powered forklifts, fuel cell-powered forklifts offer zero emissions and are quieter.
- Compared to battery-powered forklifts, fuel cell demonstrations show that fuel cells offer longer runtime, faster return to service, and constant power.
- Fast charging may reduce the competitive advantages of the fuel cell for specific applications.
- Material handling in retail distribution is dominated by battery-powered forklifts. Forklift downtime impacts productivity in high-throughput operations.
- The most important decision factors in selecting an alternative powered forklift, in order of importance, are reliability, capital cost, fuel availability, and life of the unit.
- Current forklifts generally satisfy the factors that are most important to users.
- Emissions are not considered an important decision factor for most survey respondents.
- Battery charging and maintenance negatively impact productivity, resulting in some dissatisfaction with batteries.
- Spare batteries reduce downtime during charging, and smart charger or fast charging technologies are reducing the issue of charging time.
- Fuel cell-powered forklifts may provide value by reducing downtime costs, providing high efficiency, and addressing environmental concerns.
- Potential barriers to widespread PEM fuel cell-powered forklift adoption include: high capital cost; lack of hydrogen infrastructure/cost to purchase and store hydrogen; inadequate stack life; and local hydrogen regulation.

3.2.3 Lifecycle Cost Analysis

Distribution and warehousing operations currently use battery-powered forklifts to perform the majority of their indoor material handling and lifting. Surveys identify a significant interest among users, in alternatives to batteries in forklifts to increase productivity, especially in high-throughput operations. Surveys also indicate that while users in this segment make purchase decisions based on return on investment and payback period, initial capital cost is also an important consideration. To determine if PEM fuel cell-powered forklifts are a cost competitive alternative, this section analyzes the lifecycle costs of PEM fuel cell-powered forklifts compared to battery-powered forklifts for two different classes of forklifts. The lifecycle costs of PEM fuel cells as battery replacements in pallet trucks (Class 3) and sit-down rider trucks (Class 1) are evaluated in the following sections in two different continuous-use scenarios.

The analysis examines the discounted NPV of using PEM fuel cells compared to batteries and generators using assumptions consistent with the H2A model.[65] Hydrogen storage and delivery methods are not considered in this analysis. The $5 per kg cost of hydrogen used in this analysis assumes that storage and delivery costs are amortized in the hydrogen cost. For both scenarios, a discount rate of 8% and an inflation rate of 1.9% are applied. No disposal costs are assumed for any of the technologies. It is assumed that disposal costs are included in the initial capital cost of the system or that manufacturers allow trade-in of old systems. Lifecycle costs of PEM fuel cells are analyzed with and without incentives of $1,000 per kW, as currently authorized in EPAct 2005.[66] The battery replacement schedule utilized in this analysis is 5 years and was selected based on survey responses.

3.2.3.1 Lifecycle Cost Assumptions by Scenario

In scenario 1, it is assumed that pallet trucks (Class 3) operate 7 hours per shift, three shifts a day, and 7 days a week, which totals 7,644 hours per year. Cost assumptions used in this scenario are presented in Table 3-18. Lifecycle costs are analyzed with two and three replacement batteries per truck. It is assumed in this scenario that batteries are changed out once every shift. The cost of each battery in this scenario is $1,800. The PEM fuel cell uses a 3 kW stack with nickel-metal hydride (NiMH) batteries. Hydrogen costs are assumed to be $5 per kg. It is assumed in this analysis that the fuel cell module is replaced every 5 years.

In scenario 2, it is assumed that sit-down rider trucks (Class 1) operate 7-hour shifts, three shifts per day, and 5 days a week, which totals 5460 hours per year. Cost assumptions used in this scenario are presented in Table 3-18. For each forklift truck, lifecycle costs are analyzed with two and three replacement batteries per truck. Batteries are replaced once every shift. The cost of each battery for the pallet truck is $1,800 and for the sit-down truck is $4,000. The PEM fuel cell uses an 8 kW stack with ultracapacitors. The lifecycle of the ultracapacitor is assumed to be 10 years. Hydrogen costs are assumed to be $5 per kg. The cost of delivery and storage has been amortized into the aforementioned cost.

[65] DOE Hydrogen Program: DOE H2A Analysis. DOE H2A Analysis. www.hydrogen.energy.gov/h2a_analysis.html [Accessed December 2006].

[66] Under EPAct, fuel cells receive a 30% tax credit that is capped at $1,000/kW of generating capacity.

Table 3-18. Cost Assumptions for NPV Analysis of PEM Fuel Cell- and Battery-Powered Forklifts.

	Scenario 1		Scenario 2	
	Battery-Powered Pallet Truck	PEM Fuel Cell-Powered Pallet Truck	Battery-Powered Sit-Down Truck	PEM Fuel Cell-Powered Sit-Down Truck
Cost ($)	8,000	13,500	25,000	35,000
Lifetime (yrs)	15	15	15	15
Hours of Operation (hrs/yr)	7,644[1]	7644[1]	5,460[2]	5,460[2]
Cost of Accessories ($)	2,406[3]	-	2,406[3]	-
Battery Charger	1,800	-	1,800	-
Cranes/Hoists	210	-	210	-
Cost for Battery Room	396	-	396	-
Routine Maintenance Costs ($/yr)	3,600[4]	720[5]	3,600[4]	720[5]
Electricity/Hydrogen Fuel Costs ($/yr)	1,307[6]	4,380[7]	1,307[6]	5,612[8]
Time for Refueling (min/day)	30	3	15	3
Cost of Refueling/Recharging ($/yr)	8,213[9]	274[10]	2,925[11]	390[12]
Replacement Costs ($)	1,800 – Batteries every 5 years	9,000 – Fuel cell module every 5 years	4,000 – Batteries every 5 years	24,000 – Fuel cell module every 5 years 2,600 – Ultracapacitors every 10 years

[1] Forklift operates 7 hours per shift, 3 shifts per day, and 7 days a week.
[2] Forklift operates 7 hours per shift, 3 shifts per day, and 5 days a week.
[3] Schneider. A. 2004. Vistavia Warehousing, Inc. Global Perspectives on Accounting Education. Volume 1, 25-30.
[4] Routine maintenance is 5 hours per month at $60/hr. Data obtained from Battelle market research surveys.
[5] Routine maintenance is 2 hours per quarter at $90/hr. Data obtained from Battelle market research surveys.
[6] Cost of electricity charging is based on 2.85 kW per hour at 0.06 cents per kWh. Data obtained from L.D. Bailey and Associates. 2004. Electric vs. LP Gas Cost Comparison.
[7] Tank size is 0.8 kg. Runtime from single tank is approximately 8 hours. It is assumed that the tank is filled three times a day. Industry communication, September 2006.
[8] Tank size is 3.7 kg. Runtime from single tank is approximately 18 hours. Industry communication, September 2006.
[9] Battery swapping takes approximately 30 minutes. Operator charge is $15/hr. Battery is changed out once per shift.
[10] Fuel cell takes 1 minute to refuel. The fuel cell is refueled once every shift. Industry communication, September 2006.
[11] Battery swapping takes approximately 15 minutes. Operator charge is $15/hr. Battery is changed out once per shift.
[12] Fuel cell takes 3 minutes to refuel. It is refueled 2 times per day. Industry communication, September 2006.

3.2.3.2 Lifecycle Cost Results by Scenario

Results for Scenario 1 (Battery-Powered Pallet Truck)

In scenario 1, the NPV of the total costs of the PEM fuel cell-powered pallet truck is significantly less than the NPV of the total costs of the battery-powered pallet truck with two and three replacement batteries (Table 3-19). The NPV of the total costs of the PEM fuel cell pallet truck is 50% less than the NPV of the total costs of the battery-powered pallet truck with three replacement batteries, and 48% less than the NPV of the total costs of the battery-powered pallet truck with two replacement batteries.

The NPV of total operation and maintenance costs for PEM fuel cells is 59% less than that for battery-powered trucks. When NPV of total capital costs is considered, PEM fuel cell-powered pallet trucks without tax incentives require greater investment than battery-powered pallet trucks over the 15-year analysis period. With incentives, the PEM fuel cell-powered pallet truck is more attractive, in terms of total capital investment required over the 15-year lifetime, than the battery-powered pallet truck with three batteries per truck.

Table 3-19. Scenario 1: Lifecycle Cost Comparison of PEM Fuel Cell- and Battery-Powered Pallet Trucks.

	Battery-Powered Pallet Truck (3 Batteries Per Truck)	Battery-powered Pallet Truck (2 Batteries Per Truck)	PEM Fuel Cell-Powered Pallet Truck without Incentive	PEM Fuel Cell-Powered Pallet Truck with Incentive
NPV of Capital Costs ($)	21,572	17,654	23,835	21,004
NPV of O&M Costs (Including the Cost of Fuel) ($)	127,539	127,539	52,241	52,241
NPV of Total Costs of System ($)	149,111	145,193	76,075	73,245

Results for Scenario 2 (Sit-Down Truck)

In scenario 2, the NPV of the total costs of the PEM fuel cell-powered sit-down truck without incentives is approximately 1% greater than the NPV of the total costs of the sit-down battery-powered truck with three replacement batteries. With incentives, PEM fuel cell-powered sit-down truck requires approximately 5% less investment than the sit-down battery-powered truck with three replacement batteries over the 15-year lifetime, on a total system cost basis. When compared to the battery-powered sit down truck with two replacement batteries per truck, the PEM fuel cell-powered truck requires approximately 8% more investment. With incentives, the PEM fuel cell-powered sit-down truck requires approximately 2% more investment that the battery powered sit-down truck with two replacement batteries per truck. Table 3-20 summarizes the lifecycle costs of the two systems in scenario 2. PEM fuel cells with and without incentives in this scenario require more capital investment over the 15-year lifetime when compared to sit-down battery-powered trucks with two and three replacement batteries. However, PEM fuel cells require less operation and maintenance over the 15-year lifetime.

Table 3-20. Scenario 2: Lifecycle Cost Comparison of PEM Fuel Cell- and Sit-down Battery-Powered Trucks.

	Battery-Powered Sit-down Truck (3 Batteries Per Truck)	Battery-Powered Sit-down Truck (2 Batteries Per Truck)	PEM Fuel Cell-Powered Sit-down Truck without Incentive	PEM Fuel Cell-Powered Sit-down Truck with Incentive
NPV of Capital Costs ($)	51,977	43,271	63,988	56,440
NPV of O&M Costs (Including the Cost of Fuel) ($)	76,135	76,135	65,344	65,344
NPV of Total Costs of System ($)	128,112	119,405	129,332	121,784

3.2.3.3 Lifecycle Cost Summary

From a lifecycle cost perspective, PEM fuel cell-powered pallet trucks require significantly less investment (calculated as NPV of costs) than battery-powered pallet trucks under conditions of near continuous use and battery change-out times of 30 minutes. The larger PEM fuel cell-powered sit-down trucks require slightly more investment than battery-powered sit-down forklift trucks in three shift operations with battery change-out times of 15 minutes. With incentives the PEM fuel cell-powered forklift is comparable to the battery-powered sit-down truck with three replacement batteries. The value of PEM fuel cell-powered forklifts is impacted by declining hours of operation (i.e., number of shifts), declining labor rates, the time required for battery change-outs, and the cost of hydrogen. While PEM fuel cell-powered forklift trucks require more initial capital investment than battery-powered forklift trucks, they require less investment in operation and maintenance over the lifetime.

3.2.4 Sensitivity Analysis

3.2.4.1 Sensitivity Analysis Modeling Methodology

Single-factor sensitivity analysis was performed to show the variability in average annual cost (cash basis) as individual factors were varied while all other factors were held constant. Each factor was allowed to vary by +/-10% of the base assumption. The results of the sensitivity analysis are presented in a tornado diagram (Figure 3-15). The factor that shows the greatest cost leverage is graphed at the top of the diagram, with other factors arrayed below it in descending order of cost leverage. Two numbers are shown at each end of the horizontal bar graph for each factor. The upper number is the average cost per year if this factor is varied by 10% from base assumptions, holding all other factors at base assumptions. In brackets under the average cost figure is the value of the factor when varied by 10%.

The factors varied in the PEM fuel cell-powered pallet truck cost sensitivity analysis are shown in Table 3-21. For example, the base value assumed for the forklift cost was $13,500, the high value (+10%) is $14,850, and the low value (-10%) is $12,150. In the sensitivity analysis, the average annual cash outlay ($\overline{C}$) for use of PEM fuel cells was calculated using Equation 1. Hydrogen cost and operations and maintenance costs used are annual averages.

$$\overline{C} = \frac{Forklift\,Cost}{Forklift\,Life} + \frac{Fuel\,Cell\,Cost}{Fuel\,Cell\,Life} + \frac{Battery\,Cost}{Battery\,Life} + Hydrogen\ Cost + O\ \&\ M\ Cost \qquad \text{Equation 1}$$

Table 3-21. Cost Assumptions for PEM Fuel Cell-Powered Forklift Sensitivity Analysis.

	Base	**Low**	**High**
Forklift Cost, $	13,500	12,150	14,850
Forklift Life, years	15	13.5	16.5
O&M, $ (Including Refueling Time)	1,541	1,387	1,695
Fuel Cell Replacement, $	9,000	8,100	9,900
Fuel Cell Life, years	5.0	4.5	5.5
Hydrogen, $/kg	5.00	4.50	5.50

3.2.4.2 Sensitivity Analysis Results

As shown in Figure 3-15, hydrogen cost has the greatest impact on annual cost of owning and operating a PEM fuel cell-powered pallet truck. This is followed by fuel cell life and fuel cell replacement costs. Improvements in these individual factors will have the greatest impact on annual operating cost of the PEM fuel cell-powered pallet truck.

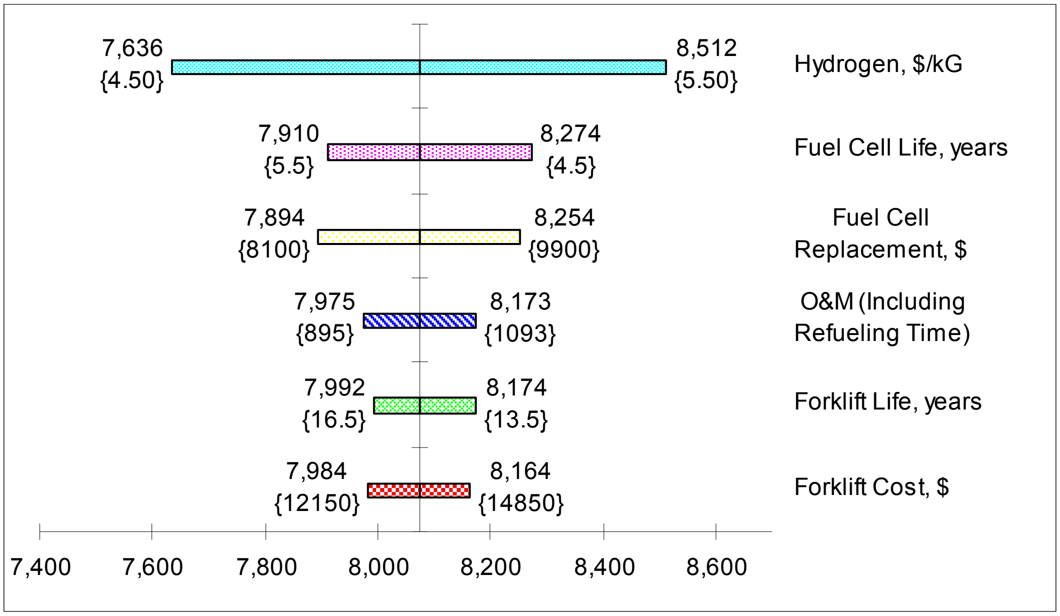

Figure 3-15. Sensitivity Analysis of Average Annual Cost of Owning and Operating a PEM Fuel Cell-Powered Pallet Forklift.

3.2.5 Market Penetration Analysis

3.2.5.1 Market Penetration Assumptions

The market penetration analysis assumes the following: cost-effective hydrogen fuel is available at the time of introduction; PEM fuel cell-powered forklifts are introduced as commercial products, and introduction can be scaled to meet demand. Table 3-22 shows the assumptions that were used for the three market adoption cases using PEM fuel cell-powered forklifts. In all three cases, it is assumed that PEM fuel cell-powered forklifts offer significant value as compared to battery-powered forklifts. PEM fuel cell-powered forklifts offer higher productivity, compared to batteries, by maintaining a constant level of power during operation and by providing rapid and easy refueling compared to replacing and recharging batteries.

For this analysis, the market for Class 1, 2, and 3 battery-powered forklifts was assumed to grow at a 5% annual rate so that the market for Class 1, 2, and 3 battery-powered forklifts in the year of introduction will be 108,606 units. It is assumed that 40% of this market is available for penetration by PEM fuel cell-powered forklifts. In all three cases, it was assumed that in the year of introduction battery-powered forklifts will be purchased at an average price of $20,000. For all three cases, it was assumed that the lifecycle cost of a forklift with a PEM fuel cell is comparative to the lifecycle cost of a battery-powered forklift. In some, but not in all cases, this is justified by the lifecycle analysis presented in the previous section of this report. A competitive lifecycle cost assumes that affordable hydrogen (including costs of production, transportation, and storage) is available. Because PEM fuel cell-powered forklifts will be manufactured and sold by the same companies that sell battery-powered forklifts, industry reaction is not expected to yield high pressure on price. Price was held constant in this analysis.

The three cases analyzed vary in the assumed level of government interventions. The communication case assumes that the government will engage in communications that will increase the strength of the innovation parameter in the model. The subsidized case assumes that the government will subsidize the purchase of PEM fuel cells at $3,000 per unit for one year.

Table 3-22. Assumptions for PEM Fuel Cell-Powered Forklift Adoption in Distribution Centers and Warehouses.

Assumption	Base Scenario	Communication Scenario	Subsidy Scenario
Market Growth Rate	5%	5%	5%
Government Actions	None	Communications	Subsidize purchase @ $3,000/unit
Values of *p* and *q*	p = 0.008 q = 0.423	p = 0.012 q = 0.423	p = 0.070 q = 0.423
Initial Number of Class 1, 2, and 3 Battery-Powered Forklifts Purchased	108,606	108,606	108,606
Initial Number of Class 1, 2, and 3 PEM Fuel Cell Powered Forklifts Purchased *(m)*	40% of total forklift market; m = 43,442	40% of total forklift market; m = 43,442	40% of total forklift market; m = 43,442
Average Initial Price of PEM Fuel Cell-Powered Forklifts	$20,000	$20,000	$20,000
Rate of Price Reduction	Stable; no price reduction	Stable; no price reduction	Stable; no price reduction
Final Share of Battery-Powered Forklift Market	100%	100%	100%

3.2.5.2 Market Penetration Results

The results of the analysis for the three market adoption cases are shown in Figures 3-16 through 3-21. Assuming that PEM fuel cell commercial products and the associated hydrogen infrastructure are available, the models show that, with subsidies, the level of market penetration achieved is significantly more than that for the base and communication cases.

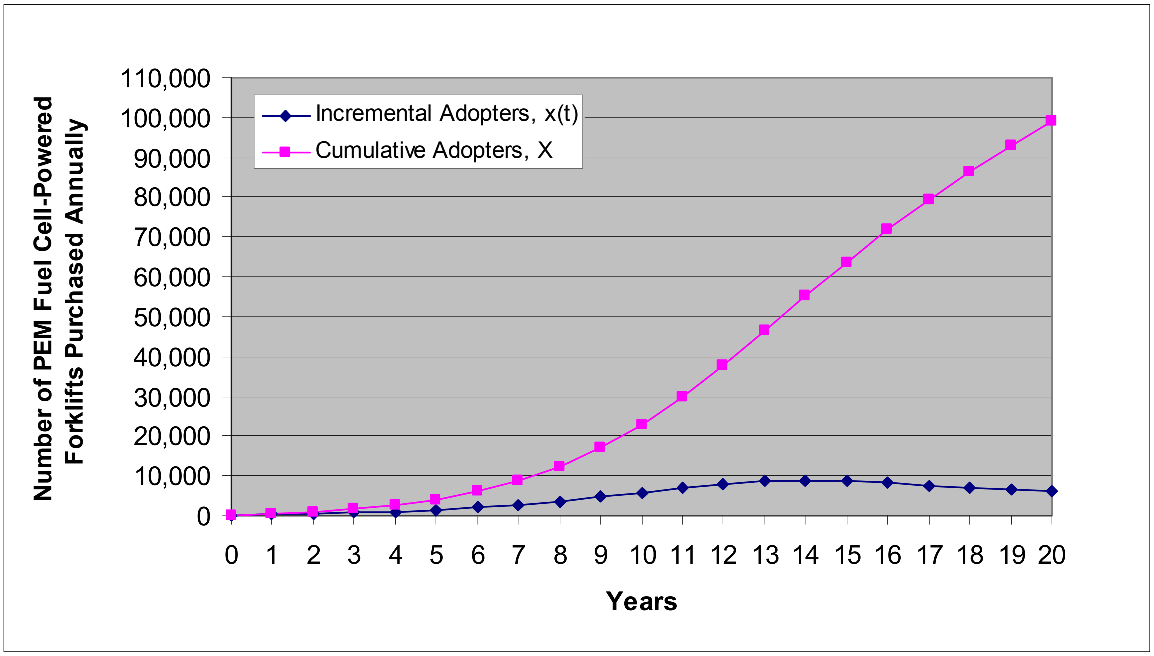

Figure 3-16. Adoptions of PEM Fuel Cell-Powered Forklifts in the Base Case.

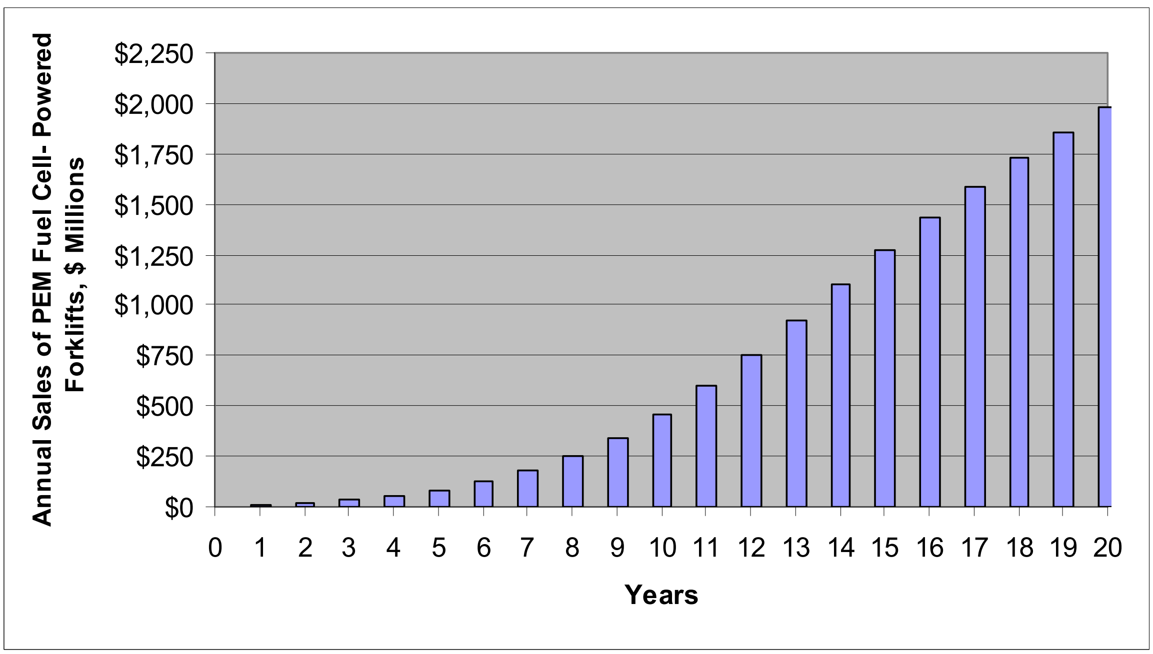

Figure 3-17. Sales of PEM Fuel Cell-Powered Forklifts in the Base Case.

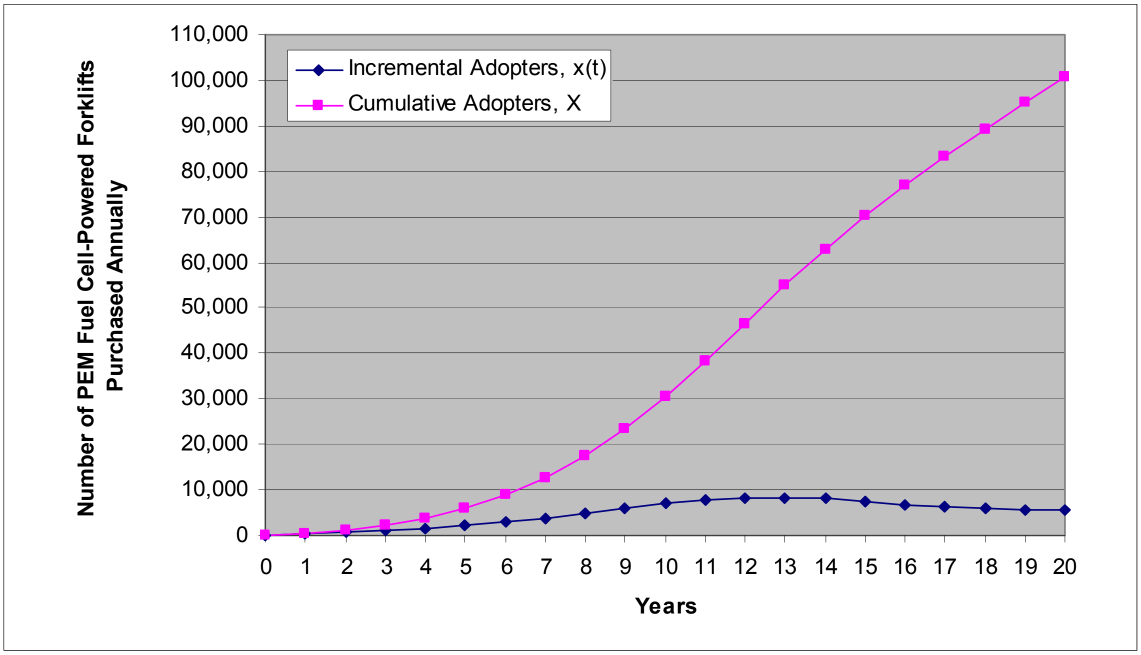

Figure 3-18. Adoptions of PEM Fuel Cell-Powered Forklifts in the Communication Case.

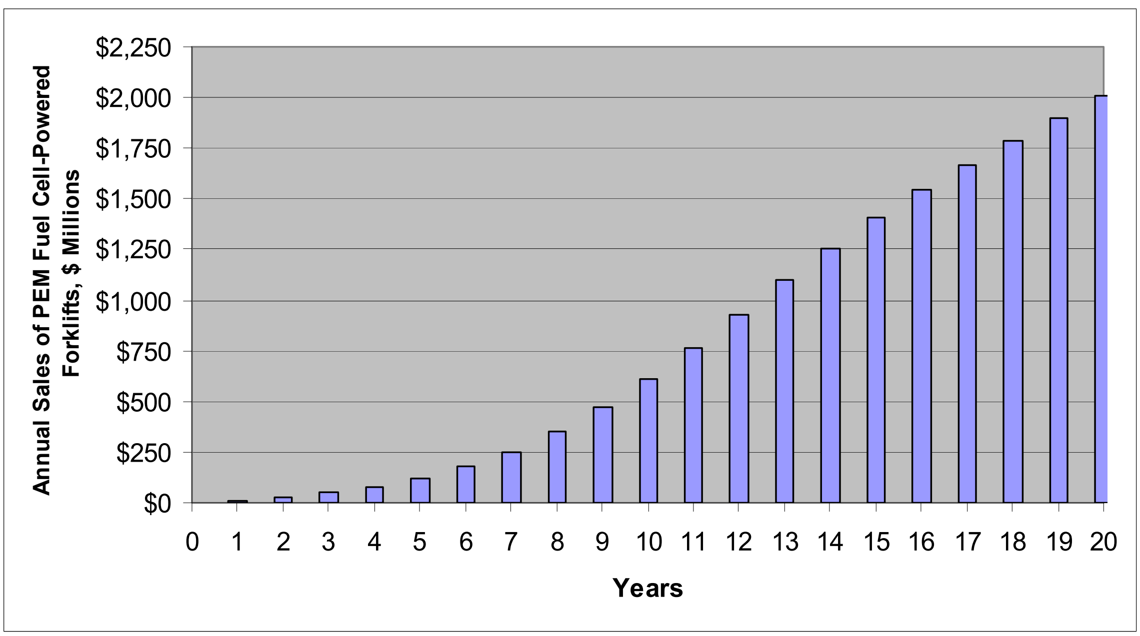

Figure 3-19. Sales of PEM Fuel Cell-Powered Forklifts in the Communication Case.

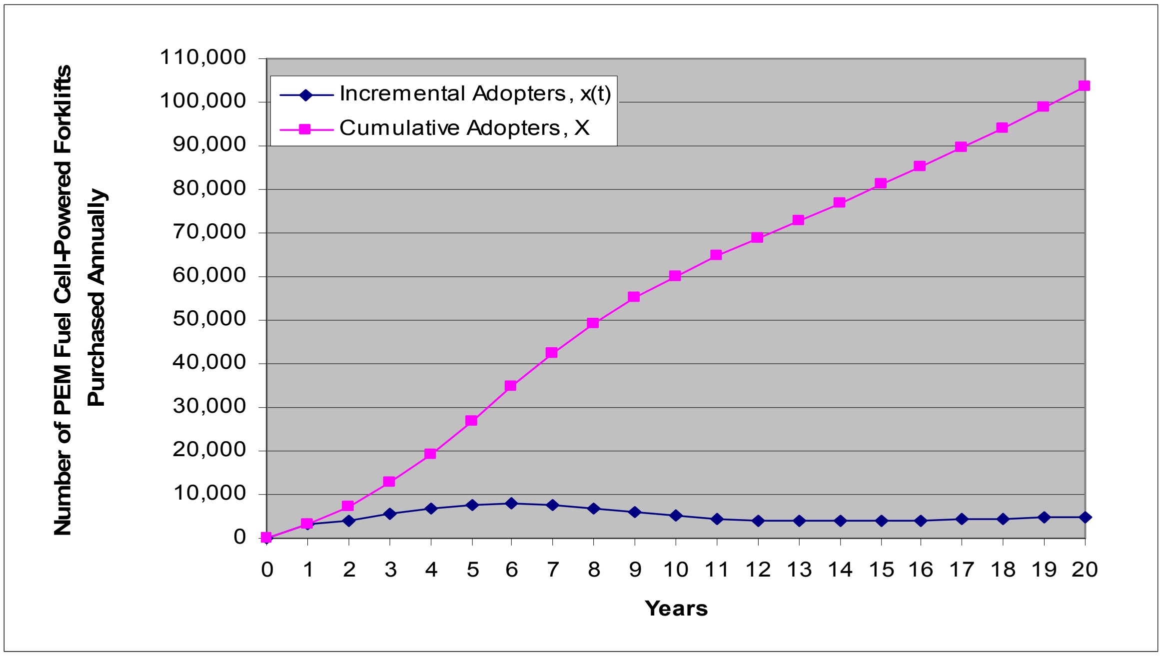

Figure 3-20. Adoptions of PEM Fuel Cell Forklifts in the Subsidy Case.

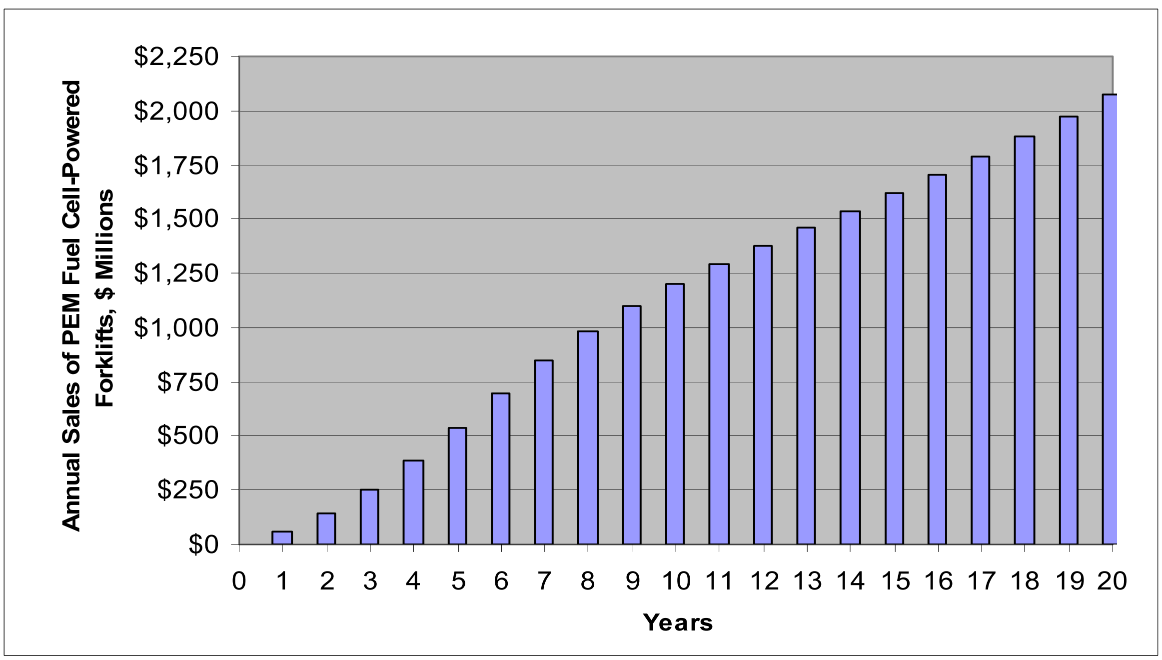

Figure 3-21. Sales of PEM Fuel Cell Forklifts in the Subsidy Case.

The models show that, for both the base and communication cases, the first year that 10,000 units are sold will be eight and seven years, respectively, after commercial introduction. In the subsidized case, 10,000 units are sold much earlier (three years after commercial introduction). Further, the models show that, in the base and communication cases, the first years that $100 million in annual sales are achieved will be six years and five years after commercial introduction, respectively. In the subsidized case, $100 million in sales are expected earlier, two years after commercial introduction. Table 3-23 provides a summary of the sales and market share data presented for each of the three cases described above.

Table 3-23. Summary of Sales and Market Share for Alternative Market Adoption Cases for PEM Fuel Cell-Powered Forklifts.

	5 Years After Commercial Introduction			10 Years After Commercial Introduction			15 Years After Commercial Introduction			20 Years After Commercial Introduction		
	Base Case	Communication Case	Subsidy Case	Base Case	Communication Case	Subsidy Case	Base Case	Communication Case	Subsidy Case	Base Case	Communication Case	Subsidy Case
Annual Sales (Units)	4,085	6,009	26,830	22,885	30,392	60,172	63,715	70,260	81,020	99,056	100,596	103,737
Annual Sales ($ millions)	82	120	537	458	608	1,203	1,274	1,405	1,620	1,981	2,012	2,075
Market Share (%)	3	4	19	13	17	34	28	31	36	34	35	36

3.2.6 Value Proposition for PEM Fuel Cell-Powered Forklifts

PEM fuel cell forklifts appear to represent a promising early opportunity for fuel cells in materials handling applications. Market research suggests that there are opportunities for alternative technologies to battery-powered forklifts in high-productivity environments. While lead-acid batteries are a known technology and are fairly reliable, there are concerns with their operation and maintenance, voltage drops as batteries discharge, and downtime during battery change-outs. Concerns over air quality are also driving users to look for alternatives to ICE-powered forklifts.

Currently, users are evaluating fast charging systems as an alternative that can increase the productivity of battery-powered forklifts. While fast charging systems eliminate many of the disadvantages of standard battery-powered forklifts (i.e., long charging and cool-down time and the need for extra batteries), they are most suitable for multi-shift operations that work on predictable schedules and have a trained workforce.

The forklift market segment represents a fairly large market opportunity for PEM fuel cells. Due to environmental regulation, it is anticipated that users will also be required to replace existing fleets with suitable alternatives. User requirements for runtime, refueling time, start-up time, operation and maintenance cost, and ease of use fit well with the capabilities offered by PEM fuel cell forklifts. However, for widespread PEM fuel cell-powered forklift adoption to be likely, reliability, capital costs, and fuel availability must be addressed. Unique benefits of PEM fuel cell-powered forklifts make them attractive for innovators. Specifically, PEM fuel cell-powered forklifts can be rapidly refueled, eliminating the time and cost of replacing batteries. The voltage delivered by the PEM fuel cell is constant as long as hydrogen fuel is available. PEM fuel cell-powered forklifts have zero emissions with only water and heat as wastes. PEM fuel cell-powered forklifts eliminate trips to the battery changing station, thus decreasing unproductive time; lower energy costs by eliminating chargers; reduce vehicle repairs due to their fewer moving parts; and eliminate the battery storage and changing rooms.

Most users consider capital costs and lifecycle costs when evaluating an alternative technology. With hydrogen costs at $5 per kg, the smaller PEM fuel cell-powered pallet trucks on a lifecycle cost basis require significantly less investment (approximately 48 to 50%) than battery-powered pallet trucks in high-throughput applications. However, the larger PEM fuel cell-powered sit-down trucks require slightly more investment (approximately 2 to 7%) on a lifecycle cost basis than battery-powered sit-down trucks in continuous applications. While PEM fuel cell-powered forklifts require more capital investment than incumbent alternatives, they provide significant savings in operation and maintenance. The lifecycle cost of PEM fuel cell-powered forklifts is most sensitive to the variability in hydrogen cost and fuel cell life. Increasing hydrogen fuel cost negatively impacts the operation and maintenance costs. Furthermore, the value of PEM fuel cell-powered forklifts compared to alternatives varies significantly by application and is impacted by declining hours of operation and declining labor rates.

In order for PEM fuel cells to compete effectively in the forklift market segment with current and emerging technologies like fast charging, research and development to improve the durability and lifetime of PEM fuel cells and the development of infrastructure to supply and store hydrogen in a cost-effective manner are critical. Furthermore, because reliability is critical to users, demonstration projects that provide data on reliability and performance of PEM fuel cells are also essential to overcoming incumbent technologies in this market segment. Investment is necessary to establish robust supply chains to develop, manufacture, distribute, and service PEM fuel cells and associated components to meet the demands of this market. While the surveys in this analysis did not indicate that government incentives were important to users, incentives decrease capital costs and result in lower lifecycle costs of owning and operating PEM fuel cell-powered forklifts. These lower costs are critical to drive adoption of PEM fuel cells in this market segment.

It is also likely that the PEM fuel cells developed for forklifts will be a platform that can be used broadly as battery replacements in other material handling equipment, such as automatic guide vehicles, other industrial trucks, and ground support equipment. Early focus on a market where PEM fuel cells offer benefits, such as forklifts in high-throughput distribution centers, could be a strategic approach to establish credibility and a technology platform with which to enter the broader material-handling market. The supply-base development and expansion of manufacturing capability derived from such early markets provide necessary infrastructure for expansion into additional and broader markets.

3.3 PEM Fuel Cells in Airport Ground Support Equipment (GSE)

3.3.1 Market Attributes

3.3.1.1 Market Segment Description

The airport GSE market is comprised of various types of specialty vehicles used to service aircraft during ground operations. Examples of GSE that are commonly used in airport operations include:[67]

- Baggage tractors (or "tugs") – used to tow baggage trailers between the aircraft and terminal
- Aircraft pushback tractors – used to push the aircraft back from the terminal to the taxiway or tow aircraft to and from the hangar for maintenance
- Belt loaders – conveyor belts used to transfer baggage between the aircraft hold and baggage trailers
- Cargo loaders – vertical lift devices with conveyor belts or rollers used to transfer containers to the aircraft's hold
- Forklifts – used for moving cargo and equipment around the airport
- Utility vehicles – used for a variety of applications including transporting personnel
- Ground power units – ground-based mobile generators used to supply electricity to the aircraft when it is parked.

This analysis focuses on ground support tractors – both baggage tugs and aircraft pushback tractors – based on the results of exploratory research on the airport GSE market. The similar terms "tug" and "tractor" are used interchangeably in this report. These tractors are designed for use in all airport applications, including ground support equipment shops, aircraft maintenance hangars, fixed base operations, corporate flight departments, and military facilities.[68] Table 3-24 identifies the SIC and NAICS codes that cover manufacturing of ground support tractors. This information was used to identify manufacturers and users of GSE equipment.

Table 3-24. SIC and NAICS Codes for Ground Support Tractor Manufacturing.

2-Digit SIC Code	35 – Industrial and commercial machinery and computer equipment
4-Digit SIC Code	3537 – Industrial trucks and tractors
NAICS Code	333924 – Industrial trucks, tractors, mobile straddle carriers and stacker machinery

Ground support tugs can be powered by batteries or ICEs. ICE-powered vehicles can be fueled by diesel, gasoline, liquefied petroleum gas (LPG, or propane), compressed natural gas (CNG), and Jet A fuel. Frequently, 4-cylinder or 6-cylinder automotive engines are used. Among the ICE-powered products offered by the manufacturers identified for this analysis, diesel- and gasoline-powered vehicles were the most common, followed by propane and CNG. Only one manufacturer was found to offer models that were capable of running on jet fuel. The capacities of diesel and gasoline engines in airport tugs vary widely, ranging from 25 HP/19 kW to 300 HP/224 kW. Larger engines are required for aircraft pushback operations, whereas baggage tractors require smaller engines.

[67] Northeast States for Coordinated Air Use Management and Center for Clean Air Policy. 2003. Controlling Airport Related Air Pollution.
[68] Victory GSE. 2003. Push Back Tractors. Available at http://www.victorygse.com/equipment/pushback/index.php4 [Accessed June 2006].

Wet cell and sealed gel cell lead-acid batteries are used in battery-powered ground support tugs. Battery-powered tugs are used for handling baggage and cargo and for towing lower weight aircraft (e.g., for small regional airline operations). Among the battery-powered tugs offered by the manufacturers identified for this analysis, capacities ranged from 2.5 HP/1.9 kW (36V motor) to 100 HP/75 kW (340V motor). Numerous models were available in the 20 HP/15 kW to 40 HP/30 kW range.

ICE-powered baggage tractors are used more often in heavy-duty applications (e.g., pushback of jumbo jets), compared to the battery-powered models. ICE-powered products are not constrained by battery charging cycles and offer significantly greater horsepower, on average, than the battery-powered tugs. A 1995 memorandum to the Federal Aviation Administration (FAA) estimated that a typical aircraft pushback tractor was operated an average of 1,721 hours per year, while a baggage tug was operated an average of 1,021 hours per year (note: estimates include both ICE- and battery-powered vehicles. It is unknown whether the estimates account for potential differences in operating time, as described below).[69]

There are key differences between battery- and ICE-powered ground support vehicles. The upfront costs associated with battery-powered vehicles are approximately 30 to 35% higher than those associated with ICE-powered vehicles.[70] However, battery-powered vehicles are more economical than ICE-powered tugs in other ways. First, battery-powered tugs are more efficient than ICE-powered vehicles, because electric motors convert about 60% of energy into motion compared to the 10% converted by ICE.[71] Also, the motors of ICE vehicles continue to run while the vehicle is idle, which wastes fuel, whereas battery-powered vehicles are turned off when they are not performing tasks. Estimates indicate that ICE idling accounts for 20 to 70% of operating time and 10 to 50% of fuel consumption.[72] Therefore, an ICE-powered vehicle runs for an average of 3.75 hours per day, while a battery-powered vehicle is capable of performing the same amount of work in 1.3 to 1.9 hours of operating time.[73] Finally, battery-powered tugs can be more reliable and require less maintenance (with fewer moving parts) than ICE-powered vehicles. Using a battery-powered vehicle eliminates the need for tune-ups, engine overhauls, exhaust system and transmission maintenance, and oil changes. Typical maintenance costs for a battery-powered tug (including battery replacement) average $1,406 annually, while the same costs for a gasoline model reach $1,893 per year.[74] Minimal maintenance requirements and reliability are particularly attractive to the airline industry, which is extremely susceptible to the financial and schedule-related impacts of equipment downtime.[75]

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[69] Webb, S. 1995. Technical Data to Support FAA's Advisory Circular on Reducing Emissions from Commercial Aviation. Memorandum to Bill Albee, Federal Aviation Administration, and Rich Wilcox, Environmental Protection Agency.
[70] Gibson, R. 2006. The True Cost of Going Electric. Ground Support Magazine (March). Available at http://www.groundsupportmagazine.com/publication/article.jsp?pubId=1&id=1479 [Accessed June 2006].
[71] Southern California Edison. 2006. Electric Transportation – Non-Road Applications. Available at http://www.sce.com/PowerandEnvironment/ElectricTransportationOld/Non-roadApplication/AirportGSE.htm [Accessed June 2006].
[72] Southern California Edison. 2006. Electric Transportation – Non-Road Applications. Available at http://www.sce.com/PowerandEnvironment/ElectricTransportationOld/Non-roadApplication/AirportGSE.htm [Accessed June 2006].
[73] Gibson, R. 2006. The True Cost of Going Electric. Ground Support Magazine (March). Available at http://www.groundsupportmagazine.com/publication/article.jsp?pubId=1&id=1479 [Accessed June 2006].
[74] Southern California Edison. 2006. Electric Transportation – Non-Road Applications. Available at http://www.sce.com/PowerandEnvironment/ElectricTransportationOld/Non-roadApplication/AirportGSE.htm [Accessed June 2006].
[75] Mercer, M. 1999. Taking Ground Support To A Higher Plane. Diesel Progress North American Edition. Available at http://www.findarticles.com/p/articles/mi_m0FZX/is_2_65/ai_54169047 [Accessed June 2006].

The price of baggage and aircraft pushback tractors generally increases with a vehicle's drawbar pull (DBP) capacity. The higher the DBP, the heavier the load the vehicle is capable of carrying. For example, an aircraft pushback tug with a DBP of 4,000 lbs is capable of towing 60,000 lbs, and one with a DBP of 12,000 lbs can tow an 180,000 lb aircraft. Tugs with 3,000 to 12,000 lb DBP are available. ICE-powered tugs from various manufacturers ranged in price from approximately $20,000 (3,000 lb DBP) to $59,000 (12,000 lb DBP).[76]

Manufacturers of ground support vehicles may also produce other types of tow tractors for use in industrial (rather than airport) environments. However, some manufacturers of airport ground support tractors specialize in airport applications and do not produce general industrial vehicles. Although ground support tractors are used at airports, airport authorities typically are not in charge of purchasing and maintaining the equipment. Instead, airlines are directly responsible for purchasing the vehicles. Airlines also hire ground support personnel to operate and maintain the vehicles. Sometimes, airlines hire contractors that specialize in ground support operations to perform these activities.

3.3.1.2 Market Size

Current data on the number of businesses manufacturing and using airport tugs are provided below. SIC Code 3537, covering manufacturing of industrial trucks and tractors, is represented in Table 3-25. Note that this SIC Code includes industrial tractors that are not used in airports.

Table 3-25. Number of Companies Potentially Involved in Airport Tug Manufacturing - Industry: Industrial Trucks and Tractors (SIC Code 3537).

SIC Code	SIC Description	No Bus.	Total Emps.	Total Sales ($)
3537-0000	Industrial trucks and tractors	391	9,184	2,049.5
3537-0111	Stands, ground servicing aircraft	5	35	3.2
3537-0200	Trucks, tractors, loaders, carriers, and similar equipment	162	2,043	351.8
3537-0216	Tractors, used in plants, docks, terminals, etc.: industrial	17	2,544	58.2
3537-0218	Trucks: freight, baggage, etc.: industrial, except mining	147	2,139	88.7
	Total	**722**	**15,945**	**2,551.4**

Sales figures are in millions. Source: www.zapdata.com, accessed June 2006.

Table 3-26 contains data on the number of potential adopters of airport GSE, including airports and flying fields (SIC Code 4581); air courier services (e.g., FedEx) (SIC Code 4513); scheduled air transportation providers (e.g., major airlines) (SIC Code 4512); and nonscheduled air transportation providers (e.g., charter flight operators) (SIC Code 4522). In both Table 3-25 and Table 3-26, only the eight-digit SIC Code specialties relevant to airport tugs are shown.

[76] Aero Specialties. 2006. Tractors, Tugs, & Pushbacks. Available at http://www.aerospecialties.com/productinfo/tractors/ [Accessed June 2006].

Table 3-26. Number of Potential Adopters of Airport Tugs.*

SIC Code	SIC Description	No Bus.	Total Emps.	Total Sales ($)
4581-0000	Airports, flying fields, and services	1,563	34,901	5,797.3
4581-0100	Hangars and other aircraft storage facilities	106	1,189	42.1
4581-0101	Aircraft storage at airports	67	485	29.3
4581-0200	Aircraft maintenance and repair services	1,405	25,102	2,984.2
4581-0202	Aircraft servicing and repairing	1,422	32,483	2,621.7
4581-0300	Airports and flying fields	51	1,216	38
4581-0301	Airport	1,665	30,122	5,610.9
4581-0302	Flying field, except those maintained by clubs	17	72	8.8
4581-0303	Military flying field	21	304	4.9
4581-9901	Air freight handling at airports	203	5,104	931.9
4581-9904	Airport terminal services	220	10,354	1,362.8
4581-9905	Airfreight loading and unloading services	53	611	54.9
4581-9906	Fixed base operator	46	856	96.2
4513-0000	Air courier services	903	22,815	3,332.6
4513-9901	Letter delivery, private air	135	9,004	2,988.4
4513-9902	Package delivery, private air	770	14,466	49,135.7
4513-9903	Parcel delivery, private air	55	2,102	11.4
4512-0000	Air transportation, scheduled	1,157	56,434	6,297.6
4512-9901	Air cargo carrier, scheduled	532	24,554	4,169.6
4512-9902	Air passenger carrier, scheduled	1,180	132,634	182,204.9
4512-9903	Helicopter carrier, scheduled	104	3,086	605.2
4522-0000	Air transportation, nonscheduled	524	6,632	1,027
4522-0100	Nonscheduled charter services	265	4,021	1,249.8
4522-0101	Air passenger carriers, nonscheduled	201	4,283	1,825.2
4522-0102	Flying charter service	946	10,508	2,055.9
4522-0103	Sightseeing airplane service	106	687	67.5
4522-9901	Air cargo carriers, nonscheduled	151	4,650	2,033.1
4522-9902	Air taxis	110	932	85.4
4522-9903	Ambulance services, air	218	4,365	1,103.5
4522-9904	Helicopter carriers, nonscheduled	334	3,807	1,148.7
	Total	**14,530**	**447,779**	**278,925**

Sales figures are in millions. Source: www.zapdata.com, accessed June 2006.
*Users include the following industries: Airports, Flying fields, and Services (SIC Code 4581); Air courier services (SIC Code 4513); Air transportation, Scheduled (SIC Code 4512); and Air transportation, Nonscheduled (SIC Code 4522)

Secondary research identified detailed but slightly dated information on the population of ground support tractors in the U.S. In 1999, EPA estimated the proportions of pushback tugs and baggage tugs in the U.S. that operated on various types of fuels (Table 3-27).[77] More detailed information on ICE-powered tugs was provided in a 2005 EPA report on non-road engines (Table 3-28). This report, which documented the source of non-road engine population values in EPA's NONROAD emissions inventory model, provided the most recent population data available (termed "base year" data) for non-road engines in a wide range of vehicles and equipment. All data were obtained from Power Systems Research, an independent market research firm that surveyed engine manufacturers and users to derive its estimates. For ground support vehicles, the years 1998 and 2000 were designated as base years. [78] While the estimates

[77] EPA. 1999. Technical Support for Development of Airport Ground Support Equipment Emission Reductions. EPA-420-R-99-007.
[78] EPA. 2005. Non-road Engine Population Estimates. EPA-420-R-05-022. Available at http://www.epa.gov/OMS/models/nonrdmdl/nonrdmdl2005/420r05022.pdf#search=%22Non-Road%20Engine%20Population%20Estimates.%20EPA420-R-05-022.%22 [Accessed June 2006].

in Table 3-27 undoubtedly have changed in the last six years (e.g., CNG-powered tugs are now available and battery-powered tugs are being more widely adopted), they do provide a recent reference point for the industry.

Table 3-27. Estimated U.S. Ground Support Tractor Population by Power Source, 1999.[79]

Ground Support Equipment (GSE) Type	Engine Type	Estimated U.S. Population	Fraction of Type-Specific GSE
Aircraft Pushback Tractor	Diesel	2,113	76.6%
	Gasoline	489	17.7%
	CNG	0	0.0%
	LPG	63	2.3%
	Battery-Powered	94	3.4%
	All	**2,759**	**100%**
Baggage Tug	Diesel	4,399	41.9%
	Gasoline	4,863	46.3%
	CNG	0	0.0%
	LPG	973	9.3%
	Battery-Powered	270	2.6%
	All	**10,505**	**100%**

Considering the data presented above and probable growth (estimated at 4% per year) in the market since the EPA's inventory was completed in 1999, the research team estimates the total current population of baggage tractors to be less than 14,000 baggage tractors; for pushback tractors it is estimated to be about 3,600 units.

Leading manufacturers of airport tugs include TUG Technologies Corporation, FMC Technologies, TLD America, Taylor-Dunn Manufacturing Co., Charlatte America, and NMC-Wollard. In the U.S., potential large end-users of airport tugs include Delta Airlines, American Airlines, Southwest Airlines, Northwest Airlines, U.S. Airways, United Airlines, and Continental Airlines.

[79] EPA. 1999. Technical Support for Development of Airport Ground Support Equipment Emission Reductions. EPA-420-R-99-007.

Table 3-28. Total Population of ICE-Powered Ground Support Equipment in the United States in 1998 and 2000.[80]

Year	Equipment Description	Min HP/kW	Max HP/kW	Avg HP/kW	U.S. Population
1998	4-Stroke airport support equipment	3/2.2	6/4.5	4.9/3.6	897
1998	4-Stroke airport support equipment	6/4.5	11/8.2	8.2/6.1	102
1998	4-Stroke airport support equipment	11/8.2	16/11.9	16.0/11.9	363
1998	4-Stroke airport support equipment	16/11.9	25/18.6	18.4/13.7	19
1998	4-Stroke airport support equipment	25/18.6	40/29.8	37.0/27.6	21
1998	4-Stroke airport support equipment	40/29.8	50/37.3	46.0/34.3	7
1998	4-Stroke airport support equipment	50/37.3	75/55.9	59.0/44.0	23
1998	4-Stroke airport support equipment	75/55.9	100/74.6	86.2/64.3	97
1998	4-Stroke airport support equipment	100/74.6	175/130.5	113.0/84.3	287
1998	LPG-airport support equipment	25/18.6	40/29.8	37.0/27.6	21
1998	LPG-airport support equipment	40/29.8	50/37.3	46.0/34.3	7
1998	LPG-airport support equipment	50/37.3	75/55.9	59.0/44.0	23
1998	LPG-airport support equipment	75/55.9	100/74.6	86.2/64.3	97
1998	LPG-airport support equipment	100/74.6	175/130.5	113.0/84.3	287
2000	Diesel-airport support equipment	6/4.5	11/8.2	8.3/6.2	1,124
2000	Diesel-airport support equipment	11/8.2	16/11.9	11.7/8.7	3
2000	Diesel-airport support equipment	16/11.9	25/18.6	21.2/15.8	14
2000	Diesel-airport support equipment	25/18.6	40/29.8	38.5/28.7	41
2000	Diesel-airport support equipment	40/29.8	50/37.3	41.0/30.6	57
2000	Diesel-airport support equipment	50/37.3	75/55.9	62.8/46.8	1,176
2000	Diesel-airport support equipment	75/55.9	100/74.6	84.2/62.8	2,142
2000	Diesel-airport support equipment	100/74.6	175/130.5	141.1/105.2	6,327
2000	Diesel-airport support equipment	175/130.5	300/223.7	221.4/165.1	2,124
2000	Diesel-airport support equipment	300/223.7	600/447.4	419.0/312.5	2,481
2000	Diesel-airport support equipment	600/447.4	750/559.3	655.0/488.4	263
2000	Diesel-airport support equipment	1,000/745.7	1200/894.9	1071.0/798.7	16
	Total Population				**18,019**

Note: Category of Ground Support Equipment is not limited to aircraft tractors and baggage tugs.

3.3.1.3 Market Trends

There has been movement in recent years away from ICE-powered airport ground support vehicles and toward battery-powered vehicles. Air quality is a major concern at airports, particularly within terminal buildings where a significant amount of baggage and cargo handling takes place. Emissions from ICE-powered vehicles, including carbon monoxide, nitrogen oxides hydrocarbons, and particulates, can have a dramatic impact on air quality in these environments, requiring airports to modify air circulation patterns and structural designs to ensure the health and safety of employees working within the terminals.[81]

[80] EPA. 2005. Non-road Engine Population Estimates. EPA-420-R-05-022. Available at http://www.epa.gov/OMS/models/nonrdmdl/nonrdmdl2005/420r05022.pdf#search=%22Non-Road%20Engine%20Population%20Estimates.%20EPA420-R-05-022.%22 [Accessed June 2006].
[81] Miami International Airport. 2001. Environmentally Friendly Battery Operated Tugs Debut at MIA. Available at http://www.miami-airport.com/html/archieved_press_release_154.html [Accessed June 2006].

Since as early as the mid-1990s, the airline industry has been investigating the benefits of using electricity or alternative fuels instead of gasoline and diesel fuel in ground support vehicles.[82] New environmental standards may further encourage the airline industry to transition away from ICE-powered vehicles. EPA recently proposed new emissions standards applicable to non-road diesel engines. These standards, to be implemented in phases between 2008 and 2014, will require diesel engine manufacturers to outfit new engines with advanced emission control technologies. New diesel-powered ICE-powered ground support vehicles will be required to meet these standards.[83]

The California Air Resources Board (CARB) has proposed to adopt more stringent emission standards and test procedures for large (> 25 HP/19 kW), spark-ignited engines in various types of equipment, including forklifts, sweepers/scrubbers, industrial tow tractors, and ground support equipment.[84] Ground support equipment includes forklifts, tugs, belt loaders, bob-tails, cargo loaders, lifts, air conditioners, service trucks, de-icers, fuel delivery trucks, and ground power units. CARB has proposed the adoption of EPA's 2007 model-year emission standard and a more stringent 2010 model-year emissions standard. CARB also has proposed stricter emission standards for fleets in use and would require operators of in-use fleets to reduce their emissions by retrofitting existing equipment or replacing uncontrolled engines with zero or low-emission engines by 2009.

Emissions from ground support vehicles impact not only the air within airport environments but also the air quality of the surrounding community. This could potentially become a concern, particularly in air quality nonattainment areas. The FAA and EPA identified a total of 126 U.S. airports in 8-hour nonattainment or maintenance areas.[85] This creates further incentive for regional air quality boards and state agencies to support cleaner GSE technology deployment because they want to avoid being penalized for nonattainment.

In the years since the figures shown in Table 3-27 Table and Table 3-28 were estimated (1999/2000), the airline industry has taken steps to replace ICE-powered tugs with battery-powered models. For example, in 2001 a major ground support service provider at Miami International Airport committed to replacing most of its gas-fueled baggage tugs in an attempt to improve terminal air quality, which had been degraded by emissions from the ICE-powered vehicles.[86]

Federal and state agencies have also begun advancing programs that support low-emission GSE. In April 2000, Congress authorized the Inherently Low-Emissions Airport Vehicle (ILEAV) Pilot Program as part of the Wendell H. Ford Aviation Investment and Reform Act for the 21st Century (AIR-21). AIR-21 authorized ten ILEAV project grants for up to $2 million each under

[82] Webb, S. 1995. Technical Data to Support FAA's Advisory Circular on Reducing Emissions from Commercial Aviation. Memorandum to Bill Albee, Federal Aviation Administration, and Rich Wilcox, Environmental Protection Agency.
[83] FAA. 2005. Aviation and Emissions - A Primer. Available at http://www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/AEPRIMER.pdf#search=%22Aviation%20and%20Emissions%20-%20A%20Primer%22 [Accessed June 2006].
[84] California Air Resources Board. 2006. Staff Report: New Emission Standards, Fleet Requirements, And Test Procedures For Forklifts And Other Industrial Equipment. Available at http://www.arb.ca.gov/regact/lore2006/isor.pdf [Accessed June 2006].
[85] FAA. 2005. List of U.S. Commercial Service Airports and their Nonattainment and Maintenance Status. Available at http://www.faa.gov/airports_airtraffic/airports/environmental/vale/media/vale_eligible_airports.xls [Accessed September 2006].
[86] Miami International Airport. 2001. Environmentally Friendly Battery Operated Tugs Debut at MIA. Available at http://www.miami-airport.com/html/archieved_press_release_154.html [Accessed June 2006].

the FAA Airport Improvement Program (AIP). The program, which ran between 2001 and 2005, gave airports the opportunity to evaluate numerous types of mobile and stationary low-emission technologies. A total of $6.7 million was allocated to six airports during this period, including Dallas/Fort Worth, Sacramento, Denver, San Francisco, and Baltimore-Washington international airports, and Baton Rouge Metropolitan Airport. Most projects involved conversion of gasoline- and diesel-powered ICE vehicles to new vehicles running on electricity and CNG.[87]

In light of the success of the ILEAV Program, FAA and EPA have expanded the initiative to all commercial airports listed in the FAA National Plan of Integrated Airport Systems (NPIAS) and located in EPA-designated air quality nonattainment areas through the Voluntary Airport Low Emission (VALE) program. The VALE program allows airport sponsors to use the AIP and Passenger Facility Charges (up to $4.50 for every enplaned passenger) to finance low-emission vehicles, refueling and recharging stations, gate electrification, and other airport air quality improvements.[88] This includes the conversion of airport vehicles and ground support equipment to low-emission technologies, modification of airport infrastructure to support use of alternative fuels, and a pilot program to explore retrofit technology for airport ground support equipment. The VALE program creates opportunities for fuel cell-powered vehicles to enter this market.[89]

Many airlines have voluntarily agreed to reduce emissions from their ground support vehicle fleets. For example, major airlines have forged agreements with state agencies in both California and Texas to reduce emissions from ground support vehicles by converting gasoline and diesel equipment to alternative fuels and electricity.[90] Air carriers operating in California's South Coast air basin entered into a Memorandum of Understanding (MOU) with CARB in 2002, committing to reduce hydrocarbon and NO_x emissions from new and in-use GSE. While the MOU was terminated in late 2005, under CARB's new proposed emission requirements those airlines still would be required to meet the MOU's zero-emission requirement for existing fleets by 2010.[91]

As alternatives to battery- and ICE-powered tugs, hydrogen-powered tugs are being developed for both military and commercial applications. The U.S. Air Force has developed a prototype fuel cell-powered ground support vehicle for testing. For this effort, Concurrent Technologies Corporation integrated Enova Systems' 120-kW HybridPower drive system with a Hydrogenics 65-kW fuel cell system in an aircraft tug. The tug will be tested at select Air Force bases and civil airports throughout the country.[92] In 2006, General Hydrogen Corporation partnered with Air Canada to investigate the use of fuel cell power packs in tugs used to tow baggage to and

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[87] FAA. 2006. Final Report: Inherently Low Emission Airport Vehicle Pilot Program. Available at http://www.faa.gov/airports_airtraffic/airports/environmental/vale/media/ileav_report_final_2005.pdf#search=%22Final%20Report%3A%20Inherently%20Low%20Emission%20Airport%20Vehicle%20Pilot%20Program%22 [Accessed June 2006].
[88] FAA. 2006. Voluntary Airport Low Emissions (VALE) Program. Available at http://www.faa.gov/airports_airtraffic/airports/environmental/vale/ [Accessed September 2006].
[89] FAA. 2005. Aviation and Emissions - A Primer. Available at http://www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/AEPRIMER.pdf#search=%22Aviation%20and%20Emissions%20-%20A%20Primer%22 [Accessed June 2006].
[90] FAA. 2005. Aviation and Emissions - A Primer. Available at http://www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/AEPRIMER.pdf#search=%22Aviation%20and%20Emissions%20-%20A%20Primer%22 [Accessed June 2006].
[91] California Air Resources Board. 2006. Staff Report: New Emission Standards, Fleet Requirements, And Test Procedures For Forklifts And Other Industrial Equipment. Available at http://www.arb.ca.gov/regact/lore2006/isor.pdf [Accessed June 2006].
[92] BioAge Group, LLC. 2005. Enova Electric Drives in Two More Fuel Cell Prototypes. Available at http://www.greencarcongress.com/fuel_cells/ [Accessed June 2006].

from aircraft. The project, funded in part by the Government of Canada, will be conducted at Air Canada's Ground Support Equipment site at Vancouver International Airport. General Hydrogen's power packs, which contain Ballard Power Systems' fuel cell stacks, are capable of operating up to three times longer on a single fueling than their battery-powered counterparts.[93] Finally, Ford Motor Company has produced a 4.6-liter, hydrogen-fueled, V6 engine that a major ground support equipment manufacturer is now using to develop off-road vehicles, including tow tractors.[94]

Industry analysts have noted several advantages of fuel cell-powered tugs. While their performance is similar to that of other battery-powered tugs, a fuel cell tug remains fully charged at all times and does not experience performance lag at the end of a shift like battery-powered tugs do. Lastly, refueling with hydrogen can be significantly more convenient and faster than changing or recharging a battery.[95]

3.3.2 Market Segment Analysis

The market analysis for ground support applications in airports is divided into two sections. Section 3.3.2.1 analyzes responses from Phase 1 surveys of manufacturers of GSE. These surveys were conducted to determine the market opportunities for PEM fuel cell-powered GSE from the manufacturers' perspective. It is anticipated that these manufacturers will also serve as potential integrators of fuel cells into their products. Section 3.3.2.2 analyzes the responses received from users of GSE, including airports, airlines, and GSE service providers, conducted during Phase 1 and Phase 2. This analysis summarizes user requirements for GSE vehicles reported by survey respondents.

3.3.2.1 Manufacturer Response Analysis

Twelve GSE manufacturers were asked to complete a survey, and four responses were received. Two interviews were also conducted. Information gleaned from this research is summarized below.

All of the system integrators who responded were small manufacturers (less than 500 employees) of tow tractors and other ground support vehicles. Two of the four manufacturers worked exclusively in the aviation industry, while the other two also produced tow tractors for general industrial use. Respondents from manufacturing organizations were typically affiliated with marketing departments. Three of the four manufacturers offered ICE- and battery-powered vehicles, while the fourth offered battery-powered vehicles only. Two of the ICE-powered manufacturers offered diesel-, propane-, and gasoline-powered vehicles; one offered diesel only.

When asked about safety concerns, a manufacturer noted that any safety issues with batteries had been resolved long ago. Another responded that disposal was once a concern, but major battery companies are now handling disposal. He added that wet-cell batteries can spill, but such spills

[93] BioAge Group, LLC. 2006. General Hydrogen in Fuel-Cell Luggage Tug Project with Air Canada. Available at http://www.greencarcongress.com/fuel_cells/ [Accessed June 2006].
[94] Weeks, B. 2005. Making a Case for Hydrogen in the GSE Industry. Ground Support Magazine (May). Available at http://www.groundsupportmagazine.com/publication/article.jsp?pubId=1&id=1044 [Accessed June 2006].
[95] Weeks, B. 2005. Making a Case for Hydrogen in the GSE Industry. Ground Support Magazine (May). Available at http://www.groundsupportmagazine.com/publication/article.jsp?pubId=1&id=1044 [Accessed June 2006].

are extremely rare. The third manufacturer pointed out that there is the possibility of electric shock during battery maintenance. The fourth manufacturer noted that batteries contain a significant amount of acid, which corrodes the tugs more than an ICE would.

Only one manufacturer commented on maintenance requirements, indicating that proper ICE maintenance is easier for their customers than proper battery maintenance.

All four manufacturers were aware of the potential for PEM fuel cells to be used as substitutes for existing power sources in their products. Two manufacturers had not considered replacing ICEs or batteries with fuel cells, although one of the two had sold a tug to another company for fuel cell R&D. One manufacturer is currently testing and demonstrating a fuel cell-powered tug. The fourth has considered using fuel cells but, because of the company's small size (and limited R&D budget), has not been able to develop anything so far. The two companies that have considered using fuel cells reported that they were responding to customer needs. One noted that airlines began discussing the removal of fossil fuels from the tarmac nearly a decade ago. The same two manufacturers pointed out that any energy source must be capable of meeting the customer's needs (i.e., towing requirements). One added that energy sources must be low-cost and easy to refuel. The manufacturer that is already demonstrating a fuel cell tug suggested that fuel cells will be a viable energy source in these vehicles, noting that he is already seeing a major shift in the forklift market, which will drive a shift in the tow tractor market (because tow tractors tend to follow forklifts). This respondent expects that fuel cells will begin to be used in forklifts and tow tractors in the very near future (within 12 months). Another manufacturer noted that fuel cells would only be viable if they could be refueled without having to install an expensive refueling station. An airport authority representative noted that fuel cells would need to provide the same operational characteristics as existing tug power sources, and they would need to withstand outdoor storage in extreme temperatures and weather conditions.

Two manufacturers identified drivers and barriers for fuel cell use in their products. Cost was cited as a major barrier by both manufacturers, particularly the cost of refueling stations. One manufacturer considered the small size of his organization as a barrier, while the other cited availability of hydrogen. The manufacturer with a fuel cell vehicle in development has no timeline for commercial release but plans to target airline and automotive applications when the vehicle does become commercially available. Regarding drivers, one manufacturer indicated that the costs of refueling would have to be reduced. The other noted that the technology must be developed to the point where it is cost-effective for the industry; right now, the infrastructure is prohibitively expensive.

All manufacturers expressed an interest in working with DOE to develop fuel cell products. One noted that DOE would have to provide sufficient resources to conduct R&D, since the company currently does not have such resources.

3.3.2.2 Ground Support Equipment User Response Analysis

Thirty users of ground support tugs were asked to participate in a detailed survey, and nine surveys were completed. Three surveys were completed as part of the Phase 1 analysis, and six surveys were completed as part of the Phase 2 analysis. In addition, eight of these users also participated in follow-up interviews as part of the Phase 2 analysis. Information from these surveys and interviews is summarized below.

Survey Participant Profile

All but one of the users represented organizations of 3,000 or more employees. Of the users who responded, four were commercial airlines, three were aviation ground support service providers, one was a parcel delivery company, and one represented a regional airport authority. Respondents from these organizations were typically airport station or GSE managers.

Applications

Survey respondents were asked to identify the types of specialty vehicles used in a typical facility, the typical applications for which these vehicles are used, and the frequency of use.

A large airline with its hub at a large international airport operates over 600 baggage tugs and 78 aircraft pushback tractors. About 40% of its baggage tug fleet at the hub airport is battery-powered, primarily with 25 HP/18.5 kW vehicles with a 3,500 lb DBP. The rest are 3,000 and 5,000 lb DBP gasoline-powered ICE baggage tugs. The airline's pushback tow tractors are diesel vehicles with a power output ranging from 100 HP/75 kW to 255 HP/190 kW and a DBP ranging from 16,000 to 78,000 lbs. These vehicles typically operate 18 to 20 hours per day, so limited time is available for maintenance and battery recharging.

A regional airline operating at a mid-sized international airport has 38 baggage tugs, all of which are gasoline-powered but one, which is a diesel-powered ICE tug. Most of these baggage tugs have a 3,000 lb DBP and operate about 17 hours per day. The airline owns three diesel- and gasoline-powered ICE aircraft tow tractors for moving aircraft between the terminal and hangar; the tow tractors operate an estimated 8 hours per day. The airline also runs 14 battery-powered aircraft pushback tractors, which operate 17 hours/day. The battery-powered vehicle pushback tractors run on two 36V batteries. Another regional airline at a major international airport has a very similar fleet of equipment with 32 baggage tugs and 15 pushback tractors. They operate these vehicles on a nearly continuous basis, 24 hours per day. A final airline surveyed has 7 baggage tractors (gas and diesel) and 4 tow tractors at a mid-sized international airport, which they also operate 24 hours a day, 7 days a week.

Respondents from the GSE service providers and the parcel delivery company surveyed tended to have shorter operating times than the airlines, suggesting that downtime may be less of an issue for this sub-segment. Three of the four operate their vehicles for 6 to 9 hours per day. One specified that it had just 6 baggage tugs at a typical facility, while others said the number ranged from just a few to several hundred per facility. Three of these organizations use predominantly diesel- and gas-powered ICE tractors. Just one ground support services organization surveyed operates only battery-powered vehicles – it has a fleet of eleven 48V burden carriers at a mid-sized international airport. Use of battery-powered vehicles was required by that particular airport.

Battery-Powered Vehicles

Six of the nine survey respondents indicated that they had some battery-powered vehicles in their fleet of baggage and aircraft pushback tractors. Users were asked detailed questions about their battery-powered vehicles, including how often they have to charge or change batteries, time required for battery maintenance, and battery lifetime. Three companies indicated that it was not necessary to change batteries during a typical 8-hour shift; just one specified that it has to change out its batteries for a cargo tractor each shift, and two did not provide information. Two companies noted that they do not change out batteries at all; they use the 4 to 6 hours of downtime each evening to recharge the vehicles. One of these companies uses rapid chargers, and the power supply will last the entire 18 to 20 hour day. The other said that the 4 to 6 hour recharge time is not sufficient for their vehicles and they often do not last a full 18 to 20 hour day. In these cases they are forced to double up baggage loads or find another vehicle.

Three respondents indicated that battery change-out time does not typically impact productivity, as long as they get a full charge at night, while three indicated that it does impact productivity. Unscheduled downtime, however, does have a major impact on productivity, particularly for airlines. One user noted that downtime can have very serious consequences, particularly when tow tractor capability is lost. Another indicated that they maintain enough vehicles at their hub to ensure continued operations in the event that a vehicle goes down, requiring a higher capital investment in GSE to manage this risk. However, it was noted by one user that, in most airport operations, other airlines tend to be cooperative and will share their equipment in order to avoid interruptions in flight schedules.

The survey asked users about battery maintenance in order to understand how it compared to maintenance for ICE-powered vehicles. Two users surveyed estimated their battery maintenance time at 2 to 3 hours per month. They typically follow or exceed the preventive maintenance schedule recommended by manufacturers. According to the manufacturers, maintenance of battery-based products primarily involves daily recharging and checking the water level in flooded lead-acid batteries. One manufacturer noted that battery life is often reduced by improper maintenance (e.g., failing to charge them daily and exposing them to extreme temperatures). Another manufacturer noted that both battery-powered and ICE-powered vehicles are subject to routine maintenance after the first 200 hours of service; this maintenance is repeated at 500 hours and every 1,000 hours thereafter.

When asked about safety concerns with battery-powered vehicles, none of the users identified any concerns. Users indicated that the expected lifetime for batteries in battery-powered baggage tugs ranged from 2 to 7 years. They expect battery chargers to last anywhere from 3 to 15 years.

Space requirements for battery charging can represent a sizeable cost for airlines because they typically lease space from airports based on square footage occupied. Respondents were asked to specify space requirements for battery charging, and answers varied widely. One airline with 14 battery-powered vehicles said they require just 5 square feet of space for recharging; a respondent with 11 vehicles has 100 square feet of dedicated space; and a third with 250 battery-powered vehicles at a large international airport indicated that their battery charging space occupied approximately 37,000 square feet.

ICE-Powered Vehicles

For ICE-powered vehicles, users were asked to describe tank refill frequency, tank fill time, and maintenance time and cost. Of the four who responded to this question, two typically refill their ICE-powered vehicles twice per day (or once per shift) and two refill them once per day. Refill time ranged from an estimated 2 to 18 minutes per vehicle. For one airline at a large international airport, refueling time represents a significant labor cost at an estimated 24 man-hours per day for all vehicles.

ICE-powered tugs are generally subject to the same maintenance requirements as any other ICE-powered vehicle (e.g., oil and other fluid changes). According to users, maintenance time for tugs was estimated at 3 to 6 hours per month, which is slightly more than the average time estimated for battery-powered vehicles.

Some users were asked whether they had safety concerns with their ICE-powered vehicles. None of the respondents identified any concerns with ICE-powered vehicle use and safety. Only one manufacturer noted any safety concerns with ICE-powered tugs; this concern was noise.

Downtime/Unscheduled Maintenance

Respondents were asked to specify which of the various ground support vehicle applications are most affected by unscheduled downtime. Of the seven who responded to this question, four indicated that all applications are critical and equally affected by downtime. Two indicated that baggage handling applications were most critical, and one indicated that aircraft pushback applications were the most affected.

As far as the frequency of downtime incidents experienced, one airline estimated that average downtime was approximately 7.4% on all equipment. Downtime incidents for other respondents ranged between four and 30 incidents of downtime per vehicle per year. Two others did not specify a number but said that downtime incidents can occur daily or weekly. One user commented that downtime was a rare event and could not estimate its frequency. Of the respondents that estimated downtime frequency, three reported that a typical downtime incident lasts greater than 8 hours; one reported that incidents generally last between 4 and 8 hours; and one specified less than 30 minutes. The number and duration of incidents suggests that downtime may represent a significant cost for these users.

Purchase Decision Factors

Of the various factors considered by users when selecting a specialty vehicle, the following were identified as "very important"[96] by users: capital cost (7 users); reliability (7 users); annual operating cost (5 users); lifetime of the unit (5 users); time between refueling or recharging (4 users); fuel availability; good past experience with this type of system (4 users); ease of use (4 users); emissions (3 users); and start-up time (2 users). These results are summarized in Figure 3-22 below.

[96] On a scale of 1 to 7, responses of 6 and 7 are classified as "very important".

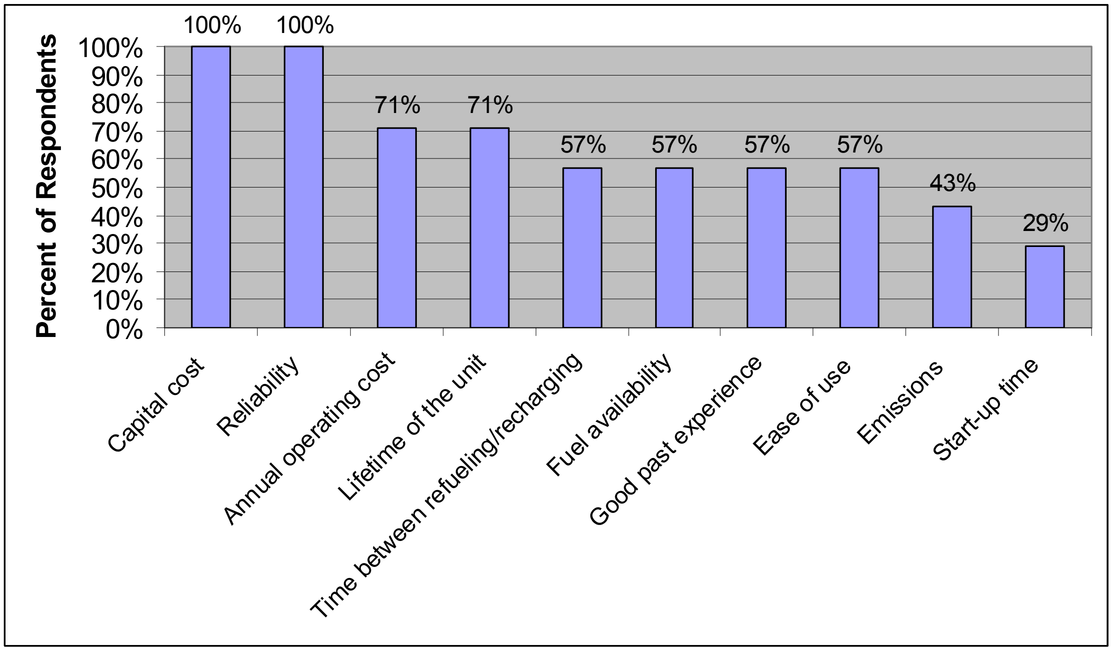

Figure 3-22. Specialty Vehicle Purchase Decision Factors Identified as Very Important (n=7).

While capital cost was identified as a very important factor by the greatest number of people, reliability ultimately may be a more important decision factor. When users were asked which three factors from the list above would most influence their decision to purchase a specialty vehicle powered by an alternative technology, all respondents to the question identified reliability (7 users). Operating costs (5 users), lifetime of the unit (4 users), capital cost (3 users), and fuel availability (1 user) were also identified as among the three most important factors influencing specialty vehicle purchase decisions.

Satisfaction with Current Vehicles

Users were asked to rate their level of satisfaction with their current specialty vehicles against the same set of characteristics (Figure 3-23). The greatest number of users identified start-up time as very good[97] (7 users), followed by fuel availability (6 users), reliability (5 users), and ease of use (5 users). While users appear to have a high level of satisfaction with start-up time and fuel availability, it is interesting to note from the analysis above that neither of these factors are among the most important to users. Reliability, however, is among the most important decision factors; just over half of the users surveyed classified reliability as very good.

[97] On a scale of 1 to 7, responses of 6 and 7 are classified as "very good".

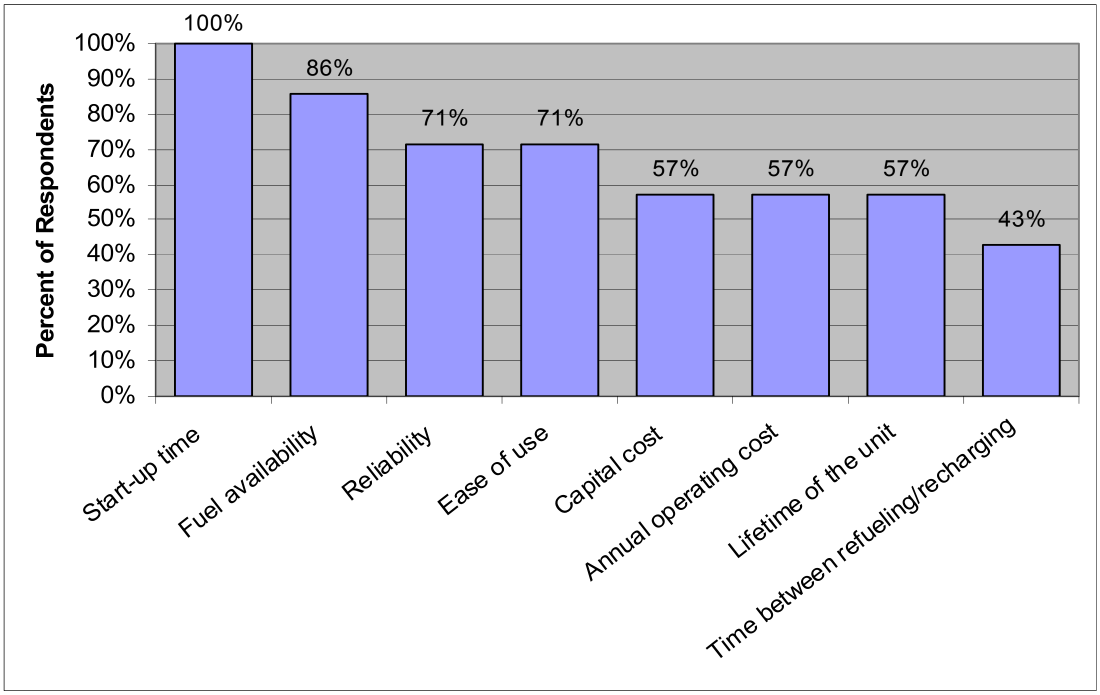

Figure 3-23. Characteristics of Current Systems that Users Identified as Very Good (n=7).

Trends and Potential for PEM Fuel Cells in Airport Tugs

Three users provided feedback on market trends. They all agreed that there will be a growing need for specialty vehicles in the ground support equipment market over the next several years. Four users have considered alternatives to their current battery- or ICE-powered products. Two users considered fuel cell airport tugs, two users considered hybrid vehicles, and another who is currently using an ICE-powered vehicle has considered battery-powered vehicles.

Just half of eight respondents had heard of PEM fuel cells as a potential power source for ground support vehicles. Of these, two users do not believe that PEM fuel cells will compete favorably with existing products any time soon. One pointed out that the cost must come down before fuel cell-powered vehicles can compete. Another user cited the lack of a hydrogen infrastructure as a major barrier. Only one user indicated that fuel cells would be well received in the industry due to a growing interest in alternative fuel sources; however, the user was unsure whether fuel cells could compete technically with existing power sources.

In follow-up interviews respondents were asked what factors would convince them to procure a fuel cell-powered ground support vehicle. A parcel delivery company said that longer time between refueling (longer runtimes), proven durability (i.e., it can withstand the daily rigors of use by ground support personnel), and reduced vehicle emissions would convince them to procure a fuel cell ground support vehicle. It was noted that the airline industry and GSE manufacturers are working toward reducing emissions from airport vehicles and aircraft, particularly in areas with strict emission laws. The drive to reduce emissions was echoed by an airport authority representative, who cited efforts to replace ICE-powered ground support equipment with battery-powered vehicles in nonattainment areas. Two aviation service providers emphasized incentives and operating costs as important drivers. One indicated that financial incentives would be more likely to influence their decision than dissatisfaction with a current technology, suggesting greater price sensitivity; the other stated that any improvements in the area of fuel and maintenance costs would get a lot of attention from them, as would availability of government incentives. Two airlines stated that fuel savings and ease of maintenance (i.e., reduced time for repairs and reduced parts to stock) would be important drivers.

Survey participants were asked about potential concerns over the use of hydrogen in airport ground support tractors. Users were asked to rate their level of concern on a scale of 1 to 7, with 1 being not at all concerned and 7 being very concerned. In general, there appears to be a relatively low level of understanding about hydrogen safety among potential airport ground support vehicle users. Three individuals provided scores ranging from 3 to 6, and three users indicated that they did not know enough about hydrogen to answer the question, although one of these respondents explained that airlines are accustomed to using hazardous fuels and probably would not be too concerned. An airport authority representative said that he assumed hydrogen storage and safety codes would be satisfied, but thought there could be potential misconceptions about safety among users.

In follow-up interviews, respondents were asked whether they would be interested in testing a fuel cell at one of their sites. All seven interviewees responded positively. Four indicated that they would definitely be interested, although one pointed out they would need guarantees that they would not be liable for equipment since their ground support agents have a reputation for being extremely hard on equipment. Three others said they would probably be interested; one said it would depend on the incentives available, and another speculated that since their company was testing fuel cells in automobiles they would probably be willing to test them in ground support vehicles too.

Eight respondents addressed the issue of how capital purchase decisions for specialty vehicles are made within their organizations. Six users indicated that their organizations conduct a formal return-on-investment analysis (incorporating total lifecycle costs, not just capital costs) when making purchase decisions. One airline at a large international airport stated that their company typically expects a one-year payback, but will at times extend that to three years. Two users also noted that they try to extend the life of the vehicle as long as possible; one said that many of their tractors are more than 20 years old. While only one user identified this as a standard procedure, it is important to consider that specialty vehicle users may have a predetermined and pre-approved make and model of ground support tractors that they typically purchase. This can make getting approval for any alternatives a greater challenge. Availability of government incentives are considered by five of the users when making a purchasing decision. One airline noted that they participated in the ILEAV program for a few years as part of an effort to acquire battery-operated baggage tractors. Another airline does not typically consider incentives, but said they are open to new ideas if something works better.

3.3.2.3 Market Research Summary Analysis

Through nine surveys and eight follow-up interviews with users, and surveys with four manufacturers, information was collected on the airport GSE market (focusing on baggage tractors and aircraft pushback tractors). This included information on user requirements, usage patterns, customer satisfaction with current systems, and perceptions regarding PEM fuel cells as an alternative power source. Information gathered through these surveys and interviews, as well as information obtained through secondary research, is summarized below.

- The total estimated current market size for baggage tractors is 14,000 baggage tractors and 3,600 pushback tractors. The vast majority of these vehicles are ICE-powered; however, recent trends in the market for GSE suggest a move away from ICE and toward battery-powered vehicles.
- Proposed new emission standards by EPA, and even stricter standards for California-based airports proposed by CARB, are driving airports to transition to lower emission GSE.
- Federal programs, including VALE, provide financial incentives to airports and airlines to convert their fleets of GSE, including baggage and pushback tractors, to low-emission technologies.
- Efforts to reduce emissions, particularly in nonattainment areas, will drive the replacement of ICE-powered vehicles with alternatives in the near future, and currently battery-powered vehicles are the most widely known alternative. While battery-powered vehicles are quickly making inroads to this market, fuel cell tugs are also being developed and will be tested.
- At major airports where baggage tractors run nearly continuously, time required for maintenance and battery charging requires costly backup equipment or results in loss of productivity.
- GSE service providers and parcel delivery companies surveyed tended to have shorter operating times than the airlines, suggesting that downtime may be less of an issue for this sub-segment of the market.
- Battery charging and unscheduled downtime required by inadequate charge time can impact productivity, particularly for airlines. Unscheduled maintenance on GSE is frequent enough to present a significant cost to users. At least one airline interviewed relies on rapid chargers for battery-powered vehicles and maintains extra vehicles to ensure continued operations if a vehicle were to go down – both of which can require sizeable investments. Space required for battery charging can also represent a significant cost.
- While capital cost is an important factor considered by all users when making ground support tractor purchase decisions, reliability and operating costs appear to be the most important factors that influence these purchase decisions.
- Users are fairly satisfied with the performance of their current vehicles; however, it is interesting to note that factors they are most satisfied with – start-up time and fuel availability – are not among the most important purchase decision factors to users.
- Many ground support tractor users have considered alternatives to their current battery- or ICE-powered products, and some have looked at PEM fuel cell-powered vehicles as alternatives.
- The ability to demonstrate cost savings – operating and maintenance costs and financial incentives that reduce capital cost – will be key factors in supporting the adoption of PEM fuel cell-powered vehicles as alternatives to battery-powered vehicles.

- Hydrogen safety is not considered a major barrier, because airlines are accustomed to dealing with hazardous fuels; however, users have a relatively low level of understanding about hydrogen safety, and education will be required.

3.3.3 Lifecycle Cost Analysis

Fleets of baggage tractors currently in operation are a mix of diesel-, propane-, and battery-powered vehicles. While most users are satisfied with their current mode of operation, there is increasing interest in seeking alternatives to ICE-powered vehicles to meet emission requirements at airports. Government programs like the VALE program are providing monetary support to facilitate the transition to cleaner vehicles, including battery-powered vehicles and fast charging battery systems. As a result, many users are currently considering the replacement of older ICE-powered vehicles with cleaner options.

This lifecycle analysis compares PEM fuel cells in baggage tractors to current technologies. Baggage tractors are considered the most attractive near-term application in the GSE segment based on Battelle's market research. To determine whether fuel cells are a suitable alternative, the lifecycle costs of a 3,000 lb DBP PEM fuel cell-powered baggage tractor are evaluated against similarly sized diesel- and battery-powered baggage tractors in three different scenarios. Scenario 1 compares the lifecycle costs of vehicles operating for six hours a day, representing a relatively low operating time for baggage tractor use, based on survey data. Scenarios 2 and 3 compare the lifecycle costs of vehicles operating for 18 hours a day, representing a typical operating time for baggage tractors owned by a large airline at a major airport. In scenario 2, it is assumed that batteries are changed out during the day to ensure continuous operations for 18 hours. In scenario 3, fast charging systems are used at the end of the day, and batteries maintain a full charge for the entire 18 hours of operation.

For all three scenarios, the NPV of total costs of the system is calculated over a 15-year analysis period. A discount rate of 8% and an inflation rate of 1.9% are applied. All assumptions are consistent with the H2A model.[98]

3.3.3.1 Lifecycle Cost Analysis Assumptions by Scenario

Scenario 1 (6 Hours of Runtime)

Scenario 1 compares the lifecycle costs of PEM fuel cell-powered baggage tractors with both diesel- and battery-powered baggage tractors for six hours of continuous operation per day (Table 3-29). It is assumed that each battery-powered baggage tractor in this scenario has only one battery that is recharged at the end of the day. It is assumed that recharging stations occupy approximately 100 square feet at a typical facility and are built at a cost of $25 per square foot.

[98] DOE Hydrogen Program: DOE H2A Analysis. 2006. DOE H2A Analysis. Available at www.hydrogen.energy.gov/h2a_analysis.html [Accessed December 2006].

Table 3-29. **Scenario 1: Cost Assumptions for Net Present Value Analysis of Baggage Tractors for 6 Hours per Day Runtime.**

	Diesel-Powered ICE Baggage Tractor	Battery-Powered Baggage Tractor	PEM Fuel Cell-Powered Baggage Tractor
Size (lbs)	3,000	3,000	3,000
Cost ($)	25,000	30,000	35,000
Lifetime (yrs)	20	20	15
Yearly Hours of Operation[1]	2,190	2,190	2,190
Routine O&M Costs ($/yr)	1,920[2]	1,440[3]	1,280[4]
Other O&M Costs ($/yr)	800[5]	-	-
Cost of Fuel ($/yr)	5,475[6]	266[7]	2,190 ($5/kg) 3,504 ($8/kg)[8]
Cost of Refueling/Recharging ($/yr)	578[9]	-	91[10]
Battery Charger ($)	-	2,000	-
Replacement Costs ($)	-	5,000 – Year 5 and 10	15,000 – Year 10 2,600 – Year 10

[1] Assumes that baggage tractors work 6 hours a day, 365 days a year. Assumption based on Battelle market research surveys.
[2] Assumes 12 hours of maintenance per quarter at $40 per hour. Assumption based on Battelle market research surveys.
[3] Assumes 9 hours of maintenance per quarter at $40 per hour. Assumption based on Battelle market research surveys.
[4] Assumes 4 hours of maintenance per quarter at $80 per hour. Assumption based on Battelle market research surveys.
[5] Assumes $200 per quarter for other O&M. Other O&M costs include oil changes, filters, and brake fluid. Assumption based on Battelle market research surveys.
[6] Assumes a 15 gallon tank which is refueled once every three days. Cost of diesel is assumed at $3 per gallon. Size of tank based on diesel tow tractors in the marketplace. Industry communication, August 2006.
[7] Cost of electricity for charging the batteries. Assumption based on Battelle market research surveys.
[8] It is assumed that the fuel cell tractor holds 3.6 kg of hydrogen. The tank is filled once every 3 days at $5 per kg and $8 per kg. Industry communication, August 2006.
[9] It takes approximately 19 minutes to refuel per day. Refueling occurs once every three days. Assumes labor rate of $15/hr. Assumption based on Battelle market research surveys.
[10] It takes approximately 3 minutes to refuel the hydrogen in the fuel cell. In this scenario the tank is refueled once every three days. Industry communication, August 2006.

The fuel cell-powered baggage tractor is designed to carry up to 15 kW of load. The fuel cell-powered baggage tractor uses a 5 kW PEM fuel cell with ultracapacitors to support peak demands. In this scenario it is assumed that the fuel cells are replaced every 10 years for $15,000. The ultracapacitors are also replaced at 10 years for $2,600. Residual value for all three types of baggage tractors is $5,000. The lifecycle costs of hydrogen fuel for the PEM fuel cell-powered baggage tractor are examined at $5 per kg and $8 per kg. Hydrogen storage and delivery methods are not considered in this analysis. The $5 and $8 per kg cost of hydrogen used in this analysis assumes that storage and delivery costs are amortized in the hydrogen cost.

Scenario 2 (18 Hours of Runtime with Battery Change-outs)

In scenario 2 the baggage tractor operates 18 hours a day (Table 3-30). This is consistent with the operating time reported by airlines at major airports. Scenario 2 assumes that each battery-powered vehicle has two batteries that are changed out to maintain operation throughout the 18-hour period. The battery replacement schedule is every 5 years at a cost of $5,000. In this analysis, it is assumed that batteries are changed out when discharged. Each battery-powered vehicle in this scenario has two replacement batteries. It is assumed that recharging stations occupy approximately 100 square feet at a typical facility and are built at a cost of $25 per square foot.

Table 3-30. Scenario 2: Cost Assumptions for NPV Analysis of Baggage Tractors for 18 Hours per Day Operation with Battery Change-outs.

	Diesel-Powered ICE Baggage Tractor	Battery-Powered Baggage Tractor	PEM Fuel Cell-Powered Baggage Tractor
Size (lbs)	3,000	3,000	3,000
Cost ($)	25,000	30,000	35,000
Lifetime (yrs)	20	20	15
Yearly Hours of Operation[1]	6,570	6,570	6,570
Routine O&M Costs ($/yr)	1,920[2]	1,440[3]	1,280[4]
Other O&M Costs ($/yr)	800[5]	-	-
Cost of Fuel ($/yr)	16,425[6]	800[7]	6,570 ($5/kg) 10,512 ($8/kg)[8]
Cost of Refueling/Recharging ($/yr)	1,734[9]	1,825[10]	274[11]
Battery Charger ($)	-	2,000	-
Replacement Costs ($)	-	5,000 – Year 5 and 10	15,000 – Year 5 and 10 2,600 – Year 10

[1] Assumes that baggage tractors work 18 hours a day, 7 days a week. Assumption based on Battelle market research surveys.
[2] Assumes 12 hours of maintenance per quarter at $40 per hour. Assumption based on Battelle market research surveys.
[3] Assumes 9 hours of maintenance per quarter at $40 per hour. Assumption based on Battelle market research surveys.
[4] Assumes 4 hours of maintenance per quarter at $80 per hour. Assumption based on Battelle market research surveys.
[5] Assumes $200 per quarter for other O&M. Other O&M costs include oil changes, filters, and brake fluid. Assumption based on Battelle market research surveys.
[6] Assumes a 15 gallon tank which is refueled once every day. Cost of diesel is assumed at $3 per gallon. Size of tank based on diesel tow tractors in the marketplace. Industry communication, August 2006.
[7] Cost of electricity for charging the batteries. Assumption based on Battelle market surveys.
[8] It is assumed that the fuel cell tractor holds 3.6 kg of hydrogen. The tank is filled only once a day at $5 per kg and $8 per kg. Industry communication, August 2006.
[9] It takes approximately 19 minutes to refuel per day. Refueling occurs once per day. Assumes labor rate of $15/hr. Assumption based on Battelle market research surveys.
[10] It takes approximately 10 minutes to change out a battery. Assumes that, to run 18 hours a day, battery has to be changed out 2 times. Assumes a labor rate of $15/hr. Batteries are charged at night. Assumption based on Battelle market research surveys.
[11] It takes approximately 3 minutes to refuel the hydrogen in the fuel cell. The tank is refueled once per day. Industry communication, August 2006.

The fuel cell baggage tractor uses a 5 kW fuel cell with ultracapacitors to support peak demands. Lifecycle costs of the PEM fuel cell-powered baggage tractor in this scenario are examined with the cost of hydrogen at $5 per kg and $8 per kg. Costs of the PEM fuel cell-powered baggage tractor were assumed to be $35,000 based on information provided by fuel cell manufacturers on the potential cost of fuel cells for this application. It should be noted that this is an estimated cost and that the actual commercial product may be different than what has been quoted in this analysis. The analysis assumes a 10-year life for the ultracapacitors, and replacement costs are assumed to be $2,600.[99] The cost of ultracapacitors is expected to go down with increasing production volumes. Scenario 2 assumes that the PEM fuel cell stack will be replaced every 5 years at $15,000. The residual value of diesel-powered baggage tractors and battery-powered electric baggage tractors at the end of 15 years is assumed to be approximately $5,000.

[99] Personal communication between Kathya Mahadevan (Battelle) and Scott Thompson (Maxwell Technologies), September 2006.

Scenario 3 (18 hours of Runtime with Fast Charging)

Assumptions for scenario 3 (Table 3-31) are similar to scenario 2 with the exception of costs for battery recharging and capital costs for the battery-powered baggage tractor. Some baggage tractor users do not change out batteries during the day and instead use fast charging during the 6-hour window of overnight downtime. Because batteries are charged at the end of the day and do not interrupt operations, no downtime costs are associated with recharging. Capital costs, however, will increase due to the cost of fast charging battery ports. Fast charging battery ports, such as those installed in airports through the ILEAV program, are assumed to cost $15,000.[100]

Table 3-31. Scenario 3: Cost Assumptions for NPV Analysis of Baggage Tractors for 18 Hours per Day Operation with Fast Charging.

	Diesel-Powered ICE Baggage Tractor	Battery-Powered Baggage Tractor	PEM Fuel Cell-Powered Baggage Tractor
Size (lbs)	3,000	3,000	3,000
Cost ($)	25,000	30,000	35,000
Lifetime (yrs)	20	20	15
Yearly Hours of Operation[1]	6,570	6,570	6,570
Routine O&M Costs ($/yr)	1,920[2]	1,440[3]	1,280[4]
Other O&M Costs ($/yr)	800[5]	-	-
Cost of Fuel ($/yr)	16,425[6]	200[7]	6,570 ($5/kg) 10,512 ($8/kg)[8]
Cost of Refueling/Recharging ($/yr)	1,734[9]	-	274[10]
Fast Charger ($)	-	15,000 per charging port	-
Replacement Costs ($)	-	5,000 – Year 5 and 10	15,000 – Year 5 and 10 2,600 – Year 10

[1] Assumes that baggage tractors work 18 hours a day, 365 days a year, 7 days a week. Assumption based on Battelle market research surveys.
[2] Assumes 12 hours of maintenance per quarter at $40 per hour. Assumption based on Battelle market research surveys.
[3] Assumes 9 hours of maintenance per quarter at $40 per hour. Assumption based on Battelle market research surveys.
[4] Assumes 4 hours of maintenance per quarter at $80 per hour. Assumption based on Battelle market research surveys.
[5] Assumes $200 per quarter for other O&M. Other O&M costs include oil changes, filters, and brake fluid. Assumption based on Battelle market research surveys.
[6] Assumes a 15 gallon tank which is refueled once everyday. Cost of diesel is assumed at $3 per gallon. Size of tank based on diesel tow tractors in the marketplace. Industry communication, August 2006.
[7] Cost of electricity for charging the batteries. Assumption based on Battelle market research surveys.
[8] It is assumed that the fuel cell tractor holds 3.6 kg of hydrogen. The tank is filled only once a day at $5 per kg and $8 per kg. Industry communication, August 2006.
[9] It takes approximately 19 minutes to refuel per day. Refueling occurs once per day. Assumes labor rate of $15/hr. Assumption based on Battelle survey responses.
[10] It takes approximately 3 minutes to refuel the hydrogen in the fuel cell. The tank is refueled once per day. Industry communication, August 2006.

3.3.3.2 Lifecycle Cost Results by Scenario

Scenario 1 Results (6 Hours of Runtime)

The battery-powered baggage tractors are most economical based on the lifecycle cost analysis presented in Table 3-32. The NPV of the total costs of the PEM fuel cell-powered baggage tractor is 32% more than the NPV of the total cost of the battery-powered baggage tractor and 30% less than the NPV of the total cost of the diesel-powered baggage tractor with hydrogen at

[100] Personal communication between Kathya Mahadevan (Battelle) and Jake Plante (Federal Aviation Administration), September 2006.

$5 per kg. With hydrogen at $8 per kg, the NPV of total costs of the battery-powered baggage tractor is 42% less than the NPV of the total costs of the PEM fuel cell-powered baggage tractor. While diesel-powered baggage tractors require the lowest capital investment, over the lifetime they require significant investment in operation and maintenance. In this scenario, the change in the cost of hydrogen impacts the investment required to operate and maintain a PEM fuel cell-powered baggage tractor over the 15-year lifetime. Despite the increase in hydrogen costs, PEM fuel cell-powered baggage tractors are more attractive than diesel baggage tractors in this scenario.

Table 3-32. Scenario 1: Lifecycle Cost Comparison of PEM Fuel Cell-, Diesel-, and Battery-Powered Baggage Tractors for 6 Hours of Runtime.

	Diesel-Powered Baggage Tractor	Battery-Powered Baggage Tractor	PEM Fuel Cell-Powered Baggage Tractor (H_2 - $5 per kg)	PEM Fuel Cell-Powered Baggage Tractor (H_2 - $8 per kg)
NPV of Total Capital Costs ($)	21,537	34,306	40,256	40,256
NPV of Total O&M Costs (Including Cost of Fuel) ($)	85,282	16,584	34,616	47,390
NPV of Total Costs of the System ($)	106,819	50,890	74,873	87,646

Scenario 2 Results (18 Hours of Runtime with Battery Change-outs)

The lifecycle cost analysis in scenario 2 shows that PEM fuel cell-powered baggage tractors with costs of hydrogen at $5 per kg require 41% less investment than diesel-powered baggage tractors over the 15-year analysis period based on the NPV of the total costs of the system (Table 3-33). The NPV of the total cost of the PEM fuel cell-powered baggage tractor is 36% more than the NPV of the total cost of the battery-powered baggage tractor. On a total capital cost basis, over the 15-year analysis period, PEM fuel cell-powered baggage tractors require 59% more capital investment than diesel-powered baggage tractors, while requiring only 15% more capital investment than battery-powered baggage tractors. When O&M costs over the 15-year analysis period are examined, diesel tugs require 2.5 and 5 times as much investment as PEM fuel cell-powered baggage tractors and battery-powered tractors, respectively. As illustrated in Table 3-33, battery-powered baggage tractors have the lowest operation and maintenance costs over the 15-year lifetime. Over the 15-year analysis period, PEM fuel cell-powered baggage tractors cost approximately 50% more in operation and maintenance than battery-powered baggage tractors.

The cost of hydrogen significantly impacts the investment required to operate and maintain the PEM fuel cell-powered baggage tractor. The NPV of the total cost of the PEM fuel cell-powered baggage tractor increases from $131,864 to $170,184 when hydrogen is varied from $5/kg to $8/kg. An increase in hydrogen cost to $8 per kg significantly impacts the competitiveness of PEM fuel cell-powered baggage tractors compared to battery-powered baggage tractors. The NPV of battery-powered baggage tractor costs are approximately 50% less over its lifetime than the PEM fuel cell-power baggage tractor when the cost of hydrogen is $8 per kg.

Table 3-33. Scenario 2: Lifecycle Cost Comparison of PEM Fuel Cell-, Diesel- and Battery-Powered Baggage Tractors for 18 Hours of Runtime with Battery Change-outs.

	Diesel-Powered ICE Baggage Tractor	Battery-Powered Baggage Tractor	PEM Fuel Cell-Powered Baggage Tractor (H_2 - $5 per kg)	PEM Fuel Cell-Powered Baggage Tractor (H_2 - $8 per kg)
NPV of Total Capital Costs ($)	21,537	45,189	52,890	52,890
NPV of Total O&M Costs (Including Cost of Fuel) ($)	202,964	39,516	78,973	117,293
NPV of Total Costs of the System ($)	224,501	84,705	131,864	170,184

<u>Scenario 3 Results (18 hours of Runtime with Fast Charging)</u>

Scenario 3 shows the impact of the higher capital costs associated with fast battery charging stations on the NPV of total system costs (Table 3-34). When just one port is installed (enabling one vehicle to be charged at a time during evening downtime), PEM fuel cell-powered baggage tractors are 48% more expensive than battery-powered baggage tractors. However, as the number of ports increases, so does the attractiveness of PEM fuel cell-powered baggage tractors compared to battery-powered baggage tractors. By installing three ports instead of one, PEM baggage tractors become just 35% more expensive than battery-powered baggage tractors. Realistically, airlines with large fleets of battery-powered baggage tractors will likely install more than one or two fast charging ports.

Table 3-34. Scenario 3: Lifecycle Cost Comparison of PEM Fuel Cell-, Diesel- and Battery-Powered Baggage Tractors for 18 Hours of Runtime with Fast Charging.

	Diesel-Powered Baggage Tractor	Battery-Powered Baggage Tractor (1 Fast Charging Port)	Battery-Powered Baggage Tractor (3 Fast Charging Ports)	PEM Fuel Cell-Powered Baggage Tractor (H_2 - $5 Per Kg)
NPV of Total Capital Costs ($)	21,537	53,177	81,842	52,890
NPV of Total O&M Costs (Including Cost of Fuel) ($)	202,964	15,942	15,942	78,973
NPV of Total Costs of the System ($)	224,501	69,119	97,425	131,864

It is also worth noting that this scenario assumes that operators adhere to a standard charging routine and ensure that the vehicles receive a full charge each night. According to some interviewees, this policy is not always put into practice and vehicles may run out of power before completing the required 18 hours of operation. As a result, airlines may be forced to maintain enough extra charged vehicles to ensure continuous operations. The cost of maintaining extra vehicles does not appear in the lifecycle cost analysis but should be considered when comparing the battery- and PEM fuel cell-powered baggage tractors.

3.3.3.3 Lifecycle Cost Summary

From a lifecycle cost perspective, PEM fuel cell-powered baggage tractors are less expensive than diesel-powered baggage tractors in both the low operating time (6 hours/day) and high operating time (18 hours/day) scenarios. This is true whether the cost per kg of hydrogen is $5 or $8 per kg. While the diesel tractors are more attractive from a capital cost perspective, the cost of diesel fuel and the O&M requirements have a notable impact on the NPV of the total system cost of the diesel tractor over a 15-year period.

Battery-powered baggage tractors have a superior lifecycle cost to PEM fuel cell-powered baggage tractors in both the low operating time and high operating time scenarios. The PEM fuel cell-powered tractor is impacted most by hydrogen and the durability of the fuel cell (15 years compared to 20 years for the battery-powered tractor). However, as the number of fast charging battery stations increases, the associated capital costs erode some of this cost advantage over PEM fuel cell-powered baggage tractors. So the size of the fleet may affect the attractiveness of battery-powered vehicles over PEM fuel cell-powered vehicles. Battery-powered baggage tractor lifecycle costs are most affected by capital cost for battery charging infrastructure, battery change-out time, and lifetime of the battery.

3.3.4 Sensitivity Analysis

3.3.4.1 Sensitivity Analysis Modeling Methodology

The factors that were varied in the PEM fuel cell sensitivity analysis are shown in Table 3-35. Each factor was varied by ±10% of the base assumption. For example, the base value assumed for the life of the PEM fuel cell-powered baggage tractor was 15 years; the high value (+10%) is 16.5 years, and the low value (-10%) is 13.5 years. In the sensitivity analysis, the average annual cash outlay ($\overline{C}$) for use of the PEM fuel cell-powered baggage tractor was calculated using equation 1. Hydrogen costs and operations and maintenance costs are assumed to be annual averages.

$$\overline{C} = \frac{Baggage\,Tractor\,Cost}{Baggage\,Tractor\,Life} + \frac{Fuel\,Cell\,Cost}{Fuel\,Cell\,Life} + \frac{Battery\,Cost}{Battery\,Life} + Hydrogen\ Cost + O\ \&\ M\ Cost \qquad \text{Equation 1}$$

Table 3-35. Cost Assumptions for PEM Fuel Cell-Powered Baggage Tractor Sensitivity Analysis: Base Assumption +/- 10%.

	Base Value	-10% of Base Value	+10% of Base Value
O&M (Including Refueling Time) ($)	1,554	1,399	1,709
Baggage Tractor Cost ($)	35,000	31,500	38,500
Baggage Tractor Life (years)	15	13.5	16.5
Fuel Cell Replacement, ($)	15,000	13,500	16,500
Fuel Cell Life (years)	5.0	4.5	5.5
Hydrogen ($/kg)	5.00	4.50	5.50

3.3.4.2 Sensitivity Analysis Results

The results of the sensitivity analysis are shown in Figure 3-24. The factors with the largest leverage on the average annual cost of PEM fuel cell-powered baggage tractors are, in descending order: the cost of hydrogen, the fuel cell life, and capital cost of the PEM fuel cell.

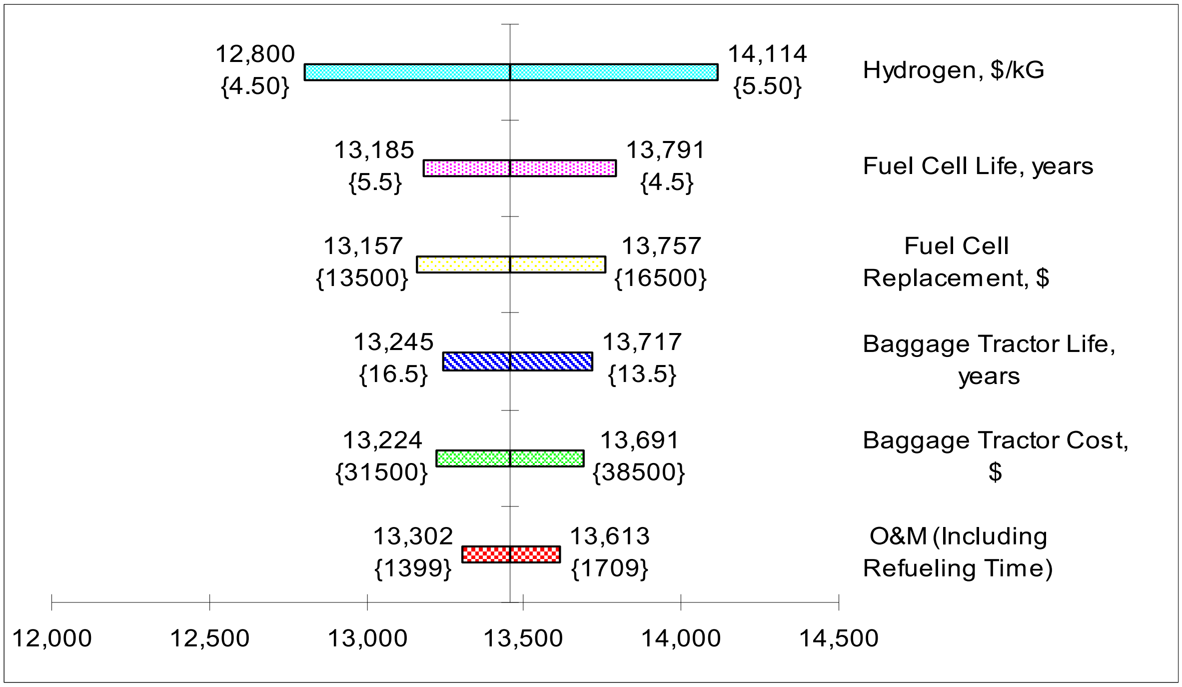

Figure 3-24. Sensitivity Analysis of Average Annual Cost of Owning and Operating a PEM Fuel Cell-Powered Baggage Tractor.

3.3.5 Market Penetration Analysis

3.3.5.1 Market Adoption Assumptions

Three cases were used to evaluate the potential market penetration of PEM fuel cells as a power source for airport baggage tractors. These cases vary in the extent of government interventions pursued. The base case assumes no government intervention. The communication case assumes that the government will engage in communications that will increase the strength of the innovation parameter in the model. The subsidized case assumes that for five years the government subsidizes the purchase of PEM fuel cells up to 50% of the cost of the baggage tractor (slightly less than $1,000 per kW). The subsidy makes the lifecycle cost of a PEM fuel cell-powered baggage tractor substantially lower than ICE-powered baggage tractors and comparable to battery-powered baggage tractors in some cases.

Table 3-36 shows the market penetration assumptions used in the three cases for adopting PEM fuel cell-powered baggage tractors. An EPA study showed that there were about 10,505 baggage tractors in use in 1999.[101] Assuming a 4% market growth rate, about 531 baggage tractors were purchased in 2006.

[101] EPA. 1999. Technical Support for Development of Airport Ground Support Equipment Emission Reductions. EPA-420-R-99-007.

For all three cases, it was assumed that the purchase of PEM fuel cell-powered baggage tractors is driven by regulation and that the value of PEM fuel cell-powered baggage tractors to the market will be significantly greater than diesel-powered baggage tractors and comparable to battery-powered tractors in some cases. As a result, it is assumed that only 40% of this market is available for penetration by PEM fuel cell-powered baggage tractors. It is also assumed that over time, PEM fuel cells will become more competitive with batteries. Therefore, the initial annual market for PEM fuel cell baggage tractors is 213 units for all three market adoption cases.

For all three cases, it was assumed that PEM fuel cell-powered baggage tractors were acquired at an initial cost of $26,000 per unit (substantial improvements to PEM fuel cell-powered baggage tractors were assumed). In the subsidized case, the subsidy would be $3,000 per unit. The three cases also assume that a hydrogen infrastructure is in place.

Table 3-36. Assumptions for PEM Fuel Cell-Powered Baggage Tractor Adoption in Airports.

Assumption	Base Case	Communication Case	Subsidy Case
Market Growth Rate	4%	4%	4%
Government Actions	None	Communications	Subsidize purchase @ $3,000 per unit
Values of *p* and *q*	$p = 0.008$ $q = 0.423$	$p = 0.012$ $q = 0.423$	$p = 0.070$ $q = 0.423$
Initial Number of Baggage Tractors Purchased	532	532	532
Initial Number of PEM Fuel Cell-Powered Baggage Tractors Purchased *(m)*	40% of baggage tractors; $m = 213$	40% of baggage tractors; $m = 213$	40% of baggage tractors; $m = 213$
Average Initial Price of PEM Fuel Cell Baggage Tractors	$26,000	$26,000	$26,000
Rate of Price Reduction	Stable; no price reduction	Stable; no price reduction	Stable; no price reduction

3.3.5.2 Market Penetration Results

The models show that, in the base and communication cases, the first year that 100 units are sold annually is ten years and nine years, respectively, after commercial introduction (Figures 3-25 and 3-27). In the subsidized case, 100 units are sold much earlier (five years after commercial introduction) (Figure 3-29). Further, the models show that, in the base and communication cases, the first years in which $1 million in annual sales are achieved will be seven years and six years after commercial introduction, respectively. In the subsidized case, $1 million in sales are expected three years after commercial introduction.

Predictions from the model are consistent with actual results from the ILEAV Pilot Program.[102] Grants potentially totaling $17 million were made available to airports to purchase cleaner alternative fuel vehicles. About 39% ($6.9 million) of the available funding was used. Purchases were made over a five-year period. The first year involved administrative execution

[102] FAA. 2006. Final Report: Inherently Low Emission Airport Vehicle Pilot Program. Available at http://www.faa.gov/airports_airtraffic/airports/environmental/vale/media/ileav_report_final_2005.pdf#search=%22Final%20Report%3A%20Inherently%20Low%20Emission%20Airport%20Vehicle%20Pilot%20Program%22 [Accessed June 2006].

`of the grant. Over the subsequent four years, funding was available for use. Purchases of vehicles under the grant program included 275 alternative fuel baggage tractors (about 69 per year of available funding). Of the 275 alternative fuel baggage tractors, 56% were battery-powered. The subsidy case for PEM fuel cells predicted that 248 baggage tractors (62 per year of available funding) would be purchased during a comparable time period with subsidies of about $1.2 million. Assuming that a $3,000 per unit subsidy for five years were used to spur early purchases of PEM fuel cell-powered baggage tractors, the cost to government would be about $1 million.

Table 3-37 provides a summary of the sales and market share data presented for each of the three cases described above.

Table 3-37. Summary of Sales and Market Share for Alternative Market Adoption Cases for PEM Fuel Cell-Powered Baggage Tractor Adoption in Airports.

	5 Years After Commercial Introduction			10 Years After Commercial Introduction			15 Years After Commercial Introduction			20 Years After Commercial Introduction		
	Base Case	Communication Case	Subsidy Case	Base Case	Communication Case	Subsidy Case	Base Case	Communication Case	Subsidy Case	Base Case	Communication Case	Subsidy Case
Annual Sales (Units)	20	29	129	108	143	275	285	311	352	414	419	429
Annual Sales ($ millions)	.5	.8	3.4	2.8	3.7	7.2	7.4	8.1	9.1	10.8	11	11.2
Market Share (%)	3	4	20	14	18	35	30	32	37	35	36	37

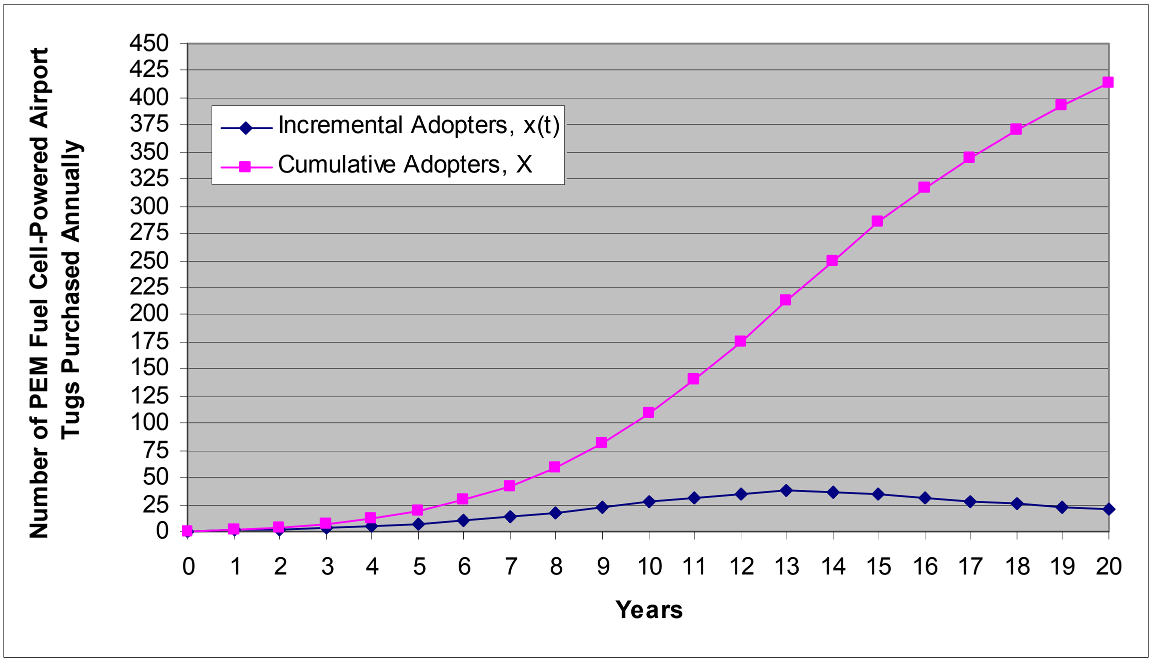

Figure 3-25. **Adoptions of PEM Fuel Cell-Powered Baggage Tractors in the Base Case.**

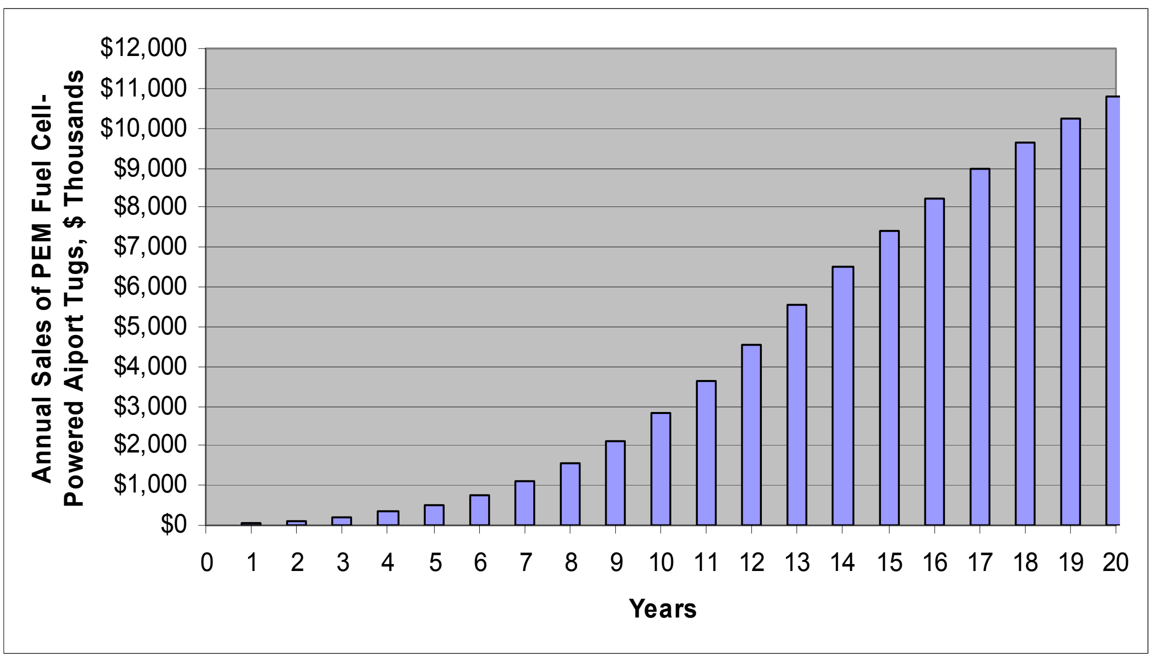

Figure 3-26. **Sales of PEM Fuel Cell-Powered Baggage Tractors in the Base Case.**

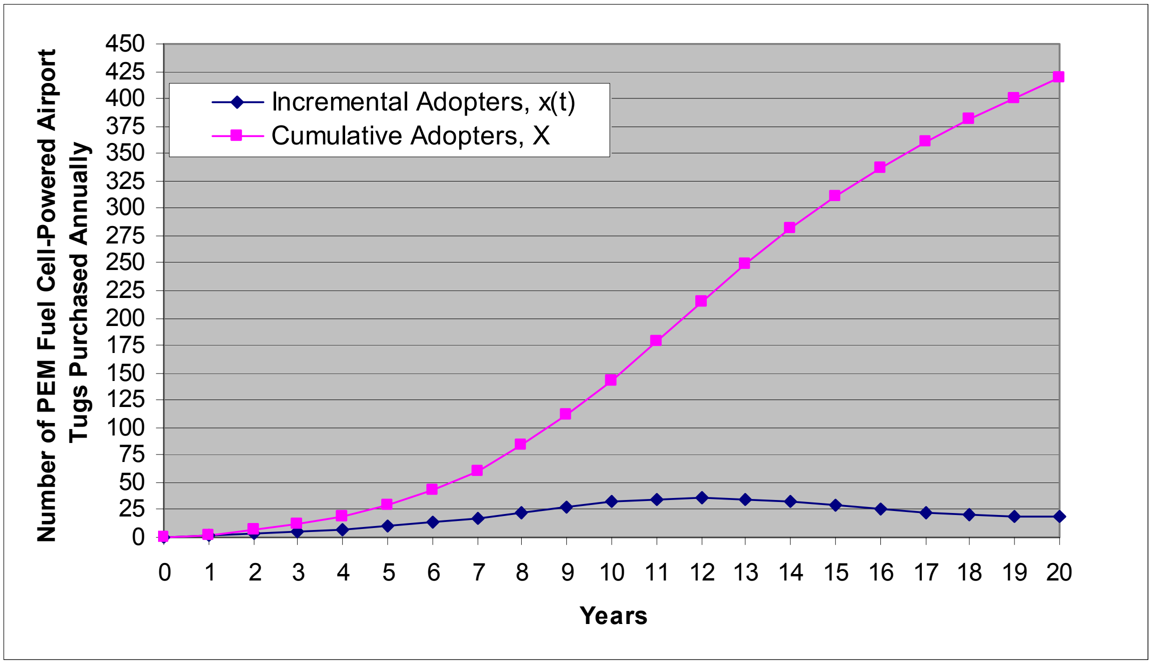

Figure 3-27. Adoptions of PEM Fuel Cell-Powered Baggage Tractors in the Communication Case.

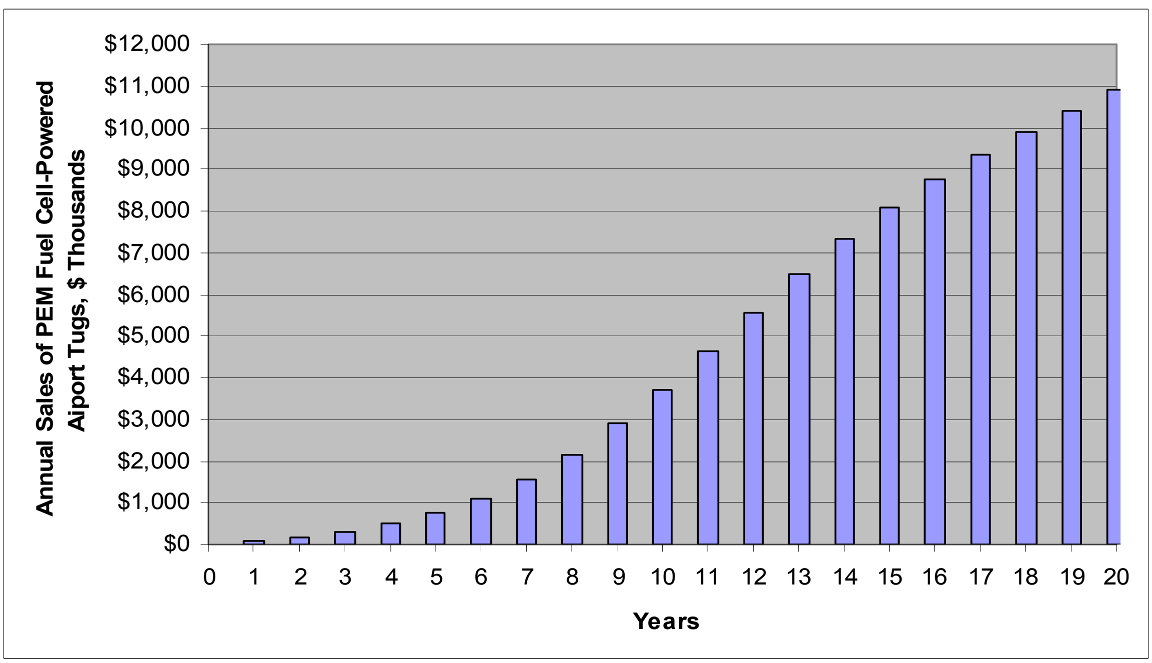

Figure 3-28. Sales of PEM Fuel Cell-Powered Baggage Tractors in the Communication Case.

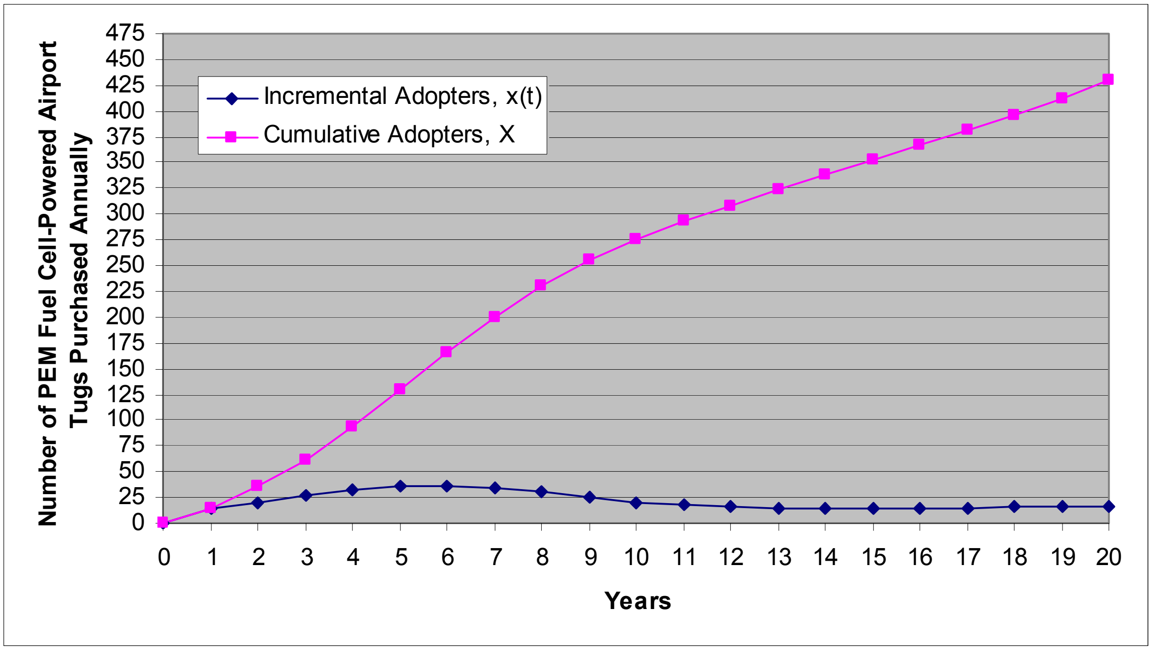

Figure 3-29. Adoptions of PEM Fuel Cell-Powered Baggage Tractors in the Subsidy Case.

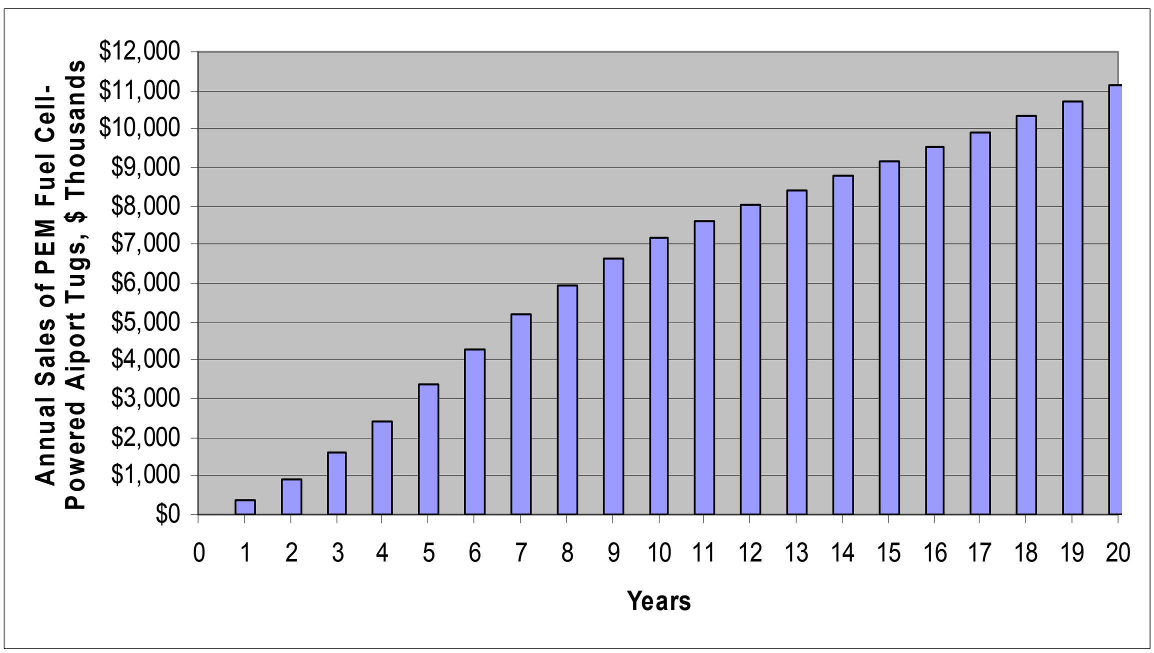

Figure 3-30. Sales of PEM Fuel Cell-Powered Baggage Tractors in the Subsidy Case.

3.3.6 Value Proposition for PEM Fuel Cells in Baggage Tractors

Airport ground support tractors represent a potentially attractive near-term market for PEM fuel cells if costs can be reduced. Air quality concerns and pressure to reduce emissions at airports and surrounding metropolitan areas are perhaps the most important drivers in this market. Many airports are located in emissions nonattainment areas, where the use of zero-emissions vehicles is encouraged or even mandated.[103] Recent concerns over air quality at airports have led manufacturers and users of the ground support vehicles to consider alternatives to the industry standard, diesel- and gasoline-powered ICEs. Programs such as ILEAV and its successor, the VALE program, provide airports and airlines with an opportunity to evaluate low-emission technologies, including battery-, CNG-, LPG-, and PEM fuel cell-powered vehicles, in an airport environment. Increasingly strict state and regional air quality requirements, such as those proposed by CARB, will also create incentives for the adoption of low-emission GSE.

The relatively small market size – while a disadvantage in some respects – could potentially make it easy for the PEM fuel cell industry to quickly penetrate this market. Because the types of vehicles used to provide ground support services are similar to work tractors used in a variety of industrial applications, this market segment could also provide an important entry point to the broader market of work trucks and tractors. The technology development experience and credibility and demonstration experience gained might be readily translated to the much larger work trucks and tractors market. In addition, captive GSE fleets offer an opportunity to test distributed hydrogen generation and fueling for specialty vehicles, potentially diminishing the fueling infrastructure challenges associated with the use of PEM fuel cells on a larger or more distributed scale.

There are, however, several potential barriers to PEM fuel cells exploiting these market conditions. For PEM fuel cells to become a viable alternative in the airport ground support tractor market, they must: be cost effective; compete effectively against batteries; be able to enter the market quickly; have an available and affordable source of hydrogen; and become known by the airport industry and accepted as a reliable alternative.

The ability for PEM fuel cell-powered baggage tractors to compete effectively in this market will be largely determined by the ability to bring down lifecycle costs of PEM fuel cell-powered tractors relative to battery-powered incumbents. Currently, battery-powered baggage tractors have a superior lifecycle cost compared to PEM fuel cell-powered baggage tractors whether they are being used just one shift a day or being operated around the clock. However, the potential to improve the total costs of the PEM fuel cell-powered tractors exists through improvements in the cost of hydrogen and the durability of the PEM fuel cell.

While PEM fuel cells are not as attractive on a total cost basis, they offer many advantages over batteries. While batteries can meet power requirements for baggage tractors, they may not be capable of providing the horsepower required to tow large aircraft. Because fuel cells may outperform batteries with these heavier vehicles, the fact that fuel cells can support a wider variety of vehicles may provide a compelling case to some. Also, battery recharging can result in lost productivity or can require maintaining extra vehicles to ensure continued operations. If baggage tractor operators follow scheduled charging routines, this is less of an issue. The airline industry is strongly affected by unscheduled downtime, particularly where they maintain round-the-clock operations. Hence, PEM fuel cells may offer a time-saving cost advantage in these environments. Furthermore, the financial competitiveness of PEM fuel cells relative to batteries will depend on the size of the fleet and the number of battery charging stations required for

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[103] Weeks, B. 2005. Making a Case for Hydrogen in the GSE Industry. Ground Support Magazine (May). Available at http://www.groundsupportmagazine.com/publication/article.jsp?pubId=1&id=1044 [Accessed June 2006].

keeping the fleet operational throughout the day. PEM fuel cell-powered tractors are expected to become more attractive as the size of the fleet, and the corresponding number of chargers required, increases.

For successful penetration of PEM fuel cell-powered GSE, demonstration projects and financial incentives, similar to those provided for low-emission vehicles under the VALE program, are critical. Initiatives must be directed to PEM fuel cell-powered baggage tractors and aircraft pushback vehicles in order to help prove that reliability, annual O&M cost, and operating performance are competitive with battery-powered vehicles. While existing incentives potentially create an opportunity for PEM fuel cell-powered baggage tractors to enter the airport baggage tractor market, the door may not be open for long. The ILEAV pilot program and its successor, the VALE program, are resulting in the creation of CNG and battery recharging infrastructures at major airports. These may strongly negatively influence the adoption of fuel cells where a hydrogen infrastructure would have to be built and additional airport space leased. To date, only a limited number of airports have made such commitments, but continued subsidies are likely to result in an increasing number of airports making comparable decisions and commitments within the next few years. To compete with other low-emission technologies currently penetrating the market, PEM fuel cells will need to enter the market quickly, and a hydrogen fueling infrastructure will need to be put in place.

Furthermore, PEM fuel cell-powered vehicles need to become more widely known and better understood by airports, airlines, aviation ground support service providers, and cargo and parcel delivery companies that use air service. Because those within the industry are not yet “sold” on fuel cells, a concerted effort to educate and inform them of the potential benefits of PEM fuel cells and the safety of hydrogen use will be essential to successful market penetration.

4.0 SUMMARY OF FINDINGS AND CONCLUSIONS

The pathway to fuel cell vehicles will likely include the introduction of direct hydrogen PEM fuel cells in near-term markets with fewer technical challenges than the automobile market. This study focused on identifying near-term market opportunities for direct hydrogen PEM fuel cells in "pre-automotive" applications that could support fuel cell industry growth and learning. However, Department of Defense applications were excluded from this scope of work. It includes an assessment of 36 likely near-term (2008) and mid-term (2012) market segments for PEM fuel cells in the 1 to 250 kW size range, as well as a detailed market and economic analysis of PEM fuel cells and competing alternatives in three of the most promising near-term markets.

The most promising near-term opportunities for PEM fuel cells in this size range are in specialty vehicle and backup power applications. PEM fuel cell systems are commercially available to support these applications and offer several potential advantages over current technologies, including lower emissions, lower O&M requirements, longer runtimes, and other productivity enhancement advantages. While both backup power and specialty vehicle users are generally satisfied with their current systems, specialty vehicle users did identify opportunities for improvement that correspond with these benefits. Across the various specialty vehicle markets analyzed, users are looking for alternatives to batteries to increase runtime and productivity, and reduce safety risks, and for opportunities to reduce O&M costs associated with their ICE vehicles. Backup power users identified few concerns with current systems, although the runtime to support extended power outages and emissions were identified as concerns by a small proportion of users. About half of specialty vehicle users had considered alternatives to their current power systems compared to 33% of backup power users surveyed.

The detailed analyses of three near-term markets suggest that PEM fuel cells offer a compelling value proposition in these markets under some circumstances. In backup power applications for emergency response radio towers, PEM fuel cells are competitive with battery-generator systems from a lifecycle cost perspective when shorter runtimes are required (i.e., 1 to 3 days). Fuel cells may also be more attractive from a lifecycle cost perspective when operating in harsh environments, which shorten the lifetime of batteries. However, PEM fuel cells were found to be much less attractive than alternatives when longer backup power runtimes are required (i.e., 1 week or more) due to the high cost of hydrogen storage and use. Financial incentives, demonstration projects, and fuel availability will be critical for PEM fuel cells to compete effectively in this segment and capture a sizeable market share in the near- to mid-term.

The analysis of PEM fuel cells for forklifts in indoor warehousing environments suggests that their value compared to alternatives varies significantly by application and is negatively impacted by declining hours of operation. PEM fuel cells can provide value over battery-powered forklifts in high productivity environments. When forklifts are operated under conditions of near continuous use, fuel cell vehicles are significantly less expensive than similar battery-powered systems from a lifecycle cost perspective. Advantages of PEM fuel cell systems operating under such conditions include rapid refueling, eliminating time and cost of replacing batteries, constant voltage delivery, increased productivity by eliminating battery recharging time, fewer repairs due to fewer moving parts, and elimination of battery storage/changing rooms and associated costs. For widespread adoption in this market, reliability must be proven through demonstration projects, and capital cost and fuel availability must be addressed.

The third near-term market analyzed, airport ground support equipment, will be more difficult for PEM fuel cells to penetrate in the near-term. While PEM fuel cells offer a cost advantage over ICE-powered systems, which currently are the most widely used technology in baggage tractors, they are currently less attractive from a lifecycle cost perspective than battery-powered systems, regardless of frequency of use. Recent federal and state air quality regulation and federal incentive programs are driving airlines to use low emission alternatives to ICE, and batteries are well-positioned to gain market share. If PEM fuel cells are to compete effectively in this market, they will need to be more cost effective than battery systems, be able to enter the market quickly, and have an affordable source of hydrogen available. While the market for airport ground support vehicles may be less attractive than the others, successful demonstrations in this market may still provide value. The vehicles used are similar to those used in the broader, much larger market for industrial work trucks/tractors and may provide an important entry point.

To penetrate these near- and mid-term markets for PEM fuel cells in backup power and specialty vehicle applications, it will be critical to ensure an affordable and available source of hydrogen near the target markets. A strategic focus of DOE should be on the location of hydrogen and on corresponding incentives for hydrogen refueling.

Alternatives to PEM fuel cells exist that adequately meet critical market needs, although fuel cells do provide some incremental benefits over alternatives. To drive market penetration, incentives that lower initial capital costs likely will be necessary in the short term. A technical focus on durability, reliability, and reducing the cost of PEM fuel cells will also be critical for market adoption. Finally, awareness is a critical first step in purchasing. It will be important to communicate to potential users the benefits of PEM fuel cells over existing technologies, in addition to the experiences gained through fuel cell demonstrations.

APPENDIX A: Survey Instruments for Analysis of Pre-automotive Markets

A.1 Phase 1 Survey: Exploratory Research Questions for PEM Fuel Cell Manufacturers and Key Suppliers

The Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) is focused on the development of hydrogen fuel cell vehicles by 2015 and realizes that there will likely be a lengthy transition period. In order to sustain industry and develop a supplier base for future automotive markets, EERE is focused on identifying market opportunities for Proton Exchange Membrane (PEM) fuel cells in stationary, off-road, and other pre-automotive applications in the public and private sector. In addition, EERE is also focused on facilitating market introduction of direct hydrogen PEM fuel cells to meet the requirements specified by the Energy Policy Act 2005.

To support EERE in this endeavor, Battelle is conducting an evaluation of private and public sector transition market opportunities for direct hydrogen PEM fuel cells in the 1-250 kW size range to 2015 (transition markets are "pre-automotive markets that include specialty vehicles, back-up power, and auxiliary power). Battelle is seeking your input to some exploratory questions regarding likely transition applications and markets, availability of products, and potential strategies for supporting market acceptance of direct PEM hydrogen fuel cells.

Battelle will use this information to identify likely pre-automotive market opportunities, evaluate the value proposition of PEM fuel cells in likely near-term markets, and identify strategies to facilitate the adoption of direct hydrogen PEM fuel cells.

Information provided in response to this questionnaire will be treated as business sensitive. Battelle requests disclosure of only non-proprietary information. Any information provided in response to this questionnaire will be kept confidential. The analysis will be performed without specific reference to the party providing the information.

Please answer the questions below to the best of your ability – use of phrases and short sentences are preferred. If you choose to skip a question, please indicate N/A or "prefer not to answer", as appropriate.

1. Name of company
2. Address
3. Name of contact
4. Job title
5. Contact information
6. Primary business of your company

7. What is the likely path of transition to automotive PEM fuel cells in 2015? (e.g., Backup power → Portable power→ Specialty vehicles→ Light duty vehicles - fleets)

8. What three specialty vehicle markets (e.g., forklifts, mining vehicles), do you believe are likely to be satisfied customers of direct hydrogen PEM fuel cells in the near-term (2008)?

9. What three specialty vehicle markets (e.g., automatic guide vehicles, unmanned vehicles), do you believe are potential adopters of direct hydrogen PEM fuel cells in the mid-term (2012) in the United States?

10. What three backup power markets, (e.g., data centers, airports), do you believe are likely to be satisfied customers of direct hydrogen PEM fuel cells in the near-term (2008) in the United States?

11. What three backup power markets, (e.g., grocery stores) do you believe are potential adopters of direct hydrogen PEM fuel cells in the mid-term (2012) in the United States?

12. Which five government agencies, in your opinion, are the most likely adopters of direct hydrogen PEM fuel cells in transition applications by 2008?

13. What are the benefits that would make fuel cells attractive to the most promising near-term (2008) backup power and specialty vehicle markets identified above, as compared to competing alternatives?

14. To facilitate direct hydrogen PEM fuel cell acceptance in the aforementioned markets what codes and standards issues need to be addressed immediately?

15. What other types of governmental support are required to facilitate the market acceptance of direct hydrogen PEM fuel cells in the specialty vehicle markets and back-up power markets in the near-term (2008)?

16. To ensure successful adoption of direct hydrogen PEM fuel cells beyond 2008 are there specific areas that require governmental support?

17. To identify high-priority transition markets, Battelle plans to utilize weighted rating criteria. Battelle is seeking your input on the importance of these criteria. Please weight (as high, medium, and low) the list of rating criteria for selecting high priority transition markets provided below.
    a) H-PEMFC product characteristics and their potential benefits must fit user requirements (high priority needs)
    b) H-PEMFC products are available for immediate application, or can be developed over the short-term
    c) H-PEMFC offer unique value to market segment not met by competing technologies

d) Sufficient market size and growth potential of the market segment to ensure current and continued fuel cell adoption
e) Cost of reaching the market, including product development and marketing, is reasonable
f) Demonstration of H-PEMFC in stationary applications in this market segment will contribute to increased learning of H-PEMFC technology operation, its reliability and cost-effectiveness by end-users, potentially leading to increased adoption of PEM fuel cells in the marketplace and impacting costs of PEM fuel cell through increased demand
g) Demonstration of H-PEMFC in this market segment will translate to improvements in automotive H-PEMFC design and development, from learning and demonstration of technology operation
h) Availability of financial support for demonstration of H-PEMFC technology
i) Codes and standards are in place or near complete to facilitate adoption of hydrogen technologies

18. What products does your organization have ready or will have ready by 2008 for back-up power applications and/or specialty vehicle markets (this includes distributed hydrogen generators, stacks)? Please provide model name and any literature on your product(s) including field studies.

19. Can you provide the current or estimated retail price for the aforementioned products?

20. Are you providing or planning to provide a warranty for the aforementioned products? If yes, please specify the period and cost (if in addition to the retail price).

21. Other comments –

A.2 Phase 1 Interview Protocol: Definition of Transitional Markets

Background

The Department of Energy's Office of Energy Efficiency and Renewable Energy is focused on the development of hydrogen fuel vehicles by 2015 and realizes that there will likely be a lengthy transition period. In order to sustain industry and develop a supplier base for future automotive markets, DOE is focused on identifying market opportunities for PEM fuel cells in stationary, off-road, and other pre-automotive applications.

The purpose of this survey is to use the expertise of Battelle and PNNL staff to help define market opportunities for direct hydrogen PEM fuel cells in transitional markets (i.e. pre-automotive) to 2015 within the private and government sectors. Transitional markets are composed of applications that have some operational characteristics similar to automotive PEM fuel cells. These operational characteristics could include frequent ON/OFF cycles (1-10 per day), the ability to quickly respond to requests for power, durability of approximately 3,000 - 5,000 hours with cycling, and approximately 50% efficiency at rated power. Ultimately these markets will help to advance the technology and develop reliable components for vehicle applications.

The research is also focused on gathering information on the most likely applications within those markets, potential users, and strategic partners that could support the demonstration and commercialization of direct hydrogen PEM fuel cells. Information on potential barriers to adoption in these transitional markets is also sought.

Interview Questions

1. What are the most likely transitional applications (e.g. back-up, intermittent power, battery replacement) and markets (e.g. telecom, forklifts) for direct hydrogen PEM fuel cells in the U.S. between now and the year 2015?

2. In your opinion, how will the transition to hydrogen fuel cell vehicles be accomplished over the next 10 years?

3. From the various transitional markets and applications identified to 2015, which of these markets and applications are likely near-term opportunities (to 2008)?

4. Can you identify specific early adopters in these near-term transitional markets? Are there any specific users you recommend we speak with to help determine market requirements for PEM fuel cells?

5. In your opinion, what is the value proposition of PEM fuel cells offer in these near-term transitional markets?

6. For these near-term opportunities, what are the critical barriers to commercialization of PEM fuel cells? Are there any market-specific barriers that come to mind for these markets? What are the technology specific barriers for transitional markets?

7. In the near-term transitional markets, what technologies are likely competitors to PEM fuel cells in the 1-250kW range?

8. Are you aware of specific developments with these competing technologies that could significantly impact PEM fuel cell market opportunity?

9. Are other fuel cells, like SOFC's and DMFC's likely competitors to PEM fuel cells in near-term transitional markets? If not, which markets are SOFC's and DMFC's fuel cells likely to be commercialized in, in the near-term?

10. To assist in the transition to hydrogen fuel cell cars, which specific near-term transitional markets should DOE focus on? What strategies might DOE employ to best facilitate the adoption of PEM fuel cells in the markets (e.g. demonstration projects, financial incentives, etc.)?

11. From your experience with development and push to commercialize fuel cell technology (e.g. through the SECA program), are there specific "lessons learned" that would like to share with us?

12. For further input, do you have suggestions on other experts at Battelle/PNNL that we should contact? Also, are there related reports or studies that you would recommend that we review?

A.3 Phase 1 Survey: Exploratory Research Questions for Candidate Fuel Cell Users in Backup Power Applications

Battelle, a non-profit research and development organization located in Columbus, Ohio is conducting research on user requirements for energy technologies and would appreciate your response to some exploratory questions regarding the use of backup power at your facilities.

The Department of Energy's Office of Energy Efficiency and Renewable Energy is focused on the development of hydrogen fuel vehicles by 2015 and realizes that there will likely be a lengthy transition period. In order to sustain industry and develop a supplier base for future automotive markets, DOE is focused on identifying market opportunities for Proton Exchange Membrane (PEM) fuel cells in stationary, off-road, and other pre-automotive applications.

The purpose of this survey is to help define market opportunities for direct hydrogen PEM fuel cells in markets to 2015. We have identified a subset of commercial, industrial, and institutional users for PEM fuel cells. We have identified your sector as a potential transitional market, and we are looking to understand the likely applications for PEM fuel cells and user requirements for new energy technologies including direct hydrogen fuel cells.

Battelle will use this information to perform analysis of likely transitional market opportunities for direct hydrogen PEM fuel cells, determine areas for R&D efforts in fuel cells, and to define opportunities for demonstration of PEM fuel cells.

Please answer the questions below to the best of your ability – use of phrases and short sentences are preferred. If you choose to skip a question, please indicate N/A or "prefer no to answer", as appropriate.

1. Name of Organization

2. Address

3. Name of Contact

4. Job Title

5. Primary Business of Your Organization

6. Approximately how many employees work for your organization?
    a. Small < 500
    b. Medium 500-3,000
    c. Large > 3,000

7. For what functions do you currently require backup power for?

8. Which of the above mentioned functions are most critical to your business operations?

9. About how many outages has your organization experienced in the last 12 months?

10. Can you estimate how long these power interruptions typically last? Please highlight or bold all that apply.
    a. < 1 second
    b. < 60 seconds
    c. < 3 minutes
    d. 3 – 5 minutes
    e. 5 minutes – to an hour
    f. 1 -4 hours
    g. 4 hours or longer
    h. Don't know

11. How disruptive would each of the following outages be if they occurred during normal operating hours? (Please determine level of disruption assuming no backup power) Please rate each on a scale of 1 to 7, with 1 being not disruptive and 7 very disruptive. Please highlight or bold all that apply.

    a. 1 second (Scale 1-7, with 1 not disruptive and 7 very disruptive)
        i. 1 2 3 4 5 6 7

    b. 3 minutes (Scale 1-7, with 1 not disruptive and 7 very disruptive)
        i. 1 2 3 4 5 6 7

    c. 1 hour (Scale 1-7, with 1 not disruptive and 7 very disruptive)
        i. 1 2 3 4 5 6 7

    d. 4 hours (Scale 1-7, with 1 not disruptive and 7 very disruptive)
        i. 1 2 3 4 5 6 7

    e. Don't Know

12. How many times a year do grid power outages occur that would be considered disruptive or very disruptive?

13. Could power outages at your organization result in any of the following? Please highlight or bold all that apply.

    a. Lives lost
    b. Security breach
    c. Implementation of emergency management plans

d. Disruptions in production
e. Disruptions in distribution
f. Other (e.g., loss of safe drinking water) _______
g. Power outage has no effect

14. How are your back-up power requirements currently being met? Please highlight or bold all that apply.
    a. Batteries
    b. Uninterruptible Power Systems
    c. Generators (diesel, propane)
    d. Solar Cells
    e. Others ______
    f. No back-up power systems

15. What is the typical size of the backup system that you use? Please highlight or bold all that apply.
    a. < 5 kW
    b. 5-15 kW
    c. 15-30 kW
    d. 30-60 kW
    e. 60-150 kW
    f. 150-250 kW
    g. > 250 kW
    h. ______kW

16. Approximately how many backup power systems do you currently have per facility? Can you estimate the number of backup power systems across all facilities in your organization? Please specify by size (e.g. we have approximately 30 - 15 kW diesel generators, 3-25kW UPS systems etc.)

17. What is the importance of the following factors in selecting a backup power system for your needs? Please rate each on a scale of 1 to 7, with 1 being not important and 7 very important. Please highlight or bold all that apply.

    a. Reliability – comes on and operates continuously every time it is needed (Scale 1-7, 1 not important, 7 very important)
        i. 1 2 3 4 5 6 7 Don't know

    b. Capital cost (Scale 1-7, 1 not important, 7 very important)
        i. 1 2 3 4 5 6 7 Don't know

    c. Lifetime of the unit (Scale 1-7, 1 not important, 7 very important)
        i. 1 2 3 4 5 6 7 Don't know

d. Annual operating cost (fuel and maintenance) (Scale 1-7, 1 not important, 7 very important)
   i. 1 2 3 4 5 6 7 Don't know

e. Emissions/environmental considerations or restrictions (Scale 1-7, 1 not important, 7 very important)
   i. 1 2 3 4 5 6 7 Don't know

f. Start-up time when power goes out (Scale 1-7, 1 not important, 7 very important)
   i. 1 2 3 4 5 6 7 Don't know

g. Ease of use, including regular maintenance (Scale 1-7, 1 not important, 7 very important)
   i. 1 2 3 4 5 6 7 Don't know

h. Fuel Availability (Scale 1-7, 1 not important, 7 very important)
   i. 1 2 3 4 5 6 7 Don't know

i. Good experience with this type of system in the past (Scale 1-7, 1 not important, 7 very important)
   i. 1 2 3 4 5 6 7 Don't know

18. Which of the above factors are most important? Choose up to three.

19. How would you rate the performance of your current backup power systems? Please rate each on a scale of 1 to 7, with 1 being not good and 7 very good. If answer is ≥4, then *skip to* Question 21.

20. What concerns, if any, do you have with the performance of your backup power system? Please identify the system of concern. Please highlight or bold all that apply.

21. Backup Power System(s) of Concern (for example Diesel Generator): ____________

    a. Not reliable
    b. Difficult to use
    c. Emissions
    d. Unable to determine if the system has charge
    e. High capital cost
    f. Other (specify)____________
    g. No concerns

22. How would you rate your current backup power system for all of the following characteristics? Please rate each on a scale of 1 to 7, where 1 is not good and 7 is very good. Please highlight or bold all that apply.

    a. Reliability – comes on and operates continuously every time it is needed (Scale 1-7, 1 not good, 7 very good)
        i. 1 2 3 4 5 6 7 Don't know

    b. Capital cost compared to alternatives (Scale 1-7, 1 not good, 7 very good)
        i. 1 2 3 4 5 6 7 Don't know

    c. Operation and maintenance costs (Scale 1-7, 1 not good, 7 very good)
        i. 1 2 3 4 5 6 7 Don't know

    d. Lifetime of the unit compared to alternatives (Scale 1-7, 1 not good, 7 very good)
        i. 1 2 3 4 5 6 7 Don't know

    e. Annual operating cost (fuel and maintenance) (Scale 1-7, 1 not good, 7 very good)
        i. 1 2 3 4 5 6 7 Don't know

    f. Emissions – environmental considerations or restrictions (Scale 1-7, 1 not good, 7 very good)
        i. 1 2 3 4 5 6 7 Don't know

    g. Start-up time when power goes out (Scale 1-7, 1 not good, 7 very good)
        i. 1 2 3 4 5 6 7 Don't know

    h. Ease of use, including regular maintenance (Scale 1-7, 1 not good, 7 very good)
        i. 1 2 3 4 5 6 7 Don't know

    i. Fuel Availability (Scale 1-7, 1 not good, 7 very good)
        i. 1 2 3 4 5 6 7 Don't know

23. Do you anticipate a growing need for backup power in your sector in the next three years? Please highlight or bold answer that applies.
    a. Yes
    b. No
    c. Don't know

24. Have you considered alternatives to your current backup power system? Please highlight or bold answer that applies.
    a. Yes. If yes, what have you considered?
    b. No

25. Have you heard of PEM fuel cells as a power source for backup power applications? Please highlight or bold answer that applies.
    a. Yes
    b. No (*if no, skip to Question 28*)

26. Do you believe that PEM fuel cells are likely to compete favorably with your existing backup power systems? Please highlight or bold answer that applies.
    a. Yes
    b. No. If no, why not?

27. Do you have any concerns about using hydrogen as a fuel? Please highlight or bold answer that applies.
    a. Yes
    b. No
    c. Don't know

28. What factors would drive your decision to purchase PEM fuel cells for backup power? Please highlight or bold all that apply.
    a. Cost of not having electricity or having a power failure (yes/no)
    b. Dissatisfaction with current mode of backup power (yes/no)
    c. Energy efficiency of PEM fuel cells as compared to alternatives (yes/no)
    d. Environmental concerns (yes/no)
    e. Availability of government incentives (yes/no)
    f. Track record of others using the PEM fuel cell system (yes/no)
    g. Other ______

29. How are capital purchase decisions for back-up power systems made in your organization? Please highlight or bold all that apply.
    a. Based on initial capital cost
    b. Based on payback period
    c. Based on return on investment
    d. Other ______
    e. Don't know

30. Are government incentives considered when making a purchasing decision? Please highlight or bold answer that applies.
    a. Yes
    b. No
    c. Don't know

31. What is the title of the person who selects the backup power systems that are purchased by your organization?

32. In the event that your market is selected as a promising transitional market for PEM fuel cells, can we contact you for more detailed information?
    a. Yes
    b. No

Thank you for your time in completing this survey!

A.4 Phase 1 Survey: Exploratory Research Questions on Candidate User Requirements for Specialty Vehicles

Battelle, a non-profit research and development organization located in Columbus, Ohio is conducting research on user requirements for specialty vehicles and would appreciate your response to some exploratory questions regarding the use of these vehicles at your facilities.

The Department of Energy's Office of Energy Efficiency and Renewable Energy is focused on the development of hydrogen fuel vehicles by 2015 and realizes that there will likely be a lengthy transition period. In order to sustain industry and develop a supplier base for future automotive markets, DOE is focused on identifying market opportunities for Proton Exchange Membrane (PEM) fuel cells in stationary, off-road, and other pre-automotive applications.

The purpose of these questions survey is to help define market opportunities for direct hydrogen PEM fuel cells in markets before 2015. We are exploring a subset of industries that use specialty vehicles as potential near-term adopters for PEM fuel cell powered specialty vehicles. Specialty vehicles can include indoor and outdoor vehicles that perform a utility function such as forklifts, tugs, tow tractors, excavators, and golf carts amongst others. We would like to understand the likely applications for specialty vehicles, as well as user requirements with regard to size and performance of these vehicles, and user perceptions of direct hydrogen fuel cells.

Battelle will use this information to perform analysis of likely pre-automotive market opportunities for direct hydrogen PEM fuel cells, determine areas for R&D efforts in fuel cells, and to define opportunities for demonstration of PEM fuel cells.

Please answer the questions below to the best of your ability – use of phrases and short sentences are preferred. If you choose to skip a question, please indicate N/A or "prefer no to answer", as appropriate.

1. Name of Organization

2. Address

3. Name of Contact

4. Job Title

5. Primary Business of Your Organization

6. Approximately how many employees work for your organization? Please highlight or bold the answer that applies.
   a) Small < 500
   b) Medium 500-3,000
   c) Large > 3,000

7. Please identify the various types of specialty vehicles used by your organization and the typical application(s) it is used for?

Product -	Application –
Product -	Application –
Product -	Application –

8. Approximately how many specialty vehicle products do you have at a single facility? Can you estimate the number of specialty vehicles across all facilities in your organization as well? Please specify by type (e.g. approximately 30 – pallet trucks).
   a) Per facility -
   b) All facilities -

9. How many shifts do you run per day for the various applications identified in question 7? Do you run shifts all 7 days per week?

10. Of the various applications identified in question 7, which applications in your opinion, are most impacted by specialty vehicle downtime? (Downtime is defined as duration of unscheduled stoppage of equipment and does not include scheduled maintenance)

11. Specialty vehicle downtime in your industry results in the following. Please highlight or bold all answers that apply.
   a) Loss in productivity through decreased movement of materials (Yes/No)
   b) Decrease in labor productivity (yes/no)
   c) Increased operations and maintenance costs (Yes/No)
   d) Other _____
   e) None ______
   f) Don't know ______

12. About how many downtime incidents has your organization experienced with its current specialty vehicles in the last 12 months? Please specify across all applications.

13. Can you estimate how long these incidents of downtime typically last? Please highlight or bold all answers that apply.
   a) < 5 minutes
   b) 5-30 minutes
   c) 30 minutes – 1 hour
   d) 1 hour – 4 hours
   e) 4 hours – 8 hours
   f) > 8 hours
   g) Don't know

14. How disruptive would these incidents of downtime be if they occurred during normal operating hours? Please highlight or bold all answers that apply.
    a) < 5 minutes (Scale 1-7, with 1 not disruptive and 7 very disruptive)
       1 2 3 4 5 6 7

    b) 5-30 minutes (Scale 1-7, with 1 not disruptive and 7 very disruptive)
       1 2 3 4 5 6 7

    c) 30 minutes – 1 hour (Scale 1-7, with 1 not disruptive and 7 very disruptive)
       1 2 3 4 5 6 7

    d) 1 hour – 4 hours (Scale 1-7, with 1 not disruptive and 7 very disruptive)
       1 2 3 4 5 6 7

    e) 4 hours – 8 hours (Scale 1-7, with 1 not disruptive and 7 very disruptive)
       1 2 3 4 5 6 7

    f) > 8 hours (Scale 1-7, with 1 not disruptive and 7 very disruptive)
       1 2 3 4 5 6 7

    g) Don't know

15. Do your current specialty vehicles utilize any or all of the following? Please highlight or bold all answers that apply.
    a) Electric drive systems with batteries – yes/no
    b) Propane ICE[104] – yes/no
    c) Diesel ICE – yes/no
    d) Other _____

16. What are the typical operation and maintenance requirements for the specialty vehicles your organization uses? Please specify the frequency of these requirements
    a) Battery-based specialty vehicle products -
    b) ICE based specialty vehicle products -

17. What safety concerns, if any, do you have with regard to use of batteries and/or ICE engines for the specialty vehicle product(s) used by you?
    a) Batteries -
    b) ICE engines –

18. What is the importance of the following factors in selecting a specialty vehicle for your needs? Please highlight or bold all answers that apply.
    a) Reliability – comes on and operates continuously every time it is needed (Scale 1-7, 1 not important, 7 very important)
       1 2 3 4 5 6 7 Don't know

[104] ICE = Internal Combustion Engine

b) Capital cost (Scale 1-7, 1 not important, 7 very important)
1 2 3 4 5 6 7 Don't know

c) Lifetime of the unit (Scale 1-7, 1 not important, 7 very important)
1 2 3 4 5 6 7 Don't know

d) Annual operating cost (fuel and maintenance) (Scale 1-7, 1 not important, 7 very important)
1 2 3 4 5 6 7 Don't know

e) Emissions – environmental considerations or restrictions (Scale 1-7, 1 not important, 7 very important)
1 2 3 4 5 6 7 Don't know

f) Start-up time (Scale 1-7, 1 not important, 7 very important)
1 2 3 4 5 6 7 Don't know

g) Time between refueling (Scale 1-7, 1 not important, 7 very important)
1 2 3 4 5 6 7 Don't know

h) Ease of use, including regular maintenance (Scale 1-7, 1 not important, 7 very important)
1 2 3 4 5 6 7 Don't know

i) Fuel availability (Scale 1-7, 1 not important, 7 very important)
1 2 3 4 5 6 7 Don't know

j) Good experience with this type of system in the past (Scale 1-7, 1 not important, 7 very important)
1 2 3 4 5 6 7 Don't know

19. Which of the above factors are most important? Choose up to three.

20. How would you rate the performance of batteries and/or ICE in your specialty vehicle product(s)? Please rate each on a scale of 1 to 7, with 1 being not good and 7 very good. If answer is ≥4, then *skip to* Question 22.

21. What concerns, if any, do you have with the performance of batteries and/or ICE in your specialty vehicle product(s)? Please identify the system of concern. Please highlight or bold all that apply.
   a) Takes to long to refuel
   b) Takes to long swap batteries
   c) Inconvenient to recharge
   d) Causes spills and leaks

e) Results in hazardous emissions
f) Unsafe
g) Other ________

22. How would you rate your current specialty vehicles against the following characteristics? Please rate each on a scale of 1 to 7, where 1 is not good and 7 is very good. Please highlight or bold all answers that apply.
    a) Reliability – comes on and operates continuously every time it is needed (Scale 1-7, 1 not important, 7 very important)
       1 2 3 4 5 6 7 Don't know

    b) Capital cost (Scale 1-7, 1 not important, 7 very important)
       1 2 3 4 5 6 7 Don't know

    c) Lifetime of the unit (Scale 1-7, 1 not important, 7 very important)
       1 2 3 4 5 6 7 Don't know

    d) Operation and maintenance costs (Scale 1-7, 1 not important, 7 very important)
       1 2 3 4 5 6 7 Don't know

    e) Start-up time (Scale 1-7, 1 not important, 7 very important)
       1 2 3 4 5 6 7 Don't know

    f) Time between refueling (Scale 1-7, 1 not important, 7 very important)
       1 2 3 4 5 6 7 Don't know

    g) Ease of use, including regular maintenance (Scale 1-7, 1 not important, 7 very important)
       1 2 3 4 5 6 7 Don't know

    h) Fuel availability (Scale 1-7, 1 not important, 7 very important)
       1 2 3 4 5 6 7 Don't know

23. Do you anticipate a growing need for specialty vehicles in your industry in the next three years? Please highlight or bold the answer that applies.
    a) Yes
    b) No
    c) Don't know

24. Have you considered alternatives to your current battery and/or ICE based specialty vehicles? Please highlight or bold the answer that applies.
    a) Yes. If yes, what have you considered?
    b) No

25. Have you heard of PEM fuel cells as a power source in existing specialty vehicles? Please highlight or bold the answer that applies.
    a) Yes
    b) No (*if no, skip to Question 29*)

26. Do you believe that PEM fuel cells are likely to compete favorably with your existing battery and/or ICE based specialty vehicles? Please highlight or bold the answer that applies.
    a) Yes
    b) No. If no, why not?

27. What factors would drive your decision to purchase PEM fuel cell based specialty vehicles? Please highlight or bold all answers that apply.
    a) Cost incurred from downtime (yes/no)
    b) Dissatisfaction with current mode of operation (too cumbersome etc.) (yes/no)
    c) Energy efficiency of PEM fuel cells as compared to alternatives (yes/no)
    d) Environmental concerns (yes/no)
    e) Availability of government incentives (yes/no)
    f) Track record of others using the PEM fuel cell specialty vehicle product(s) (yes/no)
    g) Other -

28. Do you have any concerns about using hydrogen as a fuel? Please highlight or bold the answer that applies.
    a. Yes
    b. No
    c. Don't know

29. How are capital purchase decisions for specialty vehicles made in your organization? Please highlight or bold all answers that apply.
    a) Based on initial capital cost
    b) Based on payback period
    c) Based on return on investment
    d) Other -

30. Are government incentives considered when making a purchasing decision? Please highlight or bold the answer that applies.
    a. Yes
    b. No
    c. Don't know

31. What is the title of the person who selects the specialty vehicles purchased by your organization?

32. In the event that your industry is selected as a promising transitional market for PEM fuel cells, can we contact you for more detailed information?
    a. Yes
    b. No

Thank you for your time!

A.5 Phase 1 Survey: Exploratory Research Questions for Specialty Vehicle Manufacturers

Battelle, a non-profit research and development organization located in Columbus, Ohio is conducting research on the requirements for fuel cells in specialty vehicles and would appreciate your response to some exploratory questions regarding your specialty vehicle products.

The Department of Energy's Office of Energy Efficiency and Renewable Energy is focused on the development of hydrogen fuel vehicles by 2015 and realizes that there will likely be a lengthy transition period. In order to sustain industry and develop a supplier base for future automotive markets, DOE is focused on identifying market opportunities for Proton Exchange Membrane (PEM) fuel cells in stationary, off-road, and other pre-automotive applications.

The purpose of these questions is to help define market opportunities for direct hydrogen PEM fuel cells in transitional markets (i.e. pre-automotive) to 2015. We have identified the specialty vehicle products you develop as a potentially good fit with these transition markets. Specialty vehicles can include indoor and outdoor vehicles that perform a utility function such as forklifts, tugs, tow tractors, excavators, and golf carts amongst others. We would like to understand the likely applications for PEM fuel cells in specialty vehicles, as well as user requirements with regard to size and performance of these vehicles.

Battelle will use this information to perform analysis of likely transitional market opportunities for direct hydrogen PEM fuel cells, to determine areas for R&D efforts in fuel cells, and to define opportunities for demonstration of PEM fuel cells.

Please answer the questions below to the best of your ability – use of phrases and short sentences are preferred. If you choose to skip a question, please indicate N/A or "prefer not to answer", as appropriate

1. Name of Organization

2. Address

3. Name of Contact

4. Job Title

5. Primary Business of Your Organization

6. Approximately how many employees work for your organization? Please highlight or bold answer that applies.
   a) Small < 500
   b) Medium 500-3,000
   c) Large > 3,000

7. Please identify the various types of specialty vehicle products manufactured or distributed by your company? Please specify the markets these products are typically used in.

Product -	Market –
Product -	Market –
Product -	Market –
Product -	Market –

8. Do your products use any or all of the following? Please highlight or bold all that apply.
   a) Electric drive systems with batteries – yes/no
   b) Propane ICE – yes/no
   c) Diesel ICE – yes/no
   d) Other ____

9. Of the various markets identified in question 7, which markets in your opinion, are most impacted by product downtime?

10. Product downtime in these markets results in the following. Please highlight or bold all that apply.
    a) Decreased operation (shifts/day) (Yes/No)
    b) Loss in productivity through decreased movement of materials (Yes/No)
    c) Decrease in labor productivity (yes/no)
    d) Increased operations and maintenance costs (Yes/No)
    e) Other ____
    f) None ______
    g) Don't Know ______

11. What are the operation and maintenance (O&M) requirements for your product (s)? Please specify the frequency of these requirements for the following.
    a) Battery based products O&M requirements -
    b) ICE based products O&M requirements -

12. What safety concerns, if any, do you have with regard to use of batteries and/or ICE engines in your product(s)?
    a) Batteries safety concerns -
    b) ICE engines safety concerns -

13. Is your company pleased with the performance of batteries and/or ICE engines in your product(s)?
    a) Yes
    b) No. Please elaborate.

14. Are you aware of PEM fuel cells as potential substitutes to batteries and/or ICE engines for your product(s)? Please highlight or bold the answer that applies.
    a) Yes
    b) No. If no, please skip to question 22.

15. Has your company considered PEM fuel cells as alternatives to batteries and/or ICE engines your product(s)? Please highlight or bold the answer that applies.
    a) Yes. If yes, please elaborate what alternatives were considered.
    b) No. If no, please skip to question 22

16. How do you evaluate alternative power systems for your specialty vehicle products?

17. What characteristics are most important when choosing an alternative?

18. Do you think that PEM fuel cells would be a viable alternative for your product needs? Please highlight or bold the answer that applies.
    a) Yes
    b) No
    c) May be
    d) Don't know

19. What barriers (research and development or market related barriers), if any, exist to the successful integration of fuel cells into your products?

20. If you are working on fuel cell products, when do you plan to introduce your fuel cell integrated products in the marketplace? Also, what applications are you targeting?

21. What are the key drivers for successful adoption of fuel cell based products by your customers?

22. Do you think hydrogen as a fuel would be a cause for concern with your customers? Please highlight or bold the answer that applies.
    a) Yes
    b) No
    c) May be
    d) Don't know

23. Would you be interested in working with the DOE to develop and demonstrate PEM fuel cells in your product(s)? Please highlight or bold the answer that applies.
    a) Yes
    b) No
    c) May be ____
    d) Don't know

24. As our project proceeds can we contact with further questions?
    a) Yes
    b) No

Thank you for your answers!

A.6 Phase 2 Survey: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems

Battelle, a non-profit research and development organization located in Columbus, Ohio is conducting research on user requirements for energy technologies and would appreciate your response to some exploratory questions regarding the use of backup power at your facilities.

The Department of Energy's Office of Energy Efficiency and Renewable Energy is focused on the development of hydrogen fuel vehicles by 2015 and realizes that there will likely be a lengthy transition period. In order to sustain industry and develop a supplier base for future automotive markets, DOE is focused on identifying market opportunities for Proton Exchange Membrane (PEM) fuel cells in stationary, off-road, and other pre-automotive applications.

After reviewing over 25 market segments, four were identified as the most likely near-term users of PEM fuel cell systems: *forklifts in retail distribution markets, ground support vehicles in airports, backup power for radio tower sites in the emergency response market,* and *backup power for telecommunications.* The purpose of this survey is to help us to understand the likely applications and specific user requirements that PEM fuel cells would need to meet in order to provide a viable backup power alternative for emergency response systems.

Battelle will use this information to perform an economic analysis of hydrogen PEM fuel cells relative to competing technologies, to determine priority areas for R&D efforts in fuel cells, and to define opportunities for PEM fuel cell demonstration projects.

Please answer the questions below to the best of your. If you choose to skip a question, please indicate "not applicable", "do not know", or "prefer not to answer", as appropriate.

1. Name of Organization

2. Address

3. Name of Contact

4. Job Title

5. Primary Business of Your Organization

6. Approximately how many employees work for your organization?
   a. < 500
   b. 500-3,000
   c. > 3,000

7. In the last 12 months, about how many power outages at radio tower sites has your organization experienced that you considered disruptive to your operations?

8. Can you estimate how long these power interruptions typically last? Please highlight or bold all that apply.
    a. < 1 second
    b. < 60 seconds
    c. < 3 minutes
    d. 3 – 5 minutes
    e. 5 minutes – to an hour
    f. 1 - 4 hours
    g. 4 hours or longer
    h. Don't know

9. For how many hours of continuous operation do you expect your backup system to be able run at a radio tower site?

10. Please describe the backup power systems that your organization uses at your radio tower sites.

Backup system used (e.g. diesel generator with UPS, solar cells, batteries)	Equipment make and model	Power output (e.g. 15kW)	Approx # of systems in this power range

11. What are the estimated hours of operation of these backup system per year? Include routine maintenance operating time and actual backup operating time.

12. How much labor is required for maintenance of your current systems used at radio tower sites – both scheduled and unscheduled maintenance (hours per month)?

13. What is the estimated labor rate for staff who maintain your radio tower backup power systems ($ per hour)?

14. Do you follow manufacturer's recommended maintenance schedule for your backup power systems?
    a) Yes ______
    b) No ______ If not, what schedule do you use?

15. For a typical facility, please identify any maintenance costs you incur other than labor (e.g. filters) for your current backup systems at radio tower sites.

16. If you use an internal combustion engine backup system, please indicate the expected lifetime of the engine (years).

17. Do you use a battery in conjunction with an internal combustion engine for your radio tower sites? If yes, please indicate:

    a) Battery lifetime (years) _____________________

    b) Battery charger lifetime (years) _____________

    c) Disposal costs for batteries ($) _______________

18. Is a designated space required to perform battery change outs and to charge batteries?
    a) Yes _____ If yes, please estimate amount of space required (sq ft) ____________
    b) No ______

19. What is the importance of the following factors in selecting a backup power system for radio tower sites that meets your needs? Please rate each on a scale of 1 to 7, with 1 being not important and 7 very important. Please highlight or bold all that apply.

20. Which 3 factors from the list above would most influence your decision to purchase a backup power system for radio tower sites with an alternative technology (e.g. a fuel cell powered system)? That is, if the fuel cell powered backup system performed better than your current technology in those 3 areas, you would consider buying it.

21. How would you rate your current backup power system for all of the following characteristics? Please rate each on a scale of 1 to 7, where 1 is not good and 7 is very good. Please highlight or bold all that apply.

    a) Reliability – comes on and operates continuously every time it is needed (Scale 1-7, 1 not good, 7 very good)
       1 2 3 4 5 6 7 Don't know

    b) Capital cost (Scale 1-7, 1 not good, 7 very good)
       1 2 3 4 5 6 7 Don't know

c) Operation and maintenance costs (Scale 1-7, 1 not good, 7 very good)
1 2 3 4 5 6 7 Don't know

d) Lifetime of the unit (Scale 1-7, 1 not good, 7 very good)
1 2 3 4 5 6 7 Don't know

e) Annual operating cost (fuel and maintenance) (Scale 1-7, 1 not good, 7 very good)
1 2 3 4 5 6 7 Don't know

f) Emissions – environmental considerations or restrictions (Scale 1-7, 1 not good, 7 very good)
1 2 3 4 5 6 7 Don't know

g) Start-up time when power goes out (Scale 1-7, 1 not good, 7 very good)
1 2 3 4 5 6 7 Don't know

h) Ease of use, including regular maintenance (Scale 1-7, 1 not good, 7 very good)
1 2 3 4 5 6 7 Don't know

i) Fuel Availability (Scale 1-7, 1 not good, 7 very good)
1 2 3 4 5 6 7 Don't know

22. Do you have any concerns about using hydrogen as a fuel? Rate your level of concern on a scale of 1 to 7, where 1 is not concerned and 7 is very concerned. Please highlight or bold the answer that applies.
1 2 3 4 5 6 7 Don't know

Thank you for your time in completing this survey!

A.7 Phase 2 Survey: Candidate Fuel Cell Users in Specialty Vehicle Applications

Battelle, a non-profit research and development organization located in Columbus, Ohio is conducting research on user requirements for specialty vehicles and would appreciate your response to some exploratory questions regarding the use of these vehicles at your facilities.

The Department of Energy's Office of Energy Efficiency and Renewable Energy is focused on the development of hydrogen fuel vehicles by 2015 and realizes that there will likely be a lengthy transition period. In order to sustain industry and develop a supplier base for future automotive markets, DOE is focused on identifying market opportunities for Proton Exchange Membrane (PEM) fuel cells in stationary, off-road, and other pre-automotive applications.

After reviewing over 25 market segments, four were identified as the most likely near-term users of PEM fuel cell systems: *forklifts in retail distribution markets, ground support vehicles in airports, backup power for emergency response systems,* and *backup power for telecommunications.* The purpose of this survey is to help us understand user requirements with regard to size and performance for specialty vehicles, such as forklifts and airport tugs, which are used for industrial and commercial applications.

Battelle will use this information to perform an economic analysis of hydrogen PEM fuel cells relative to competing technologies, to determine priority areas for R&D efforts in fuel cells, and to define opportunities for PEM fuel cell demonstration projects.

Please answer the questions below to the best of your ability. If you choose to skip a question, please indicate "not applicable", "do not know", or "prefer not to answer", as appropriate.

1. Name of Organization

2. Address

3. Name of Contact

4. Job Title

5. Primary Business of Your Organization

6. Approximately how many employees work for your organization? Please highlight or bold the answer that applies.
    a) < 500
    b) 500-3,000
    c) > 3,000

7. Please identify the types of specialty vehicles used in a typical facility where you operate (e.g. distribution center, airport), the typical application(s) they are used for, and frequency of use.

Equipment make and model	Applications (e.g. materials handling in distribution center, airline baggage tractor)	Power output (e.g. 65 kW)	Type of engine (e.g. diesel engine, propane engine, electric)	# of hours per day vehicle operates (excluding main-tenance time)	# of shifts per day/ week vehicle operates	# of vehicles per facility

8. For battery-powered vehicles, please indicate:

Applications (e.g. materials handling in distribution center, baggage tractor)	# of times batteries are changed out in an 8-hour shift	Time required for battery maintenance (mins or hrs per battery per day)	Battery lifetime (years)

9. Does battery change-out time result in lost productivity or do you have extra vehicles to ensure continued operations?

10. How much does it cost your company to dispose of a battery?

11. Is a designated space required to perform battery change outs and to charge batteries?
    a) Yes ____ If yes, please estimate amount of space required (sq ft) _______
    b) No _____

12. What is the typical lifetime (years) of a battery charger?

13. For ICE[105]-powered vehicles, please indicate:

Applications (e.g. materials handling in distribution center, baggage tractor)	Tank fill time (minutes)	Tank refill frequency (times per shift)	Labor time required for ICE maintenance (hours per month or quarter)	Engine maintenance costs other than labor ($ per month or quarter)

14. What is the labor rate of a specialty vehicle operator?

15. Of the various applications identified in question 7, which applications in your opinion, are most impacted by specialty vehicle downtime? Downtime is defined as duration of unscheduled maintenance.

16. On average, how many times per year does unscheduled maintenance occur on your vehicles? Please specify for what applications/equipment.

17. Can you estimate how long these incidents of downtime typically last? Please highlight or bold all answers that apply.
    a) < 5 minutes
    b) 5-30 minutes
    c) 30 minutes – 1 hour
    d) 1 hour – 4 hours
    e) 4 hours – 8 hours
    f) > 8 hours
    g) Don't know

18. Do you follow manufacturer's recommended maintenance schedule?
    a) Yes ______
    b) No ______ If not, what schedule do you use?

19. What is the importance of the following factors in selecting a specialty vehicle for your needs? Please highlight or bold all answers that apply.

[105] ICE = internal combustion engine (e.g. diesel or propane engine)

a) Reliability – comes on and operates continuously every time it is needed (Scale 1-7, 1 not important, 7 very important)
1 2 3 4 5 6 7 Don't know

b) Capital cost (Scale 1-7, 1 not important, 7 very important)
1 2 3 4 5 6 7 Don't know

c) Lifetime of the unit (Scale 1-7, 1 not important, 7 very important)
1 2 3 4 5 6 7 Don't know

d) Annual operating cost (fuel and maintenance) (Scale 1-7, 1 not important, 7 very important)
1 2 3 4 5 6 7 Don't know

e) Emissions – environmental considerations or restrictions (Scale 1-7, 1 not important, 7 very important)
1 2 3 4 5 6 7 Don't know

f) Start-up time (Scale 1-7, 1 not important, 7 very important)
1 2 3 4 5 6 7 Don't know

g) Time between refueling or recharging (Scale 1-7, 1 not important, 7 very important)
1 2 3 4 5 6 7 Don't know

h) Ease of use, including regular maintenance (Scale 1-7, 1 not important, 7 very important)
1 2 3 4 5 6 7 Don't know

i) Fuel availability (Scale 1-7, 1 not important, 7 very important)
1 2 3 4 5 6 7 Don't know

j) Good experience with this type of system in the past (Scale 1-7, 1 not important, 7 very important)
1 2 3 4 5 6 7 Don't know

k) Interest in using novel cutting-edge technology
1 2 3 4 5 6 7 Don't know

20. Which 3 factors from the list above would most influence your decision to purchase a specialty vehicle powered by an alternative technology (e.g. a fuel cell powered vehicle)? That is, if the fuel cell vehicle performed better than your current technology in those 3 areas, you would consider buying it.

21. How would you rate your current specialty vehicles against the following characteristics? Please rate each on a scale of 1 to 7, where 1 is not good and 7 is very good. Please highlight or bold all answers that apply.

   a) Reliability – comes on and operates continuously every time it is needed (Scale 1-7, 1 not important, 7 very important)
      1 2 3 4 5 6 7 Don't know

   b) Capital cost (Scale 1-7, 1 not important, 7 very important)
      1 2 3 4 5 6 7 Don't know

   c) Lifetime of the unit (Scale 1-7, 1 not important, 7 very important)
      1 2 3 4 5 6 7 Don't know

   d) Operation and maintenance costs (Scale 1-7, 1 not important, 7 very important)
      1 2 3 4 5 6 7 Don't know

   e) Start-up time (Scale 1-7, 1 not important, 7 very important)
      1 2 3 4 5 6 7 Don't know

   f) Time between refueling or recharging (Scale 1-7, 1 not important, 7 very important)
      1 2 3 4 5 6 7 Don't know

   g) Ease of use, including regular maintenance (Scale 1-7, 1 not important, 7 very important)
      1 2 3 4 5 6 7 Don't know

   h) Fuel availability (Scale 1-7, 1 not important, 7 very important)
      1 2 3 4 5 6 7 Don't know

22. Do you have any concerns about using hydrogen as a fuel? Rate your level of concern on a scale of 1 to 7, where 1 is not at all concerned and 7 is very concerned. Please highlight or bold the answer that applies.
      1 2 3 4 5 6 7 Don't know

Thank you for your time!

A.8 Phase 2 Interview Protocol: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems

1. *Review any answers in the survey that are not clear.*

2. How are capital purchase decisions for backup power systems made in your organization? For example, do emphasize initial capital cost, return on investment over the life of the system?

3. Does your organization consider the availability of government incentives when making a capital purchasing decision for a backup power system?

4. How would your company typically finance investments in backup power systems? Out of current cash reserves or through a loan?

    i) Would the option of getting a loan guarantee for purchase of a fuel cell vehicle impact your decision? (A loan guarantee would allow banks to provide lower interest rates on loans).

5. What is the acceptable price range you would pay for a back up power system for a radio tower?

6. Have you considered alternatives to your current backup power system? If yes, what have you considered?

7. Have you heard of PEM fuel cells as a power source for backup power applications?

8. Do you believe that PEM fuel cells are likely to compete favorably with your existing backup power systems? If no, why not?

9. Would you be interested in testing the fuel cell at one of your sites?

10. What would convince you to procure a fuel cell-powered backup system? (e.g. dissatisfaction with current mode of operation, environmental concerns, etc)

A.9 Phase 2 Interview Protocol: Candidate Fuel Cell Users in Specialty Vehicle Applications

1. *Review any answers in the survey that are not clear. Be sure we understand how many days per week the vehicle operates, as well as shifts per day.*

2. How are capital purchase decisions for specialty vehicles made in your organization? For example, do emphasize initial capital cost, return on investment over the life of the vehicle?

3. Does your organization consider the availability of government incentives when making a capital purchasing decision for (forklifts or airport tugs)?

4. How would your company typically finance investments in (forklifts or airport tugs)? Out of current cash reserves or through a loan?

    j) Would the option of getting a loan guarantee for purchase of a fuel cell vehicle impact your decision? (A loan guarantee would allow banks to provide lower interest rates on loans).

5. What is the acceptable price range you would pay for a (forklift or airport tug)?

6. Have you considered alternatives to your current battery and/or ICE based specialty vehicles? If so, what alternatives have you considered?

7. Have you heard of PEM fuel cells as a power source in existing specialty vehicles, such as (forklifts or airport tugs)?

8. Do you believe that PEM fuel cells are likely to compete favorably with your existing battery and/or ICE based specialty vehicles? If no, why not?

9. Would you be interested in testing the fuel cell at one of your sites?

10. What would convince you to procure a fuel cell-powered vehicle? (e.g. dissatisfaction with current mode of operation, environmental concerns, etc)

11. Would you be interested in participating in a focus group with other retail distribution centers regarding fuel cell use in forklifts?

APPENDIX B: Complete List of Respondents and Level of Participation

Table B-1. Survey and Protocol-Based Interview Respondents – Phase 1 and Phase 2 Research.

Application	Market Segment	Company	Responded to:						
			Phase 1 Survey: Exploratory Research Questions for Candidate Fuel Cell Users in Backup Power Applications	*Phase 1 Survey: Exploratory Research Questions for Specialty Vehicle Manufacturers*	*Phase 1 Survey: Exploratory Research Questions on Candidate User Requirements for Specialty Vehicles*	*Phase 2 Survey: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Survey: Candidate Fuel Cell Users in Specialty Vehicle Applications*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Specialty Vehicle Applications*
Backup Power	Airports	City of San Jose Airport	✓						
Backup Power	Airports	Hillsborough County Aviation Authority	✓						
Backup Power	Airports	Metropolitan Washington Airports Authority	✓						
Backup Power	Airports	Port of Portland Airport	✓						
Backup Power	Airports	Port of Seattle DBA Sea-Tac International Airport	✓						
Backup Power	Airports	Sacramento County Airport System	✓						
Backup Power	Casinos	Jumers Casino Rock Island	✓						
Backup Power	Chemical	ERCO	✓						

Table B-1. Survey and Protocol-Based Interview Respondents – Phase 1 and Phase 2 Research.

Application	Market Segment	Company	Responded to:						
			Phase 1 Survey: Exploratory Research Questions for Candidate Fuel Cell Users in Backup Power Applications	*Phase 1 Survey: Exploratory Research Questions for Specialty Vehicle Manufacturers*	*Phase 1 Survey: Exploratory Research Questions on Candidate User Requirements for Specialty Vehicles*	*Phase 2 Survey: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Survey: Candidate Fuel Cell Users in Specialty Vehicle Applications*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Specialty Vehicle Applications*
	Manufacturing	Worldwide (USA) Inc.							
Backup Power	Chemical Manufacturing	Dow Chemical	✓						
Backup Power	Computer and Electronic Products	AlfaMag Electronics LLC	✓						
Backup Power	Computer and Electronic Products	Catalyst Manufacturing Services, Inc.	✓						
Backup Power	Computer and Electronic Products	Multek Flexible Circuits, Inc.	✓						
Backup Power	Computer and Electronic Products	Texas Instruments	✓						
Backup Power	Electric Utility Substations	DTE Energy	✓						
Backup Power	Electric Utility Substations	WE Energies	✓						
Backup Power	Federal Agencies	DOE - Brookhaven National Laboratory	✓						
Backup Power	Federal Agencies	NASA - Glenn Research Center	✓						

Table B-1. Survey and Protocol-Based Interview Respondents – Phase 1 and Phase 2 Research.

Application	Market Segment	Company	Responded to:						
			Phase 1 Survey: Exploratory Research Questions for Candidate Fuel Cell Users in Backup Power Applications	*Phase 1 Survey: Exploratory Research Questions for Specialty Vehicle Manufacturers*	*Phase 1 Survey: Exploratory Research Questions on Candidate User Requirements for Specialty Vehicles*	*Phase 2 Survey: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Survey: Candidate Fuel Cell Users in Specialty Vehicle Applications*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Specialty Vehicle Applications*
Backup Power	Federal Agencies	NOAA - NWS	✓						
Backup Power	Federal Agencies	EPA	✓						
Backup Power	Federal Agencies	EPA - Edison Facility	✓						
Backup Power	Federal Agencies	EPA/NVFEL (National Vehicle and Fuel Emissions Laboratory)	✓						
Backup Power	Federal Agencies	USCG	✓						
Backup Power	Grocery Stores and Large Department Stores	Costco Wholesale	✓						
Backup Power	Grocery Stores and Large Department Stores	Giant Eagle	✓						
Backup Power	Grocery Stores and Large Department Stores	Herbco	✓						
Backup Power	Grocery Stores and Large Department Stores	Whole Foods Market, Inc.	✓						
Backup Power	Healthcare	Children's Hospital	✓						
Backup Power	Healthcare	VA Medical Center -	✓						

Table B-1. Survey and Protocol-Based Interview Respondents – Phase 1 and Phase 2 Research.

Application	Market Segment	Company	Responded to:						
			Phase 1 Survey: Exploratory Research Questions for Candidate Fuel Cell Users in Backup Power Applications	*Phase 1 Survey: Exploratory Research Questions for Specialty Vehicle Manufacturers*	*Phase 1 Survey: Exploratory Research Questions on Candidate User Requirements for Specialty Vehicles*	*Phase 2 Survey: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Survey: Candidate Fuel Cell Users in Specialty Vehicle Applications*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Specialty Vehicle Applications*
		Brecksville							
Backup Power	Healthcare	VA Medical Center - Chillicothe	✓						
Backup Power	Healthcare	VA Medical Center - Cincinnati	✓						
Backup Power	Healthcare	VA Medical Center - Dayton	✓						
Backup Power	Metal Processing and Refining	Blue Blade Steel	✓						
Backup Power	Metal Processing and Refining	California Cast Metal Association	✓						
Backup Power	Metal Processing and Refining	Hexacon Electric Company	✓						
Backup Power	Metal Processing and Refining	Mittal Steel (Slab Product Plant)	✓						
Backup Power	Mining	Stillwater Mining	✓						
Backup Power	National and State Parks	Pacific West Region, National Park Service	✓						
Backup Power	Oil and Gas Manufacturing - Production of Gasoline, Heating	Chevron San Ramon and Chevron Concord	✓						

Table B-1. Survey and Protocol-Based Interview Respondents – Phase 1 and Phase 2 Research.

Application	Market Segment	Company	Responded to:						
			Phase 1 Survey: Exploratory Research Questions for Candidate Fuel Cell Users in Backup Power Applications	*Phase 1 Survey: Exploratory Research Questions for Specialty Vehicle Manufacturers*	*Phase 1 Survey: Exploratory Research Questions on Candidate User Requirements for Specialty Vehicles*	*Phase 2 Survey: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Survey: Candidate Fuel Cell Users in Specialty Vehicle Applications*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Specialty Vehicle Applications*
	Oil								
Backup Power	Oil and Gas Manufacturing - Production of Gasoline, Heating Oil	Plains Pipeline LP	✓						
Backup Power	Professional Scientific and Technical Services	aspStation, Inc.	✓						
Backup Power	Professional Scientific and Technical Services	Battelle	✓						
Backup Power	Railways	Alaska Railroad Corporation	✓						
Backup Power	Railways	Arkansas Missouri Railroad	✓						
Backup Power	Railways	CSX Railroad	✓						
Backup Power	Railways	DMJM Harris Inc.	✓						
Backup Power	Railways	Large Railroad Company (2)	✓✓						
Backup Power	Ski Resorts	Aspen Skiing Company	✓						

Table B-1. Survey and Protocol-Based Interview Respondents – Phase 1 and Phase 2 Research.

Application	Market Segment	Company	Responded to:						
			Phase 1 Survey: Exploratory Research Questions for Candidate Fuel Cell Users in Backup Power Applications	*Phase 1 Survey: Exploratory Research Questions for Specialty Vehicle Manufacturers*	*Phase 1 Survey: Exploratory Research Questions on Candidate User Requirements for Specialty Vehicles*	*Phase 2 Survey: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Survey: Candidate Fuel Cell Users in Specialty Vehicle Applications*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Specialty Vehicle Applications*
Backup Power	State and Local Departments of Emergency Response	Baker County Emergency Services	✓						
Backup Power	State and Local Departments of Emergency Response	Boone County Sheriff's Office				✓			
Backup Power	State and Local Departments of Emergency Response	Bureau County Enhanced 9-1-1				✓		✓	
Backup Power	State and Local Departments of Emergency Response	Franklin County Sheriff's Office	✓						
Backup Power	State and Local Departments of Emergency Response	Governor's Office of Emergency Services (CA)				✓		✓	
Backup Power	State and Local Departments of Emergency Response	Huron County EMA	✓			✓		✓	
Backup Power	State and Local Departments of	KITTCOM (Kittitas County				✓			

Table B-1. Survey and Protocol-Based Interview Respondents – Phase 1 and Phase 2 Research.

Application	Market Segment	Company	Responded to: *Phase 1 Survey: Exploratory Research Questions for Candidate Fuel Cell Users in Backup Power Applications*	*Phase 1 Survey: Exploratory Research Questions for Specialty Vehicle Manufacturers*	*Phase 1 Survey: Exploratory Research Questions on Candidate User Requirements for Specialty Vehicles*	*Phase 2 Survey: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Survey: Candidate Fuel Cell Users in Specialty Vehicle Applications*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Specialty Vehicle Applications*
	Emergency Response	911)							
Backup Power	State and Local Departments of Emergency Response	Lake Havasu City Police Department	✓						
Backup Power	State and Local Departments of Emergency Response	Martin County Sheriff's Office	✓						
Backup Power	State and Local Departments of Emergency Response	Miami-Dade Police Department	✓						
Backup Power	State and Local Departments of Emergency Response	Morrow County 911	✓						
Backup Power	State and Local Departments of Emergency Response	Ohio Emergency Management Agency	✓						
Backup Power	State and Local Departments of Emergency Response	Ohio MARCS (Multi-Agency Radio Communication				✓			

Table B-1. Survey and Protocol-Based Interview Respondents – Phase 1 and Phase 2 Research.

Application	Market Segment	Company	Responded to:						
			Phase 1 Survey: Exploratory Research Questions for Candidate Fuel Cell Users in Backup Power Applications	*Phase 1 Survey: Exploratory Research Questions for Specialty Vehicle Manufacturers*	*Phase 1 Survey: Exploratory Research Questions on Candidate User Requirements for Specialty Vehicles*	*Phase 2 Survey: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Survey: Candidate Fuel Cell Users in Specialty Vehicle Applications*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Specialty Vehicle Applications*
		System)							
Backup Power	State and Local Departments of Emergency Response	Orange County E911	✓						
Backup Power	State and Local Departments of Emergency Response	Pike County Sheriffs Office	✓						
Backup Power	State and Local Departments of Emergency Response	San Diego County Sheriff's Department	✓			✓			
Backup Power	State and Local Departments of Emergency Response	Sangamon County Emergency Telephone System	✓						
Backup Power	State and Local Departments of Emergency Response	Shelby County 9-1-1	✓			✓		✓	
Backup Power	State and Local Departments of Emergency Response	Shelby County Sheriff's Office	✓						

Table B-1. Survey and Protocol-Based Interview Respondents – Phase 1 and Phase 2 Research.

Application	Market Segment	Company	Responded to:						
			Phase 1 Survey: Exploratory Research Questions for Candidate Fuel Cell Users in Backup Power Applications	*Phase 1 Survey: Exploratory Research Questions for Specialty Vehicle Manufacturers*	*Phase 1 Survey: Exploratory Research Questions on Candidate User Requirements for Specialty Vehicles*	*Phase 2 Survey: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Survey: Candidate Fuel Cell Users in Specialty Vehicle Applications*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Specialty Vehicle Applications*
Backup Power	State and Local Departments of Emergency Response	Skagit 911				✓		✓	
Backup Power	State and Local Departments of Emergency Response	Washington State E911 Program	✓			✓			
Backup Power	State and Local Departments of Emergency Response	Pierce County Radio Communications							
Backup Power	Transportation Equipment	DaimlerChrysler	✓						
Backup Power	Transportation Equipment	NGK Spark Plugs	✓						
Backup Power	Water/Wastewater Treatment	CDM Inc.	✓						
Backup Power	Water/Wastewater Treatment	Columbia Wastewater Department	✓						
Backup Power	Water/Wastewater Treatment	Orange County Utilities (2)	✓✓						
Backup Power	Water/Wastewater Treatment	Champlain Water District	✓						
Backup Power	Water/Wastewater	City of	✓						

Table B-1. Survey and Protocol-Based Interview Respondents – Phase 1 and Phase 2 Research.

Application	Market Segment	Company	Responded to:						
			Phase 1 Survey: Exploratory Research Questions for Candidate Fuel Cell Users in Backup Power Applications	*Phase 1 Survey: Exploratory Research Questions for Specialty Vehicle Manufacturers*	*Phase 1 Survey: Exploratory Research Questions on Candidate User Requirements for Specialty Vehicles*	*Phase 2 Survey: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Survey: Candidate Fuel Cell Users in Specialty Vehicle Applications*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Specialty Vehicle Applications*
	Treatment	Columbus, Division of Water							
Backup Power	Water/Wastewater Treatment	City of Sandusky	✓						
Specialty Vehicles	Airport Tugs	A&G Mercury, A Division of A&G Mfg.		✓					
Specialty Vehicles	Airport Tugs	American Airlines			✓		✓		✓
Specialty Vehicles	Airport Tugs	DALGlobal Services			✓				✓
Specialty Vehicles	Airport Tugs	FMC Technologies, Inc.		✓					
Specialty Vehicles	Airport Tugs	Horizon Air/Seattle GSE Shop					✓		✓
Specialty Vehicles	Airport Tugs	JetBlue Airways			✓		✓		
Specialty Vehicles	Airport Tugs	Lektro Inc.		✓					
Specialty Vehicles	Airport Tugs	Matheson Flight Extenders, Inc.					✓		✓
Specialty Vehicles	Airport Tugs	Menzies Aviation					✓		✓
Specialty Vehicles	Airport Tugs	Trowin Industries, Inc.		✓					
Specialty Vehicles	Airport Tugs	UPS					✓		✓

Table B-1. Survey and Protocol-Based Interview Respondents – Phase 1 and Phase 2 Research.

Application	Market Segment	Company	Responded to:						
			Phase 1 Survey: Exploratory Research Questions for Candidate Fuel Cell Users in Backup Power Applications	*Phase 1 Survey: Exploratory Research Questions for Specialty Vehicle Manufacturers*	*Phase 1 Survey: Exploratory Research Questions on Candidate User Requirements for Specialty Vehicles*	*Phase 2 Survey: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Survey: Candidate Fuel Cell Users in Specialty Vehicle Applications*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Specialty Vehicle Applications*
Specialty Vehicles	Airport Tugs	US Airways – Seattle					✓		✓
Specialty Vehicles	Automated Guide Vehicles	Transbotics, Inc.		✓					
Specialty Vehicles	Automated Guide Vehicles	Egemin Automation		✓					
Specialty Vehicles	Automated Guide Vehicles	FMC Technologies, Inc.		✓					
Specialty Vehicles	Commercial Sweepers	Factory Cat		✓					
Specialty Vehicles	Commercial Sweepers	Nilfisk Advance		✓					
Specialty Vehicles	Commercial Sweepers	Tennant Corporation		✓					
Specialty Vehicles	Electric Lift Trucks/Forklifts	Advance Auto Parts					✓		
Specialty Vehicles	Electric Lift Trucks/Forklifts	Anonymous distribution center			✓				
Specialty Vehicles	Electric Lift Trucks/Forklifts	Anonymous online retail distributor					✓		
Specialty Vehicles	Electric Lift Trucks/Forklifts	B&B Forklifts		✓					
Specialty Vehicles	Electric Lift	Big Lots Stores,			✓				

Table B-1. Survey and Protocol-Based Interview Respondents – Phase 1 and Phase 2 Research.

Application	Market Segment	Company	Responded to:						
			Phase 1 Survey: Exploratory Research Questions for Candidate Fuel Cell Users in Backup Power Applications	*Phase 1 Survey: Exploratory Research Questions for Specialty Vehicle Manufacturers*	*Phase 1 Survey: Exploratory Research Questions on Candidate User Requirements for Specialty Vehicles*	*Phase 2 Survey: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Survey: Candidate Fuel Cell Users in Specialty Vehicle Applications*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Specialty Vehicle Applications*
	Trucks/Forklifts	Inc.							
Specialty Vehicles	Electric Lift Trucks/Forklifts	Dollar General Co.			✓				
Specialty Vehicles	Electric Lift Trucks/Forklifts	Home Depot					✓		✓
Specialty Vehicles	Electric Lift Trucks/Forklifts	Jacksonville Warehouse Companies					✓		
Specialty Vehicles	Electric Lift Trucks/Forklifts	Limited Brands Inc.			✓				
Specialty Vehicles	Electric Lift Trucks/Forklifts	Marzetti Company			✓		✓		
Specialty Vehicles	Electric Lift Trucks/Forklifts	Meijer					✓		
Specialty Vehicles	Electric Lift Trucks/Forklifts	Nacco Materials Handling Group, Inc.		✓					
Specialty Vehicles	Electric Lift Trucks/Forklifts	Nordstrom, Inc.					✓		✓
Specialty Vehicles	Electric Lift Trucks/Forklifts	OKI Systems		✓					
Specialty Vehicles	Electric Lift Trucks/Forklifts	Raymond Corp.		✓					
Specialty Vehicles	Electric Lift Trucks/Forklifts	Safety-Kleen					✓		✓
Specialty Vehicles	Electric Lift	Sam's Club					✓		

Table B-1. Survey and Protocol-Based Interview Respondents – Phase 1 and Phase 2 Research.

Application	Market Segment	Company	Responded to:						
			Phase 1 Survey: Exploratory Research Questions for Candidate Fuel Cell Users in Backup Power Applications	*Phase 1 Survey: Exploratory Research Questions for Specialty Vehicle Manufacturers*	*Phase 1 Survey: Exploratory Research Questions on Candidate User Requirements for Specialty Vehicles*	*Phase 2 Survey: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Survey: Candidate Fuel Cell Users in Specialty Vehicle Applications*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Specialty Vehicle Applications*
	Trucks/Forklifts								
Specialty Vehicles	Electric Lift Trucks/Forklifts	BJ's Wholesale Club					✓		
Specialty Vehicles	Golf Carts	Columbia ParCar Corp.		✓					
Specialty Vehicles	Golf Carts	Yamaha Golf Car Company		✓					
Specialty Vehicles	Lawn Mowers	Encore Power Equipment		✓					
Specialty Vehicles	Lawn Mowers	Exmark Manufacturing Company		✓					
Specialty Vehicles	Lawn Mowers	The Toro Company (Commercial Division)		✓					
Specialty Vehicles	Mining Vehicles	Arch Coal Inc., Arch Western Bituminous Group			✓				
Specialty Vehicles	Mining Vehicles	BHP Billiton – San Juan Coal Co.			✓				
Specialty Vehicles	Mining Vehicles	Foundation Coal Corporation			✓				
Specialty Vehicles	Mining Vehicles	Kennecott Greens			✓				

Table B-1. Survey and Protocol-Based Interview Respondents – Phase 1 and Phase 2 Research.

Application	Market Segment	Company	Responded to:						
			Phase 1 Survey: Exploratory Research Questions for Candidate Fuel Cell Users in Backup Power Applications	*Phase 1 Survey: Exploratory Research Questions for Specialty Vehicle Manufacturers*	*Phase 1 Survey: Exploratory Research Questions on Candidate User Requirements for Specialty Vehicles*	*Phase 2 Survey: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Survey: Candidate Fuel Cell Users in Specialty Vehicle Applications*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Backup Power Applications for Emergency Response Systems*	*Phase 2 Interview Protocol: Candidate Fuel Cell Users in Specialty Vehicle Applications*
		Creek Mining Company							
Specialty Vehicles	Mining Vehicles	Sterling Mining Company			✓				
Specialty Vehicles	Unmanned Aerial Vehicles	AeroVironment Inc.		✓					
Specialty Vehicles	Wheelchairs	Hoveround		✓					
Specialty Vehicles	Wheelchairs	Invacare		✓					
Specialty Vehicles	Wheelchairs	Pride Mobility Products Corp.		✓					

Table B-2. Phase 1 Industry Organizations Interviewed/Surveyed for General Industry Trends

Type of Stakeholder	Company
Research Organization	Battelle
Research Organization	Pacific Northwest National Laboratory
Venture Capital Firm	Battelle Ventures
Venture Capital Firm	Hydro-Quebec Capitech
Venture Capital Firm	Yellowstone Energy Ventures LP
Venture Capital Firm	Expansion Capital Partners
Venture Capital Firm	Mohr, Davidow Ventures
Venture Capital Firm	Crysalix Energy Management
Venture Capital Firm	ARCH Venture Partners
Venture Capital Firm	Rockport Capital Partners
Fuel Cell Company	Ballard Power Systems
Fuel Cell Company	Plug Power
Fuel Cell Company	ReliOn
Fuel Cell Company	Nuvera Fuel Cells
Fuel Cell Company	UTC Power
Fuel Cell Company	Millennium Cell
Fuel Cell Company	MTi MicroFuel Cells
Fuel Cell Company	Proton Energy Systems
Fuel Cell Company	Hydrogenics
Component Supplier	Arkema Inc
Component Supplier	Asbury Carbons
Component Supplier	GrafTech International
Component Supplier	Dana Corporation
Component Supplier	Süd-Chemie Inc.
Industry Trade Association	Methanol Institute
Hydrogen Supplier	Chevron Technology Venture

APPENDIX C: SUMMARY RESEARCH FOR MARKET SEGMENTS ANALYZED

RESEARCH SUMMARY:
AIRPORTS

MARKET SEGMENT DESCRIPTION

This market segment includes establishments primarily engaged in operating, leasing, and maintaining airports and flying fields (except those maintained by aviation clubs); cleaning, servicing, repairing (except on a factory basis), maintaining, and storing aircraft; operating and renting airport hangars; and furnishing coordinated handling services for airfreight or passengers at airports. This industry also includes private establishments primarily engaged in air traffic control operations. This analysis considers the potential for PEM fuel cells for backup power at airports. Table a-1 identifies the SIC and NAICS classifications that cover airport operations.

Table a-1. SIC and NAICS Codes for Airport Operations.

2-Digit SIC Code	45 – Transportation by air
4-Digit SIC Code	4581 – Airports, flying fields, and airport terminal services
NAICS Code	488119 – Other airport operations

This market segment does not include: government air traffic control operations (classified in Public Administration, SIC Code 9621); aircraft modification centers and establishments primarily engaged in factory type overhaul of aircraft (classified in Manufacturing, SIC Code 37); and flying fields maintained by aviation clubs (classified in Services, SIC Code 7997).

The impacts of power outages at airports, whether caused by grid failure or backup power malfunctions, can include flight delays, security breaches, and disruptions in operations. The widespread blackout of August 2003 is an extreme example. Flights were delayed and in some cases airports were closed in Toronto, Newark, New York, Detroit, Cleveland, Montreal, Ottawa, Islip, Syracuse, Buffalo, Rochester, Erie, and Hamilton. Key airport operations were affected, halting flights out of affected airports for several hours or more. Critical functions which were affected included passenger air traffic control, security screening, and baggage x-ray systems. Blackouts also affected less critical, but still important systems, such as electronic ticketing. The delays in outgoing traffic impacted scheduling throughout the national (and international) air traffic system, as both passengers and planes missed scheduled flights at other (operating) airports. Some incoming flights were diverted to other airports, crowding those facilities. Neither the FAA nor the airlines could estimate the total number of flights that were affected.

As described above, power failures can cause a number of delays and disruptions in normal airport operations. Downtime is estimated to cost $668,586 per hour in the transportation sector.[106] Secondary research indicates that backup power is typically provided for a number of critical systems, including: security systems; incident command centers; critical computer systems and control rooms; telecommunications; minimal building functions (e.g., lighting); landing systems; navigational equipment; and runway lights.

[106] META Group, Inc. 2002. Quantifying Performance Loss: IT Performance Engineering and Measurement Strategies. Available at http://www.metagroup.com/us/displayArticle.do?oid=18750 [Accessed October 2006].

Some airports have additional emergency power for such functions as: additional lighting in public areas; ticket counters; bag screening systems; boarding bridges; police/fire buildings; fuel farm; regulator vault controlling airfield lighting; parking lots; and gas pumps.

Given the heightened security requirements following September 11, 2001, and the aftermath of the August 2003 blackout, the airport sector is concerned with ensuring a continuous power supply. Traditional backup power sources at airports include diesel generators and UPS systems. Gas turbines and alternate energy systems (e.g., solar power) may also be used to provide backup power. Examples of backup power systems at airports are presented below.

- *Diesel Generators* – Diesel generators appear to be the most popular backup power system at airports. Airports typically use several generators of varying sizes for different backup power applications; for example, Concord Regional Airport in North Carolina employs three backup power generators installed at strategic locations in the airport.[107] The three generators include: a 250 kW diesel generator set with a 405 gallon fuel tank and automatic transfer switch serves the main 18,000 square foot terminal building, which includes a concourse for arriving and departing passengers, an operations center, and offices. The generator holds enough fuel to run for more than 20 hours at full load, if necessary. A second on-site generator, a 100 kW diesel genset, provides backup power for the airport's instrument landing system, navigational equipment, and runway lights. A third unit, a 45 kW liquid propane gas-fueled genset, provides standby power for the airport's fuel farm.
- *Uninterruptible Power Supplies (UPS)* – UPS systems are generally associated with telecommunications equipment, computer systems, and other facilities such as airport landing systems and air traffic control systems, where even brief commercial power interruptions could cause injuries or fatalities, serious business disruption, or data loss.
- *Gas Turbine Power Plants* – Single gas turbine power generating plants are operated at some airports to improve regional electrical reliability and provide backup power for the airport in the event of a prolonged regional outage. One airport (San Francisco) issued a memorandum of understanding (MOU) with the Public Utilities Commission to site a single gas turbine power generating plant with a 48 MW capacity on airport property.[108] The plant would be activated in the event of a state-wide grid outage, providing backup power to the airport. Because the plant's 48 MW capacity is in excess of the airport's peak hour demands, the plant will also be able to serve communities surrounding the airport.
- Solar Energy – Some airports use solar energy. For example, FedEx announced plans in 2005 to build a 904 kW solar power array to provide electricity for its hub at Oakland International Airport. The solar panels, covering the roof of the company's two buildings at the airport, are expected to produce almost enough electricity to run FedEx's Oakland hub. The FedEx solar array will provide approximately 80% of the peak load demand for the shipping company's Oakland operations.[109]

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[107] Generac Power Systems, Inc. 2002. Generaction: Information for Specifying Engineers. Volume 2, Issue 2. Available at http://www.generac.com/PublicPDFs/Generaction_Vol2_Issue2.pdf [Accessed October 2006].
[108] San Francisco Airport Commission. 2004. Minutes. Available at http://www.flysfo.com/about/organization/pdf/minutes/M050404.pdf [Accessed July 2006].
[109] Sharp Electronics Corporation. 2004. FedEx to Build California's Largest Corporate Solar Power System on FedEx Facility in Oakland. Available at http://solar.sharpusa.com/files/sol_dow_Fedex_PR101804.pdf [Accessed October 2006].

MARKET SIZE

The market for backup power in the airline sector is difficult to determine. Table a-2 presents current data on the number of airfields nationwide.

Table a-2. Number of Businesses in the Airports, Flying Fields, and Services Industry (4581).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)
4581-0000	Airports, flying fields, and services	1,513	35,344	6,258.6
4581-0100	Hangars and other aircraft storage facilities	104	1,187	45.5
4581-0101	Aircraft storage at airports	69	575	26.3
4581-0102	Airport hangar rental	94	960	77.8
4581-0103	Hangar operation	76	2,217	67
4581-0200	Aircraft maintenance and repair services	1,450	26,297	3,755.8
4581-0201	Aircraft cleaning and janitorial service	271	6,974	2,387.2
4581-0202	Aircraft servicing and repairing	1,369	30,416	2,620.7
4581-0203	Aircraft upholstery repair	41	381	33.5
4581-0300	Airports and flying fields	48	1,215	36.9
4581-0301	Airport	1,653	28,213	5,727.3
4581-0302	Flying field, except those maintained by clubs	14	68	8.7
4581-0303	Military flying field	22	305	5
4581-9901	Air freight handling at airports	205	5,988	1,055.2
4581-9902	Airport control tower operation, except government	53	2,582	46.6
4581-9903	Airport leasing, if operating airport	32	512	80.1
4581-9904	Airport terminal services	216	10,099	958.4
4581-9905	Airfreight loading and unloading services	54	597	65.7
4581-9906	Fixed base operator	47	879	108.2
	Total	**7,331**	**154,809**	**23,364.6**

Note: Sales figures are in millions. Source: www.zapdata.com, accessed October 2006.

A survey conducted by the Clear Airport Partnership for the DOE in 2003 assessed the energy consumption of 10 airports.[110] Information from these reports was used to estimate a total electricity use of nearly 8 billion kW hours per year at large- and medium-hub airports (Table a-3). However, the percentage of airports' total electricity consumption that is allocated to the generation of backup power is unclear.

[110] Clean Airport Partnership, Inc. 2003. 10 Airport Survey: Energy Use, Programs and Policies for Terminal Buildings. Report to the U.S. Department of Energy, May 16, 2003. Available at http://www.cleanairports.com/reports/cap10airportsurvey.pdf [Accessed October 4, 2006].

Table a-3. Electricity Use at Large- and Medium-hub Airports (1999).[111]

1999 Energy Use	Electricity Use
Large Hubs (69)	
▪ Average kW hours/year	• 85,539,918 kW hours/year
▪ Total kW hours/year	• 5,902,254,341 kW hours/year
Medium Hubs (48)	
▪ Average kW hours/year	• 43,345,075 kW hours/year
▪ Total kW hours/year	• 2,080,563,587 kW hours/year
Combined kW hours/year	**7,982,817,942 kW hours/year**

Note: The U.S. Department of Transportation's Bureau of Transportation Statistics 1999 report, "Airport Activity Statistics of Certificated Air Carriers" indicates that there are 69 large hubs, 48 medium hubs, 73 small hubs, and 604 non-hub airports in the U.S.[112]

MARKET TRENDS

There is growing international interest in reducing the use of petroleum fuels and the production of carbon emissions at airports through operational measures and new technologies including fuel cells.[113] The potential utility of fuel cells for backup power in airport/aviation applications has been considered primarily for communications equipment at control towers. A number of organizations, including the DOE and DoD, have supported fuel cell demonstration projects for various applications in the airport sector. A sampling of these projects is presented below:[114]

- **Albany Airport**, *Albany, New York:* Demonstration of Plug Power Inc.'s prototype GenCore began in July 2003, and was replaced by the GenCore 5T in February 2004. This fuel cell system served as the primary backup source for Verizon's remote terminal housing telecommunications equipment. Upon completion of the project, the project partner, Verizon, purchased several GenCore 5T systems, siting one at Albany Airport. Natural gas was used to supply hydrogen fuel.[115]
- **Keflavick Airport,** *Keflavick, Iceland:* A 5 kW PEM fuel cell (Plug Power Gencore) has been installed for telecommunication backup power at the Leifur Eríksson Air Terminal at Keflavik International Airport.[116]

MARKET SEGMENT ANALYSIS

To identify the market opportunities for direct PEM fuel cells for backup power applications at airports, 42 airports were contacted and five responses were received. Three brief interviews were also conducted with U.S.-based international airports. One respondent represented a small airport, and four respondents represented medium-sized airports. Respondents indicated a variety of applications that require backup power, including:

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[111] Clean Airport Partnership, Inc. 2003. 10 Airport Survey: Energy Use, Programs and Policies for Terminal Buildings. Report to the U.S. Department of Energy, May 16, 2003. Available at http://www.cleanairports.com/reports/cap10airportsurvey.pdf [Accessed October 4, 2006].

[112] The U.S. Department of Transportation, Bureau of Transportation Statistics. 1999. Airport Activity Statistics of Certificated Air Carriers. Available at http://www.bts.gov/publications/airport_activity_statistics_of_certificated_air_carriers/ [Accessed October 4, 2006].

[113] Bayer, J. 2002. Fuel Cell Airport/Aviation Challenges and Opportunities. Presented at: Aviation Operation Measures for Fuel and Emissions Reduction Workshop, November 5-6, 2002. Available at http://www.icao.int/icao/en/env/workshop/ottawa_2002/judith_bayer.pdf [Accessed October 2006].

[114] Note: DoD has been particularly active in sponsoring fuel cell demonstration projects at air force bases. Additional examples of projects can be seen at: http://dodfuelcell.cecer.army.mil/res/site_list.php4 [Accessed October 2006].

[115] Fuel Cells 2000. 2005. Worldwide Fuel Cell Installations. Available at http://www.fuelcells.org/info/charts/FCInstallationChart.pdf [Last updated October 2005; accessed October 2006].

[116] U.S. Army Corps of Engineers. 2006. DoD Fuel Cell ERDC/CERL Projects. Available at http://dodfuelcell.cecer.army.mil/res/site_list.php4 [Accessed October 2006].

- Airfield lighting
- Security gates and other security systems
- Code-required lighting and functions in buildings
- Terminals
- Elevators
- Sewage pumps
- Ticket counters
- Parking structures
- Fueling station
- Towers
- Building lighting, building power
- Communications center power
- Domestic water
- Aircraft operations
- Fire departments
- Wastewater treatment plants
- Fire system supply pump houses
- Electrical distribution substations
- Additional lighting in public areas
- Baggage systems
- Boarding bridges
- Fuel farms
- Gas pumps
- Life safety systems
- Emergency lights
- Server networking

Three respondents stated that no backup power applications were less important than others. One reported that life safety equipment was most important, while another indicated that airfield lighting, communications center power, and security were the most important. One interviewee noted that critical computer systems, control rooms, and emergency lighting are critical. A second indicated that a backup system is currently being designed for an incident command center.

The small airport respondent estimated that three power outages had occurred in the last 12 months; these lasted less than 1 second but were very disruptive. Of the medium-sized airports, one respondent indicated that no outages had occurred in the past year, one estimated that six momentary partial outages had occurred (lasting less than 1 second up to 60 seconds), one reported eight outages (lasting 5 minutes to 1 hour), and another reported 10 outages (lasting 3 to 5 minutes, 5 minutes to 1 hour, and 1 to 4 hours). Respondents reported that the impact of these outages varied from somewhat disruptive to very disruptive. As expected, the longer the outage, the greater the disruption. All five respondents indicated that power outages could result in security breaches. Four stated that loss of lives and implementation of emergency management plans were possible consequences. Three respondents indicated that disruptions standard airport operations could result, and one stated that disruptions in movement of passengers and cargo might occur. Other possible consequences identified included loss of fire suppression capability and flight delays.

All respondents reported using UPS systems and generators for backup power. One interviewee also reported using solar power. All but one respondent also reported using batteries. Sizes of UPS systems ranged from less than 1 kW to 150 kW, while generators ranged from 35 kW to over 1,500 kW. The small airport reported utilizing three 1,500 kW diesel generators, one 1,000 kW diesel generator, two 600 kW diesel generators, and various smaller sized units depending on the system (e.g., two 120 kW UPS systems and other variously sized UPS systems). The medium-sized airports reported using a variety of systems, as shown in Table a-4.

Table a-4. Backup Power Systems Used at Four Medium-sized Airports.

	Airport 1	Airport 2	Airport 3	Airport 4
Diesel Generators	25, varying sizes: • < 5 kW: 10 • 50 - 100 kW: 5	17, ranging from 60 kW to 2 MW	13, ranging from 150 kW to 750 kW	For each of 6 facilities, sizes ranging from 250 kW to 650 kW

	• 200 - 400 kW: 5 • 900 - 1200 kW: 5			
UPS Units	20, varying sizes: • 15 kW: 7 • 35 kW: 3 • 40 kW: 4 • 75 kW: 6	3, ranging from 40 kVA to 150 kVA	1, 45 kVA UPS	Systems ranging from 0.5 kW to 60 kW for critical applications (security, baggage, life support)
Batteries		Several small battery banks for controlling switchgear	Batteries for phone systems and for each security control panel	
Feeders				6 feeders from the local utility – 2 for each primary facility

Respondents indicated that reliability, startup time, and good experience were the most important characteristics of their backup power systems. The next most important factor was emissions, followed by ease of use and fuel availability. The least important factors, although still rated as relatively important, were capital cost and lifetime of unit.

In general, all respondents reported that their current backup power systems were fairly good. However, the following concerns were identified: difficult to use, emissions, age of systems, storage tanks and battery charge cannot support an extended outage, high capital cost, and space issues. On average, respondents rated the performance of their current backup power systems on a scale of 1 to 7 with 7 being very good and 1 being not good as follows:[117] fuel availability (6); startup time (6); lifetime (5); reliability (5); operation and maintenance (5); ease of use (5); capital cost (5); annual operating cost (5); and emissions (3).

Two of the five respondents cited an increased need for backup power in 3 years, two did not anticipate additional backup power needs, and one expected a need for further backup in 5 years. Three respondents had considered alternative fuel sources. One respondent had considered installing additional feeders from a secondary electric utility substation which is fed from an independent source, other than the primary substation. Another had considered using gasoline generators to generate electricity. One interviewee had heard of fuel cells but did not think the return on investment would be sufficient motivation to invest in new technology. Only one of the respondents had heard of PEM fuel cells. One respondent had considered fuel cells but cited a number of barriers, including: large footprint (space requirements), insufficient power size, high cost, and unproven performance. The respondent had no concerns with using hydrogen as a fuel. According to this respondent, factors that would drive a decision to purchase PEM fuel cells are: cost of not having electricity, or having a power failure; energy efficiency of PEM fuel cells as compared to alternatives; environmental concerns; availability of government incentives; track record of others using PEM fuel cells; sufficient power capacity; and space requirements. Two respondents indicated that capital purchase decisions are made based on initial capital cost, payback period, and return on investment. Other considerations include annual operating costs, load requirements, need, and lifecycle cost. Four respondents stated that government incentives are considered in making purchasing decisions. Some respondents reported that the process for

[117] On a scale of 1 to 7, with 7 being very good and 1 being not very good.

making capital purchasing decisions involves presenting recommendations to senior staff; others reported that development committees make purchasing decisions.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

Characteristics of fuel cells desired by airports include: large kW capacity, modular design, production of reliable, high-quality power, minimal noise, low emissions, high efficiency, capability for continuous operations, and ability for flexible siting. Secondary research did not generate a significant amount of information on the viability of PEM fuel cells in backup power applications at airfields except for backup of communications equipment at terminals and radio control towers. Primary research among the airports contacted also indicated a lack of interest in the near-term adoption of fuel-cell technology for backup power. Airports contacted for primary research noted a growing need for backup power, but added concerns that fuel cells were an expensive technology and not sufficiently tested.

Currently PEM fuel cells are limited to small power sizes and as a result may be suitable only for some backup power applications such as ticketing counters, emergency lighting and alarm systems, and communications equipment. It is anticipated that current technologies like UPS systems will meet user requirements for small critical distributed applications, while technologies such as turbines and solar power may emerge to meet larger backup power needs for facilities and terminals. Potential near-term niche applications for PEM fuel cells in this market segment are communications equipment at airport control towers and terminals. However, there are also a number of other barriers to the adoption of PEM fuel cells by airports for these applications. Lack of reliability data for application of PEM fuel cells at airports could deter users from adopting fuel cell technology. Furthermore, as capital purchase decisions are based on initial capital cost and the availability of government incentives, early adoption may be limited in this market segment.

RESEARCH SUMMARY:
AMUSEMENT PARKS

MARKET SEGMENT DESCRIPTION

This market segment encompasses establishments of the type known as amusement parks, kiddie parks, piers, and theme parks which may group together and operate a number of attractions, such as mechanical rides, amusement devices, refreshment stands, and picnic grounds. This analysis considers the potential for PEM fuel cells for backup power at amusement parks. Table b-1 identifies the SIC and NAICS codes associated with this market segment.

Table b-1. SIC and NAICS Codes for Amusement Parks.

2-Digit SIC Code	79 – Amusement and recreation services
4-Digit SIC Code	7996 – Amusement parks
NAICS Code	713110 – Amusement and theme parks

Amusement parks aim to make guests feel safe and secure. Safety and accident records are public knowledge; a safety incident will have an asymmetrical impact on public trust. Therefore, safety, and the perception of safety, are primary concerns at amusement parks. The August 2003 blackouts impacted a number of amusements parks in the Northeastern United States and eastern Canada. During this power outage at Cedar Point Amusement Park in Sandusky, Ohio, park employees had to help guests walk down the steps of a 200-foot-tall rollercoaster that had stopped on the lift hill due to the blackout.[118]

Large theme parks utilize redundant feeds for built-in reliability and often have their own dedicated medium- or high-voltage substations and distribute power themselves.[119] Emergency backup power is often provided to ensure safety on high-risk attractions, such as roller-coasters. Power is often provided only to specific applications in order to minimize cost while delivering benefit to the most critical applications. Parks will use backup power for functions other than safety. For instance, "four-dimensional" theaters use UPS systems to coordinate the technologies for audio, visual, and sensory input, which are difficult to re-synchronize following a power outage.[120]

A number of technologies, including UPS systems, are being used for backup power. Photovoltaic systems are being used to provide alternative energy sources. For instance, a 50 kW photovoltaic system provides primary power for a Ferris wheel at Pacific Park on the Santa Monica Pier. The system provides 71,000 kWh, which is more than sufficient to power the wheel, and excess energy is used to reduce the park's overall electric consumption.[121]
There are no federal safety standards that require backup power on rides and other park services; amusement park rides and water slides are exempt from federal safety oversight. Saferparks, a

[118] Wikimedia Foundation, Inc. 2006. Northeast Blackout of 2003. Available at http://en.wikipedia.org/wiki/2003_North_America_blackout#Ohio.2C_USA [Accessed June 2006].
[119] Horwitz, B. 2002. The Big Thrill. Consulting-Specifying Engineer (September 1, 2002). Available at http://www.syska.com/Media/news/article.asp?Articles.ART_ID=133 [Accessed June 2006].
[120] Horwitz, B. 2002. The Big Thrill. Consulting-Specifying Engineer (September 1, 2002). Available at http://www.syska.com/Media/news/article.asp?Articles.ART_ID=133 [Accessed June 2006].
[121] Valentine, M. 1999. Fun With the Sun. The American Society of Mechanical Engineers. Available at http://www.memagazine.org/backissues/membersonly/february99/departments/input_output/input_out.html [Accessed June 2006].

consumers' organization for safer park rides, reports that amusement rides in the United States are regulated through a diverse patchwork of federal, state, and local laws, riddled with holes and special exemptions. Some amusement rides are subject to safety regulation at the state or local level. Carnival rides, go-karts, and inflatables are regulated under the Consumer Product Safety Act. Consumer protection laws vary widely from state to state, ride type to ride type, and venue to venue.[122]

MARKET SIZE

The U.S. has more than 600 amusement parks and traditional attractions. In 2005, 335 million people visited these venues and enjoyed more than 1.5 billion rides, generating $11.2 billion in revenues in 2005. Attendance and revenues at America's approximately 600 parks and attractions have increased nearly every year since 1990.[123] There are 22 amusement and theme park companies in the U.S. (NAICS Code 713110).[124] The top ten companies, by sales, are listed in Table b-2.

Table b-2. Top Ten U.S. Amusement and Theme Park Companies, by Sales.

Company Name	Location	Sales ($)
The Walt Disney Company	Burbank, CA	31,944.0
Sony Corporation of America	New York, NY	22,330.9
Anheuser- Busch Companies, Inc.	St. Louis, MO	15,035.7
NBC Universal, Inc.	New York, NY	14,689.0
Walt Disney Parks and Resorts, LLC	Lake Buena Vista, FL	9,023.0
Six Flags, Inc.	New York, NY	1,089.7
Cedar Fair, L.P.	Sandusky, OH	568.7
Coinstar, Inc.	Bellevue, WA	459.7
Hershey Entertainment & Resorts Company	Hershey, PA	220.4
Great Wolf Resorts, Inc.	Madison, WI	139.4

Sales figures are in millions. Source: Hoover's, Inc. 2006. Available at www.Hoovers.com. Accessed July 2006.

MARKET TRENDS

As noted above the amusement park industry is growing. It is also changing in nature, as rides and attractions require increased energy to power flashing lights, special effects, motors, and backup systems. As more and more cities adopt energy conservation regulations, increased energy-efficiency standards may eventually be applied to parks.[125] This acts as a driver for the adoption of more energy-efficient uses of sources of backup power.

A number of amusement parks have exhibited an interest in environmental stewardship; this could also imply a related interest in the use of energy sources which have lower environmental impact, such as fuel cells. Park environmental programs include Disney's "Environmentality™", which addresses water and energy conservation, the promotion of wildlife and habitat conservation, education, support of research and technology, accountability and evaluation, and waste minimization. However, at present, no fuel cell activity was found for this market.

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122 Saferparks. 2006. Safety Regulation. Available at http://www.saferparks.org/regulation/ [Accessed June 2006].
123 International Association of Amusement Parks and Attractions (IAAPA). 2006. Amusement Industry Statistics. Available at http://www.iaapa.org/fastfacts.asp#indstats [Accessed June 2006].
124 Hoover's Incorporated. 2006. Theme Parks Fact Sheet. Available at www.Hoovers.com [Accessed June 2006].
125 Horwitz, B. 2002. The Big Thrill. Consulting-Specifying Engineer (September 1, 2002). Available at http://www.syska.com/Media/news/article.asp?Articles.ART_ID=133 [Accessed June 2006].

MARKET SEGMENT ANALYSIS

Sixteen amusement parks were contacted to further determine requirements for backup power and the potential for application of fuel cells. One interview was conducted, but no complete responses from amusement park representatives were received.

The one interview respondent reported that the amusement park currently uses diesel, gas, and natural gas generators to provide on-site backup power and maintains agreements with third-party providers to supplement on-site generation capabilities with portable generators. The company has not considered the use of fuel cell technology in its amusement parks. The respondent stated that the company has no plans for major additions to existing on-site backup generation capability, but there may be small projects that replace existing equipment and add new equipment as an integral part of larger capital projects.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

Limited primary and secondary information was available to determine the potential for PEM fuel cells in this market segment. No specific drivers for adoption of alternative technologies could be determined in this market segment. Numerous parks are presently adopting solar power and other alternative power sources to support their growing energy requirements. Since the growth rate of amusement parks is low, it is likely that PEM fuel cells will have to compete in the same market space as newly adopted alternatives like solar power and wind-power. No information on the application of fuel cells at amusement parks could be located.

It is likely that the "green" image offered by PEM fuel cells may offer an incentive for amusement parks wanting to promote environmental stewardship. As safety features on rides and attractions are often hidden to maintain the guest experience, the small space requirements of PEM fuel cells might offer another advantage to using fuel cells as a source of backup power for amusement parks.[126] Additionally, as PEM fuel cells are scalable, the technology could be sized appropriately to meet a park's expanding power needs. However, the lack of demonstration projects in this sector, and the lack of response to surveys, may indicate that users in this sector are not prepared to pursue PEM fuel cell technology at this time. Furthermore limited secondary information on current and future backup power requirements suggests that the amusement park market is not an attractive market opportunity for PEM fuel cells in the near-term.

[126] Horwitz, B. 2002. The Big Thrill. Consulting-Specifying Engineer (September 1, 2002). Available at http://www.syska.com/Media/news/article.asp?Articles.ART_ID=133 [Accessed June 2006].

RESEARCH SUMMARY:
CASINOS

MARKET SEGMENT DESCRIPTION

The U.S. casino industry consists of land-based commercial casinos, riverboat casinos, tribal-run casinos, racetrack casinos, and card rooms. The casino industry includes land-based casinos both with and without lodging, as well as racetracks, riverboats, and dockside casinos. Commercial gaming (permitted in 11 states) and Indian casino operations (in 28 states) are subsets of the casino industry. This analysis considers the potential for direct hydrogen PEM fuel cells for casino backup power. Table c-1 identifies the SIC and NAICS codes associated with this market segment.

Table c-1. SIC and NAICS Codes for the Casino Industry.

2-Digit SIC Code	70 – Hotels, rooming houses, camps, and other lodging places
4-Digit SIC Code	7011 – Hotels and motels
8-Digit SIC Code	7011-0301 – Casino hotels
NAICS Code	721120 – Casino hotels

Casinos have been compared to hotels, one of the greatest energy users in the commercial sector, in light of the large amounts of energy that they consume. Energy costs in the lodging industry average nearly $2 per square foot per year, and the hotel industry spends about $500 per room per year for fuel and electricity.[127] However, casinos have an even greater need for energy and backup power than standard hotels because, in addition to the guest rooms, casinos have gaming floors, restaurants, bars, spa facilities, retail stores, event centers for concerts and conference exhibitions, night clubs, theaters, amusement park rides, health clubs, and other entertainment facilities. A key trend in the casino resort segment, "entertainment convergence" refers to casinos and resorts broadening the appeal of their facilities to attract more people and provide a variety of attractions that will entice guests to lengthen their stay.[128] The addition of these multiple uses and components increases the size of facilities and creates a correspondingly larger but also more diverse energy load.

Concerns about power reliability are a priority within this market sector due to the potential significant financial loss of gaming revenues. For instance, the power outage that lasted nearly 4 days in April, 2004 at the Bellagio in Las Vegas was estimated to have cost the company up to $3 million per day in revenues and $750,000 to $1 million daily in net operating income in addition to the equipment and overtime labor for repairs.[129]

An article on standby power plants in Las Vegas notes that, although emergency power systems typically are thought of as crucial for public health and safety, for casinos in Las Vegas, keeping power running nonstop to slot machines and other gaming operations is considered just as

[127] Fedrizzi, R. and J. Rogers. 2002. Energy Efficiency Opportunities: The Lodging Industry. Available at http://files.harc.edu/Sites/GulfCoastCHP/MarketAssessments/EnergyEfficiencyOpportunitiesLodging.pdf [Accessed July 2006].
[128] Fedrizzi, R. and J. Rogers. 2002. Energy Efficiency Opportunities: The Lodging Industry. Available at http://files.harc.edu/Sites/GulfCoastCHP/MarketAssessments/EnergyEfficiencyOpportunitiesLodging.pdf [Accessed July 2006].
[129] Findarticles™. 2006. Bellagio blackout doesn't dim Las Vegas' boomtown luster; Blau back with Wynn. Available at http://www.findarticles.com/p/articles/mi_m3190/is_17_38/ai_n6013745 [Accessed July 2006].

critical.[130] Applications for backup power at casinos include: emergency lighting and alarm systems, lights, surveillance cameras, heating and ventilation systems (i.e. air conditioning in Las Vegas), and some games.[131] In addition to the social and economic impacts, there are safety issues associated with losing power at a casino. Loss of power and public panic in a crowded area such as a casino can lead to a fire hazard. Interviews with fire officials indicate that backup power and redundant systems are desirable in order to prevent emergencies.[132]

Casinos produce a significant amount of electricity onsite and often use the grid as backup. Casinos typically use CHP systems to meet the electricity as well as hot and cold water requirements.[133] Casinos use a mixture of natural gas and diesel generators, CHP systems, UPS units, and other technologies to provide additional and backup power.

Examples of backup power operations in casinos include:

- Tulalip Tribes Casino: The casino's 2 MW generator provides sufficient power to run all of the electronic games and 90% of the casino lights. A second generator is planned to function as a source of backup power.[134]
- Casino Morongo: This casino in Banning, California installed a cogeneration plant to protect the new facility from rolling blackouts and other impacts from heavy usage in other parts of the state. The casino experiences low-voltage outages on a regular basis. The peak electrical load for the 28-story hotel tower, casino, and spa complex was estimated at 4.62 MW; the minimum electrical load was estimated at 3 MW, with an average load of 3.62 MW; and the new cooling system must have chilled water capacity of 3,600 tons with a 2,400-ton peak load. Allowing for 15% future load growth, the casino complex was estimated to need at least 5.3 MW. Furthermore, the facility required a minimum addition of 6 MW of diesel-fired generation to back up the gas-fired generators.[135]

MARKET SIZE

In 2005, there were an estimated 969 U.S. establishments in the casino industry, employing over 266,920 individuals. Total annual sales in this industry were reported at $52,520.102 million.[136] The breakdown by casino market and associated revenue for the 10 U.S. casino markets is shown in Table c-2.

The casino industry has been growing steadily. Total commercial casino revenues increased by approximately $15 billion (110%) over the 10-year period from 1994 to 2004. Total gaming

[130] O'Malley, P.G. 2004. Standby Power Plants Make Sure the Lights Stay On in Las Vegas. Distributed Energy, the Journal for Onsite Power Solutions (May/June). Available at http://www.distributedenergy.com/de_0405_standby.html [Accessed July 2006].
[131] O'Malley, P.G. 2004. Standby Power Plants Make Sure the Lights Stay On in Las Vegas. Distributed Energy, the Journal for Onsite Power Solutions (May/June). Available at http://www.distributedenergy.com/de_0405_standby.html [Accessed July 2006].
[132] O'Malley, P.G. 2004. Standby Power Plants Make Sure the Lights Stay On in Las Vegas. Distributed Energy, the Journal for Onsite Power Solutions (May/June). Available at http://www.distributedenergy.com/de_0405_standby.html [Accessed July 2006].
[133] EPA. 2006. Combined Heat and Power Partnership. Available at http://www.epa.gov/chp/project_resources/hotels.htm [Accessed July 2006].
[134] Wolcott, J. 2003. Casino is 'high tech' facility, says engineer. Snohomish County Business Journal (May). Available at http://www.snohomishcountybusinessjournal.com/archive/tulalip03/hightech-tulalip03.htm [Accessed July 2006].
[135] Corum, L. 2005. Betting on Power at Casino Morongo. Distributed Energy, the Journal for Onsite Power Solutions (November/December). Available at http://www.forester.net/de_0511_betting.html [Accessed July 2006].
[136] Dun and Bradstreet. 2006. Zapdata industry report. Available at www.zapdata.com [Last updated May 2006; accessed June 2006].

revenues grew by $38.8 billion (97%) over the same period.[137] In 1988, Congress passed the Indian Gaming Regulatory Act, affirming tribal gaming as a legitimate tool for reservation development and tribal self-sufficiency. Today, nearly half (224) of the nation's 562 federally recognized tribes operate 354 gaming operations. Numbers of operations are increasing steadily.[138] Today, commercial casinos represent the largest share of gross gambling revenue (GGR) at $30.59 billion (39%).

Table c-2. Top 20 U.S. Casino Markets by Annual Revenue (2005).[139]

Casino Market	2005 Annual Gross Revenues
Las Vegas Strip	$6.031 billion
Atlantic City, NJ	$5.018 billion
Chicagoland, IN/IL	$2.441 billion
Detroit, MI	$1.229 billion
Tunica/Lula, MS	$1.187 billion
Connecticut	$982.65 million
St. Louis, MO/IL	$959.60 million
Reno/Sparks, NV	$920.22 million
Boulder Strip, NV	$885.99 million
Shreveport, LA	$814.23 million

MARKET TRENDS

For casinos, fire codes in a number of cities, including Las Vegas, mandate that critical fire and life safety functions must be up and running within 10 seconds of any power loss. In some complexes, additional regulations, such as the International Building Code and the national electrical requirements, also apply. The minimal amount of backup power is not specified in building and fire codes; however, regulations are designed to allow for safe evacuation of a building. Additional backup capacity is used to provide power for non-critical functions in case of an emergency.[140]

As noted above, a number of technologies are being used for backup power in casinos. Several projects whereby casinos have installed wind turbine operations may indicate an increased focus on green power.[141,142] This trend has been primarily seen in Indian casinos, although one commercial casino has also invested in green power.[143] To date, only one casino has installed fuel cell technology for backup power. The Mohegan Sun Casino in Connecticut installed a fuel cell to provide backup power for the Mohegan Energy, Environment, Economics, and Education

[137] American Gaming Association, Christiansen Capital Advisors LLC. 2006. Gaming Revenue: 10-Year Trends. Available at http://www.americangaming.org/industry/factsheets/statistics_detail.cfv?id=8 [Accessed August 2006].
[138] National Indian Gaming Association. 2006. Indian Gaming Facts. Available at http://www.indiangaming.org/library/indian-gaming-facts/index.shtml [Accessed December 13, 2006].
[139] The Innovation Group (TIG). 2006. Casino Statistics in the U.S. Available at http://www.theinnovationgroup.net/map_us.asp [Accessed April 2006].
[140] O'Malley, P.G. 2004. Standby Power Plants Make Sure the Lights Stay On in Las Vegas. Distributed Energy, the Journal for Onsite Power Solutions (May/June). Available at http://www.distributedenergy.com/de_0405_standby.html [Accessed July 2006].
[141] DOE. 2006. Tribal Energy Program. Spirit Lake Sioux: Project Summary. Available at http://www.eere.energy.gov/tribalenergy/title26/sl_sioux_summary.html [Accessed December 13, 2006].
[142] Native Wind. 2006. Timeline. Available at http://www.nativewind.org/html/timeline.html [Accessed December 13, 2006].
[143] Marina Energy. 2006. Borgata Goes Green; Signs 20-Year Contract with Marina Energy for Renewable Energy. Available at http://www.sjindustries.com/marina/marinanews/marina6.htm [Accessed December 13, 2006].

Center, which is located within the casino.[144] The system is based on Distributed Energy's UNIGEN® Regenerative Fuel Cell System and includes a high pressure (over 1,000 psi), high-output hydrogen generator.[145] The Mohegan system was also made possible by a grant from the Connecticut Clean Energy Fund.[146]

Mohegan Sun also installed two 200 kW phosphoric acid fuel cell (PAFC) systems that run on natural gas in March 2002. The Mohegan Sun was a Buy Down Recipient of the FY1996-1997 DoD Climate Change Fuel Cell Program.[147] The PAFC is used to provide electricity to the casino's UPS systems. The system is also part of the tribe's educational program. The primary driver for the installation of this system was to offset carbon dioxide emissions from diesel generators.

MARKET SEGMENT ANALYSIS

To identify the market opportunities for direct PEM fuel cells in the casino market, 35 casinos and casino organizations were contacted. The response rate for this segment was very low. Only two interviews were conducted, and one complete survey response was received. The survey response will be summarized first, followed by the interview responses.

Survey Summary

The one complete response was received from a small casino that employs less than 500 staff. The respondent reported that backup power is a critical requirement for casino surveillance, although management information systems also have backup power. The casino uses 15 to 30 kW UPS systems for backup power; however, the respondent noted that no outages have occurred in the past 11 years. While the casino has not experienced any power outages, the respondent indicated that a power failure could potentially result in security breaches and implementation of emergency management plans. The longer a power outage, the more disruptive it is expected to be.

The respondent rated the performance of the casino's current backup power systems on various characteristics: start-up time, ease of use, and fuel availability were considered very good; reliability and lifetime of the unit were considered good; capital cost, operation and maintenance costs, annual operating cost, and emissions were rated fair. The respondent noted no overall concerns with the casino's current backup power systems. It was noted that reliability was overall the most important factor in selecting a backup power system, although various other factors were important as well. Reliability, capital cost, lifetime of the unit, annual operating cost, emissions, start-up time, and fuel availability were considered very important. Ease of use (including regular maintenance) and good experience with a system were considered important factors. The casino has considered diesel generators but not fuel cells as an alternative backup power source. The respondent had not heard of PEM fuel cells for backup power applications.

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144 Wallheimer, B. 2006. Connecticut leads national fuel cell effort. Norwich Bulletin (May 25, 2006). Available at http://www.boston.com/news/local/connecticut/articles/2006/05/25/connecticut_leads_national_fuel_cell_effort/ [Accessed December 13, 2006].

145 The Mohegan Tribe. 2004. Press Room. Available at http://www.mohegan.nsn.us/pressroom/ViewPressRelease.aspx?articleID=73 [Accessed June 2006].

146 The Mohegan Tribe. 2004. Press Room. Available at http://www.mohegan.nsn.us/pressroom/ViewPressRelease.aspx?articleID=73 [Accessed June 2006].

147 Fuel Cells 2000. 2005. Worldwide Fuel Cell Installations. Available at http://www.fuelcells.org/info/charts/FCInstallationChart.pdf [Accessed December 2006].

The respondent predicted a growing need for backup power in the casino sector. This may be due to growth in the casino industry. They noted that decisions for capital purchases are typically based on initial capital cost, payback period, and return on investment. Government incentives are also considered. The president of the company makes final decisions regarding the selection of backup power systems.

Interview Summary
One interviewee represented one of the largest casinos in world. The other also represented a large casino operation, with diverse properties. Both interviewees indicated that life safety systems, such as water pumps for sprinkler systems, ingress/egress lighting, emergency lighting, and emergency systems, were critical applications requiring backup power. Diesel generators were the primary source of backup power used by both interviewees. UPS systems were used for critical systems, but only for the 8 seconds or less that it takes for generator backup power to come online. One interviewee reported that UPS was also used to back up certain information technology (IT) equipment; UPS systems are distributed and sized to allow computer systems to shut down in an orderly manner, but UPS systems are not intended for prolonged use of equipment.

One interviewee reported that the size of backup power generation varies by property but is generally in the 1 to 3 MW range. The large casino also reported that each property is different in terms of the quantity of its fuel supply and how long it could last on backup power alone. In addition, the city, county, and state have requirements that apply to backup power for life safety systems.

The large casino interviewed reported experiencing no outages that lasted longer than 1 hour; as a result, outages were not a significant concern. However, the casino did report one past significant outage that was prolonged due to on-site equipment failure.

The large casino interviewed commented on the potential for PEM fuel cells to be used for backup power in casinos. The company is interested in new environmentally friendly operations and has begun a new Leadership in Energy and Environmental Design (LEED) project. However, the interviewee reported that they are satisfied with the existing backup power system and have not considered using PEM fuel cells.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS
The casino market appears to be a growing market with fairly large power requirements. Reliable backup power is a critical need for casinos. Despite the size and growth pattern of this industry, it is unlikely that PEM fuel cells will offer a unique value proposition in this market segment.

Most casinos have redundant power supplies in the form of additional power lines from the grid, large generators, and/or CHP units. As casinos are in the hospitality business, they also require an adequate supply of backup power to support both non-critical and critical functions. For critical functions, additional backup power is provided through UPS systems.

It appears that the power size (~ 1 to 5 MW) and lack of CHP efficiency of the commercial and pre-commercial PEM fuel cells is a limiting factor for application in this market segment. Additionally, many casinos have made large investments in generator and other backup power sources as well as cogeneration plants; to replace these investments, PEM fuel cells would need to be able to meet casinos' size requirements and offer a significant advantage over existing backup power sources. PEM fuel cells will likely be a better fit for backup power applications currently supported by UPS systems, including computers, emergency lighting, and sprinkler systems. However, UPS systems are sized to provide just enough run-time to cover operations until other sources of backup take over.

There are limited drivers for the adoption of PEM fuel cells in this market segment; no regulatory drivers were identified. There are few environmental efforts in the casino industry, which could serve as a market driver for the adoption of alternative energy technologies. However, here PEM fuel cells would have to compete with other sources of green power. Furthermore, the three casinos contributing to this analysis reported satisfaction with their current backup power systems and had not considered adopting PEM fuel cell technology.

Limited interest in alternatives for smaller backup applications, lack of technology fit for larger application, and lack of drivers suggests that this market segment is not an attractive market opportunity for PEM fuel cells in the near term.

RESEARCH SUMMARY:
CHEMICAL MANUFACTURING

MARKET SEGMENT DESCRIPTION

The chemical manufacturing industry is highly energy intensive and has many sub-sectors offering a variety of opportunities for the application of PEM fuel cells for backup power and grid parallel power. This analysis focuses on sub-sectors within the chemical industry that: a) use large quantities of hydrogen in their process, and/or b) produce hydrogen as a manufacturing by-product. It was assumed that because these sub-sectors currently maintain an on-site infrastructure for use and/or storage of hydrogen in industrial processes, they would be more likely to adopt hydrogen as a fuel source.

Several sub-sectors of the chemical industry met these criteria. The largest-scale processes using hydrogen in the chemical manufacturing industry include: ammonia synthesis, methanol synthesis, and other petrochemical and inorganic synthesis processes for hydrogenation.[148] Sub-sectors of the chemical industry that produce significant quantities of by-product hydrogen include chlor-alkali and sodium chlorate manufacturing.[149] Additional secondary research,[150] as well as recent fuel cell development activities in the chemical industry (e.g., see Dow Chemical and Nedstack demonstrations),[151] suggest that the most likely near-term opportunities for fuel cells within the chemical industry would focus on industries that meet the second criterion above, i.e., industries producing by-product hydrogen that could be used in fuel cell applications.

This analysis focuses on chlor-alkali and sodium chlorate manufacturing, as these industries have large-scale processes, are highly energy intensive, and produce hydrogen as a manufacturing by-product. Table d-1 provides the SIC and NAICS codes for these subsectors.

Table d-1. SIC and NAICS Codes for the Chlor-alkali and Sodium Chlorate Subsectors.

2-Digit SIC Code	28 – Chemicals and allied products
4- Digit SIC Codes	2812 – Alkalies and chlorine manufacturing 2819 – Industrial inorganic chemicals (includes sodium chlorate as well as other inorganic chemicals not otherwise specified)
NAICS Codes	325181 – Alkalies and chlorine manufacturing 325188 – All other basic inorganic chemical manufacturing (includes sodium chlorate as well as other inorganic chemicals not otherwise specified)

Most facilities in the chlor-alkali and sodium chlorate segments typically produce all or a portion of their own power via co-generation. Hydrogen generated during processes is typically used as fuel in the cogeneration units, sold as hydrogen gas, or vented. Backup power for facilities is provided at two levels: 1) an operation level backup, which includes all of the motors and the

[148] Manitoba Energy Development Initiative, Department of Energy, Science and Technology. 2003. Preliminary Hydrogen Opportunities Report. Available at http://www.gov.mb.ca/est/energy/hydrogen/hydrogen.pdf [Accessed September 2006].
[149] Manitoba Energy Development Initiative, Department of Energy, Science and Technology. 2003. Preliminary Hydrogen Opportunities Report. Available at http://www.gov.mb.ca/est/energy/hydrogen/hydrogen.pdf [Accessed September 2006].
[150] Frost & Sullivan. 2003. North American Stationary Fuel Cells Markets. ABI Research, #A426-14. Available at http://www.frost.com/prod/servlet/report-homepage.pag?repid=A426-01-00-00-00&ctxht=FcmCtx1&ctxhl=FcmCtx2&ctxixpLink=FcmCtx3&ctxixpLabel=FcmCtx4 [Accessed September 2006].
[151] NedStack Fuel Cell Technology B.V. 2006. PEM Power Plant: Stationary Power Generation with By-Product Hydrogen. Presented at Fuel Cell 2006, Raleigh-Durham, North Carolina. Available at http://www.fuelcell-magazine.com/PresentationsPDF/Nedstack06.pdf [Accessed September 2006].

large equipment, 2) and a control systems level backup, which includes support for critical systems to facilitate shut-down of manufacturing processes in a controlled fashion. Currently, most facilities have several levels of redundancy to support operations level backup to avoid even small levels of disruption. For example, the Dow facility in Midland, Texas, has two-level redundancy for their operations level backup. Redundancy is provided by power from the grid from two distinct sources, a nuclear plant and a gas-fired coal burning power plant. For control systems backup, a combination of battery backups, UPS systems, and generators are used.

Chlor-Alkali Market Segment Description

Chlorine and alkalies are typically co-produced via the electrolysis of salt water; they are some of the most important inorganic chemical commodities, and used in many diversified applications. They are primarily sold to industry for uses such as the production of pulp and paper, soaps and detergents, fibers and plastics, petrochemicals, fertilizers, solvents, disinfection chemicals and others. The most common chlor-alkali chemicals are chlorine (Cl_2) and sodium hydroxide (NaOH, caustic soda); other chemicals also include potassium carbonate, potassium hydroxide (caustic potash), sodium bicarbonate, and sodium carbonate (i.e., soda ash). Chlorine and chlorine derivative products comprise 45% of the country's gross domestic product.[152]

Typically, the chlor-alkali production process involves a brine system, an electrolysis system (electrolytic cell), a chlorine liquefaction process, caustic evaporation, and (if desired) hydrochloric acid synthesis. The chlorine and hydrogen produced in the electrochemical membrane process leave the cells at a pressure slightly higher than atmospheric pressure. After cooling in heat exchangers, chlorine undergoes additional processing in the form of chlorine liquefaction. The excess hydrogen is often further processed (along with chlorine) to generate hydrochloric acid, burned as fuel within the process (e.g., power for the caustic soda concentration), compressed and sold as a product, or vented to the atmosphere.

Sodium Chlorate Market Segment Description

Sodium chlorate is an oxidizing agent, used primarily to generate chlorine dioxide for bleaching paper pulp.[153] In the pulp and paper bleaching process, chlorine dioxide is a substitute for traditional chlorine, which has largely been phased out of the pulp and paper industry in the U.S. and elsewhere due to environmental concerns. In 2004, the application of sodium chlorate to chlorine dioxide production represented 99% of total consumption in North America.[154] Other minor applications of sodium chlorate include use as an herbicide, the production of other chlorates (potassium chlorate and sodium chlorite), and several other smaller applications.

Production of sodium chlorate is a multistage reaction where the electrode reaction products (chlorine and hydroxide) form hypochlorite, which then chemically is converted to sodium chlorate, and then purified by crystallization. The main part of this reaction, including production of hydrogen, takes place in the electrolytic cell.

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[152] ERCO Worldwide. 2006. Chlorine. Available at http://www.ercoworldwide.com/products_chlorine.asp [Accessed September 2006].

[153] Cellchem. 2002. Sodium Chlorate. Available at http://www.cellchem.com/docs/products-services/sodium_chlorate.htm [Accessed September 2006].

[154] Schlag, S. and K. Yagi. 2005. Chemical Economics Handbook Program - CEH Report: Sodium Chlorate. Available at http://www.sriconsulting.com/CEH/Public/Reports/732.1000/ [Accessed September 2006].

MARKET SIZE

The U.S. chemical industry is a nearly $1.67 trillion global enterprise; representing over 27% of total production. The U.S. is the largest chemical producer in the world, with over 9,500 chemical firms, which operate more than 13,000 facilities. [155] The chemical industry is also the second largest consumer of energy in manufacturing; production of organic chemicals accounts for the highest energy requirements of all chemical sectors. The U.S. chemical industry consumed about 6.1 quads (quadrillion Btu, or 1015 Btu) of energy in 1998.[156] The largest use of fuel energy is for heat and power (35%) in the boilers used to produce steam to drive chemical reactions and perform product separation and finishing operations. Heating and cooling processes account for an additional 25% of energy use.

Chlor-Alkali Market Size

As of July 2005, more than 500 companies produced chlor-alkali at over 650 sites worldwide.[157] In 2004, world production of caustic soda was estimated to be 51 million tons, and chlorine about 48 million tons.[158] About half of all plants are located in Asia, but many of these are relatively small. In the U.S., there are an estimated 206 establishments, employing over 13,290 people, with average annual sales of $13,667.3 million (Table d-2). Major chlor-alkali manufacturers in the U.S. include Dow, Formosa, Occidental Chemicals (OxyChem, and including Basic Chemicals Co.), Olin, Oxyvinyls, and PPG.[159,160]

Table d-2. Number of Businesses in the Alkalies and Chlorine Industry (2812).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)
2812-0000	Alkalies and chlorine	76	5,956	1,833.1
2812-0100	Alkalies	5	214	7.4
2812-0101	Caustic potash, potassium hydroxide	5	150	87
2812-0102	Caustic soda, sodium hydroxide	5	602	1.1
2812-0103	Potassium carbonate	2	6	1
2812-0104	Sal soda (washing soda), sodium carbonate (hydrated)	6	15	2
2812-0105	Soda ash, sodium carbonate (anhydrous)	9	1,818	2,934.1
2812-0106	Sodium bicarbonate	34	811	43.6
2812-9901	Chlorine, compressed or liquefied	64	3,718	8,758
	Total	**206**	**13,290**	**13,667.3**

Sales figures are in millions. Source: www.zapdata.com; accessed June 2006.

Sodium Chlorate Market Size

The three major developed regions of the world represent 87% of the total global sodium chlorate capacity - North America accounted for 63%, Western Europe for 23%, and Japan for 1

[155] Energy Information Administration - EIA - Official Energy Statistics from the U.S. Government. 2006. Chemicals Industry Analysis Brief. Available at http://www.eia.doe.gov/emeu/mecs/iab98/chemicals/index.html [Accessed September 29, 2006].
[156] Energy Information Administration - EIA - Official Energy Statistics from the U.S. Government. 2006. Chemicals Industry Analysis Brief. Available at http://www.eia.doe.gov/emeu/mecs/iab98/chemicals/index.html [Accessed September 29, 2006].
[157] Schlag, S. and K. Yagi. 2005. Chemical Economics Handbook Program - CEH Report: Sodium Chlorate. Available at http://www.sriconsulting.com/CEH/Public/Reports/732.1000/ [Accessed September 2006].
[158] Srinivasan, V., P. Arora, and P. Ramadass. 2006. Report on the Electrolytic Industries for the Year 2004. J. Electrochem. Soc. 153(4): K1-K14.
[159] The Innovation Group (TIG). 2004. Chemical Profile for Sodium Chlorate. Available at http://www.the-innovation-group.com/ChemProfiles/Sodium%20Chlorate.htm [Accessed June 2006].
[160] SRI Consulting. 2006. Directory of Chemical Producers. Available at http://www.sriconsulting.com/DCP [Accessed June 2006].

%.[161] Over 75% of world sodium chlorate capacity is operated by four companies - Eka Chemicals (a subsidiary of Akzo Nobel), Erco Worldwide, Kemira, and Canexus.[162] In the U.S., seven out of ten sodium chlorate facilities were operating in 2006 with a combined capacity of 772,000 short tons per year (100% $NaClO_3$ basis).[163] Top U.S. producers include Erco Worldwide, Eka Chemicals, FINNCHEM USA, and Kerr-McGee (Tronox, Inc). Increasing energy costs in recent years prompted several sodium chlorate plants in the U.S. to be idled, including ATOFINA's plant in Portland , Oregon, the Georgia Gulf plant at Plaquemine, Louisiana, and a Canexus plant in Taft, Louisiana (replaced by a lower-cost expansion of their sodium chlorate plant in Brandon, Manitoba, which is the world's largest sodium chlorate facility and has one of the lowest cost structures in the industry.)[164]

In the U.S. sodium chlorate industry, a subset of the industrial inorganic chemicals sector, there are approximately 1,200 establishments, employing 47,873 people, and generating annual sales of $25,048 million (Table d-3).

Table d-3. Selected Businesses in the Industrial Inorganic Chemicals Sector (2819).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)
2819-0000	Industrial inorganic chemicals, not elsewhere classified	1,020	43,709	22,759.9
2819-0102	Alkali metals: sodium, potassium	1	8	N/A
2819-0400	Sodium & potassium compounds	6	160	824.2
2819-0406	Sodium compounds or salts, inorg., ex. refined sod. chloride	6	201	697.3
2819-0407	Sodium hyposulfite, sodium hydrosulfite	4	57	5.4
2819-0408	Sodium silicate, water glass	2	31	N/A
2819-0409	Sodium sulfate, glauber's salt, salt cake	2	33	4.8
2819-0410	Sodium sulfides	1	700	N/A
2819-1001	Bleaching powder, lime bleaching compounds	5	29	1.2
2819-9902	Chemicals, high purity: refined from technical grade	111	2,213	632.6
2819-9903	Chemicals, reagent grade: refined from technical grade	42	732	122.2
	Total	**1,200**	**47,873**	**25,048**

Sales figures are in millions. Source: www.zapdata.com; accessed June 2006.

In a 2001 report by the Lawrence Berkeley National Laboratory, the chlor-alkali industry (SIC Code 2812) and the inorganic chemical industry (SIC Code 2819, which includes sodium chlorate manufacturing) were identified as two of 43 industries likely to be most susceptible to economic harm from disruptions in electricity supply.[165] To indicate the magnitude of each industry's susceptibility, Table d-4 shows total purchased electricity along with energy intensity for SIC Codes 2812 and 2819.

[161] Schlag, S. and K. Yagi. 2005. Chemical Economics Handbook Program - CEH Report: Sodium Chlorate. Available at http://www.sriconsulting.com/CEH/Public/Reports/732.1000/ [Accessed September 2006].
[162] Srinivasan, V., P. Arora, and P. Ramadass. 2006. Report on the Electrolytic Industries for the Year 2004. J. Electrochem. Soc. 153(4): K1-K14.
[163] SRI Consulting. 2006. Directory of Chemical Producers. Available at http://www.sriconsulting.com/DCP [Accessed June 2006].
[164] The Innovation Group (TIG). 2004. Chemical Profile for Sodium Chlorate. Available at http://www.the-innovation-group.com/ChemProfiles/Sodium%20Chlorate.htm [Accessed June 2006].
[165] Eto, J., J. Koomey, B. Lehman, N. Martin, E. Mills, C. Webber, and E. Worrell. 2001. Scoping Study on Trends in the Economic Value of Electricity Reliability to the U.S. Economy. LBNL-47911. Available at http://eetd.lbl.gov/emills/PUBS/PDF/LBNL_47911.pdf [Accessed December 13, 2006].

Table d-4. Purchased Electricity and Electricity Intensity for SIC Codes 2812 and 2819.[166]

SIC Code	Description	Purchased Electricity (Twh)	Electricity Intensity (Kwh/ 000 – Us$ Value Added)
2812	Alkalies and Chlorine	13.8	8,552.3
2819	Industrial inorganic chemicals	36.1	3,465.9

MARKET TRENDS

In addition to demanding constant power to ensure continual operations, the chemical industry requires backup power to ensure reliability of operation and safe shutdown in the event of a power interruption. According to site security guidelines for the U.S. chemical industry developed by industry groups, it is recommended that chemical facilities secure utilities including communications (telephone and computer), water, sewer, and gas from a security standpoint as well as a safety and operations standpoint. These guidelines note that key resources such as control centers, rack rooms, computer servers, and telecommunications equipment may warrant a backup power source, such as a generator.[167] The EPA has also conducted outreach to the chemical industry regarding prevention of chemical accidents caused by electric power outages, and recommends the installation of backup power supplies and services if there is critical equipment that needs to operate to ensure the safe state of the process or work area. EPA suggests that services such as emergency pumps, lighting, alarms, and instruments and controls, particularly computer operated distributed control systems (DCS), may need to operate using backup power generators or UPS systems. According to EPA, steam or diesel driven pumps should be considered to maintain critical flows while a process is shutting down or otherwise dealing with a power outage.[168]

About one-fifth of electricity used by the chemical industry as a whole is produced on-site, primarily by means of cogeneration.[169] The chemical industry is one of the largest cogenerators in the manufacturing sector, second only to pulp and paper mills. The chemical industry has steadily increased its cogeneration capacity. The chlor-alkali and sodium chlorate sectors of chemical manufacturing also produce significant quantities of by-product hydrogen, which is often used on-site as fuel for power generation, offsetting requirements and costs for natural gas. Excess quantities of by-product hydrogen are also sometimes sold (e.g., to gas purification/distribution companies or petroleum refineries), or vented as a waste. More recently, several companies have investigated the use of by-product hydrogen in PEM fuel cells installed on-site.

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[166] Eto, J., J. Koomey, B. Lehman, N. Martin, E. Mills, C. Webber, and E. Worrell. 2001. Scoping Study on Trends in the Economic Value of Electricity Reliability to the U.S. Economy. LBNL-47911. Available at http://eetd.lbl.gov/emills/PUBS/PDF/LBNL_47911.pdf [Accessed December 13, 2006].

[167] American Chemistry Council, Chlorine Institute, Inc., Synthetic Organic Chemical Manufacturers Association. 2001. Site Security Guidelines for the U.S. Chemical Industry. Available at http://www.chlorineinstitute.org/Files/PDFs/SecurityguidanceACC1.pdf [Accessed September 2006].

[168] EPA. 2001. Chemical Accidents from Electric Power Outages. EPA-550-F-01-010. Available at http://yosemite.epa.gov/oswer/Ceppoweb.nsf/vwResourcesByFilename/power.pdf/$File/power.pdf [Accessed September 2006].

[169] Energy Information Administration - EIA - Official Energy Statistics from the U.S. Government. 2006. Chemicals Industry Analysis Brief. Available at http://www.eia.doe.gov/emeu/mecs/iab98/chemicals/index.html [Accessed September 2006].

Chlor-Alkali Market Trends

The demand for both caustic and chlorine saw a general decline in recent years.[170] This was largely attributed to high natural gas prices, which eliminated the cost advantages of U.S. chlor-alkali manufacturers. For example, Pioneer, which has been idling its 225,000 ton per year plant in Tacoma, Washington, since March 2002, announced that it will not resume production because it was unable to obtain reasonably priced power.[171] Other reasons for reductions in the demand for chlorine cited in the literature include: decreases in the use of chlorine in the pulp and paper industry as a bleaching agent (in response to environmental pressures to reduce chlorinated organic substances in wastewater effluents),[172] and decreases during the 1998 to 2002 period in the overall demand growth for chlorine in the manufacture of organic chemicals (largely due to process changes in ethylene dichloride/polyvinyl chloride, or EDC/PVC, manufacture).[173]

In 2004, however, there was a reversal of this declining trend with a strong demand for chlorine (largely due to China's enormous growth), a general rebounding of the global economy, and a lack of new capacity.[174] Growth for chlorine and caustic through 2006 (the forecast period) were projected to be 2 and 1.4 % per annum, respectively.[175,176] In a recent electrochemical industry update,[177] construction of new facilities in the northwest U.S. was reported (Equapac is building a 75,000 ton per year plant in Longview, WA; Ineos Chlor and Equa-Chlor have started work on a 80,000 ton per year plant in Longview, WA, using Ineos Membrane electrolyze technology).

Sodium Chlorate Market Trends

An analysis by the Innovation Group (TIG)[178] notes that in the U.S. through 2001, sodium chlorate market trends were largely driven by the 1998 U.S. EPA ruling that addressed concerns about chlorine dioxins and organic halides in pulp mill effluents; the ruling stated that chlorine could be replaced with chlorine dioxide, which is produced from sodium chlorate. Until April 2001, the deadline for implementing the substitute technology, the conversion to elemental chlorine free (ECF) bleaching was a key demand driver in increasing the sodium chlorate market. The mature markets and competitive situation of North America in the paper and pulp industries indicated that consumption of sodium chlorate is expected to be relatively stagnant from 2004 to 2009.[179]

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170 Srinivasan, V., P. Arora, and P. Ramadass. 2006. Report on the Electrolytic Industries for the Year 2004. J. Electrochem. Soc. 153(4): K1-K14.

171 Srinivasan, V., P. Arora, and P. Ramadass. 2006. Report on the Electrolytic Industries for the Year 2004. J. Electrochem. Soc. 153(4): K1-K14.

172 Schlag, S. and K. Yagi. 2005. Chemical Economics Handbook Program - CEH Report: Sodium Chlorate. Available at http://www.sriconsulting.com/CEH/Public/Reports/732.1000/ [Accessed September 2006].

173 The Innovation Group (TIG). 2003. Chemical Profile for Chlorine. Available at http://www.the-innovation-group.com/ChemProfiles/Chlorine.htm [Accessed June 2006].

174 Srinivasan, V., P. Arora, and P. Ramadass. 2006. Report on the Electrolytic Industries for the Year 2004. J. Electrochem. Soc. 153(4): K1-K14.

175 The Innovation Group (TIG). 2003. Chemical Profile for Chlorine. Available at http://www.the-innovation-group.com/ChemProfiles/Chlorine.htm [Accessed June 2006].

176 The Innovation Group (TIG). 2003. Chemical Profile for Caustic Soda. Available at http://www.the-innovation-group.com/ChemProfiles/Caustic%20Soda.htm [Accessed June 2006].

177 Srinivasan, V., P. Arora, and P. Ramadass. 2006. Report on the Electrolytic Industries for the Year 2004. J. Electrochem. Soc. 153(4): K1-K14.

178 The Innovation Group (TIG). 2004. Chemical Profile for Sodium Chlorate. Available at http://www.the-innovation-group.com/ChemProfiles/Sodium%20Chlorate.htm [Accessed June 2006].

179 Schlag, S. and K. Yagi. 2005. Chemical Economics Handbook Program - CEH Report: Sodium Chlorate. Available at http://www.sriconsulting.com/CEH/Public/Reports/732.1000/ [Accessed September 2006].

Fuel Cell Activity in the Chlor-Alkali Market Segment

As mentioned previously, hydrogen gas produced as a by-product of the chlor-alkali electrolytic cell process is often captured and burned as a fuel in on-site power stations (e.g., power for caustic soda drying/concentration). Excess hydrogen can also be used in the manufacture of hydrochloric acid, or compressed and sold as a product. Several projects have investigated potential applications of by-product hydrogen from the chlor-alkali industry to PEM fuel cell power generation, although none identified were specifically cited as being for backup power applications. Projects are being pursued both in the U.S. and internationally.

Dow Chemical and General Motors are currently collaborating on the installation of a large-scale PEM system to produce electricity (up to 35 MW), using hydrogen produced as a by-product from chlorine production at a Freeport, Texas, facility.[180] The Freeport facility of Dow Chemical is one of the largest chlor-alkali sites in the country, producing about 3,240 thousand short tons of chlorine per year (using diaphragm and membrane processes) and 3,564 thousand short tons of sodium hydroxide per year.[181] The project will provide valuable information regarding the viability of fuel cells in process industries using by-product hydrogen.

NedStack Fuel Cell Technology (Arnhem, The Netherlands) is working with Azko Nobel chlor-alkali facilities at Delfzijl and Rotterdam Harbor in the Netherlands in a project supported by the Dutch Ministry of Economic Affairs through its Energy Innovation Program. The project involves construction of a 20 MW PEM fuel cell power plant with a system life of 175,000 hours, and cost of € 250/kW and 0.01 €/kWh.[182] To date, a durable stack has been developed and tested in a pilot plant, a 100 kW module has been tested and is ready for installation in the Akzo Nobel plant in Delfzijl, and it is expected that 1 MW systems will be available in early 2007.

In 2005, Nuvera Fuel Cells, Inc., an international developer of multi-fuel reforming and PEM fuel cell technology, and UHDENORA SpA, a world developer and supplier of electrochemical plants for the production of chlorine and caustic soda, announced that they will develop a modular fuel cell system designed to increase the eco-efficiency of chlor-alkali plants.[183] According to the agreement, Nuvera and UHDENORA will engage in a three-phase joint initiative aimed at developing a rugged base-load system capable of reducing a plant's power consumption by approximately 20%.[184] The new system will be capable of converting the available hydrogen into DC current, delivering high-efficiency electricity. The system is also being designed to integrate safely and reliably with chlor-alkali electrolyzers, avoiding any interference with ongoing plant production. The companies began initial testing of the fuel cell system in May 2005.

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[180] The Dow Chemical Company. 2006. Fuel Cell Program. Available at: http://www.dow.com/commitments/studies/fuelcell/ and http://www.eere.energy.gov/industry/bestpractices/energymatters/articles.cfm/article_id=233 [Accessed September 2006].

[181] SRI Consulting. 2006. Directory of Chemical Producers. Available at http://www.sriconsulting.com/DCP [Accessed June 2006].

[182] NedStack Fuel Cell Technology B.V. 2006. PEM Power Plant: Stationary Power Generation with By-Product Hydrogen. Presented at Fuel Cell 2006, Raleigh-Durham, North Carolina. Available at http://www.fuelcell-magazine.com/PresentationsPDF/Nedstack06.pdf [Accessed September 2006].

[183] PR Newswire Europe Ltd. 2005. UHDENORA, Nuvera to Develop Advanced Energy Saving Systems for the Electrochemical Industry. Available at http://www.prnewswire.co.uk/cgi/news/release?id=139540 [Accessed September 2006].

[184] Cross, J., A. Maggiore, and G. Sibilia. 2005. PEM Technology for the Chlor-Alkali Industry. Presented at the 2005 Fuel Cell Seminar, November 18, 2005. Available at http://www.fuelcellseminar.com/pdf/2005/Friday-Nov18/Cross_James_573.PDF [Accessed September 2006].

Fuel Cell Activity in the Sodium Chlorate Market Segment
In Vancouver, Canada, a fuel cell demonstration project[185,186] is currently being conducted involving the use of waste by-product hydrogen from a sodium chlorate manufacturing plant. Although the electricity generated by PEM fuel cells in this project will not be directly used by the sodium chlorate facility itself, the project demonstrates that sodium chlorate plants have the potential to provide an important supply of low-cost hydrogen to support the commercialization of fuel cell and other hydrogen-based technologies.

MARKET SEGMENT ANALYSIS

Overall, nine organizations from the chlor-alkali industry and seven organizations from the sodium chlorate industry were contacted. As several of the contacts were unable to provide all the detail requested by the survey, interviews were conducted to gather information on general trends and potential for application of PEM fuel cells in their market segment. Nine organizations participated in the interview. In addition, two organizations that participated in the interview also provided completed surveys. Seven representatives declined to answer the survey or participate in the interview, and indicated that there were no feasible applications for fuel cells at their facilities. Information received from the surveys will be summarized first, followed by the information received from the interviews.

Survey Summary

Of the two organizations that responded to the survey, one was large (> 3,000 employees) and one was small (< 500 employees). Both responses were received from the energy managers at these facilities. According to these respondents, functions that required backup power included computers, instruments, vibration monitors, fire eyes, motors, and drives with process facilities as well as emergency equipment needed to shut down the manufacturing plant.

Of the two respondents, one respondent had one to two partial outages in the past year, which lasted less than 60 seconds, while the other had three outages that lasted 4 hours or longer. Both respondents indicated that any level of disruption without backup power was very disruptive. Primary potential impacts of power outages were disruptions in production, disruptions in distribution, and implementation of emergency management plans. Both users indicated that they used a combination of batteries, UPS systems, and generators to provide backup power to their facilities. One respondent reported that backup power was being supplied by one 1 MW diesel generator, multiple UPS systems for control system backup, and battery backups for main switchgear control power.

In selecting a backup power system, respondents stated that reliability, start-up time, fuel availability, emissions, and good experience with this type of system in the past were very important factors. Capital cost was less of a concern to one respondent than the aforementioned factors. Both respondents were very satisfied with the current performance of their backup systems. Respondents were particularly satisfied with reliability, fuel availability, and other

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185 Natural Resources Canada. 2006. New Project Supports Advancement of Hydrogen Fuel Cell Technology for Lift Trucks - Hydrogenics, GM and NMHG to Strengthen Collaboration. Available at http://www.nrcan.gc.ca/es/etb/ctfca/NewsReleases_e.html [Accessed September 2006].

186 Government of Canada Newsroom. 2005. Minister Emerson Announces $12.2 Million Contribution to Advance Hydrogen Economy. Available at http://news.gc.ca/cfmx/view/en/index.jsp?articleid=174809&keyword=IWHUP&keyword=IWHUP& [Accessed September 2006].

critical performance categories. One respondent was dissatisfied with the capital costs of his 1 MW generator system. Neither of the respondents had considered alternatives for their smaller backup needs. Both respondents had heard of PEM fuel cells for backup power. However, neither had considered them as a viable alterative because of their high capital costs. One respondent indicated they would purchase PEM fuel cells based on a track record of others using them and the energy efficiency of PEM fuel cells as compared to other competing alternatives. Both respondents indicated that government incentives were taken into consideration when making purchasing decisions. Respondents indicated that capital purchase decisions are made on the basis of return on investment. One respondent indicated that they also considered capital costs and payback period.

Interview Summary

Representatives in the electrochemical industry (including chlor-alkali and sodium chlorate manufacturers) indicated that backup power needs are generally met in this sector. Interview participants indicated that technologies being used to meet backup power requirements include UPS systems (five facilities), batteries (five facilities), and/or diesel generators (four facilities). In two cases, interviewees indicated that the need for backup power was generally limited at their facilities due to a high level of power redundancy (e.g., self-sufficient power cogeneration on-site, plus grid backup).

Backup power for operational systems usually demands large amounts of energy and needs are typically met via multiple levels of power redundancy (e.g., multiple grid sources, co-generation). Backup power for control systems and other small critical applications are usually met via diesel generators, UPS or other battery systems. Another interviewee indicated that the power demands of most operations-level systems were likely beyond the capabilities of fuel cells, but that fuel cell technologies could be applied in some operations with smaller power draw (on the order of 20 kW) and small critical operations, such as control systems.

Regarding the durations and impacts of outages, one interviewee indicated that power outages were on the order of nanoseconds, and one indicated that power outages lasted 4 hours or longer. One interviewee indicated that no disruptive power outages had occurred at their facility due to a high level of power supply redundancy.

All interviewees responding in this area indicated that they were generally very satisfied with their current backup power technologies. No interviewees indicated specific concerns regarding their current backup power systems. Some interviewees reported testing fuel cells for supplemental power systems, but no interviewees had considered fuel cells for backup power applications.

Information was not provided by industry regarding potential opportunities for future procurement of new backup power systems. However, there were a number of concerns regarding the use of PEM fuel cells and of hydrogen in backup power applications. Regarding perceptions of PEM fuel cells as backup power and the use of hydrogen as a fuel source, interviewees indicated that by-product hydrogen is already commonly used as a fuel in the electrochemical industry. The majority (6 facilities) indicated that their facility generated a large portion of their process power through cogeneration; excess by-product hydrogen from the chlor-alkali process was cited in most of these cases (5 facilities) as being an important source of fuel for power cogeneration. Excess by-product hydrogen that was not used by facilities for power cogeneration (or that exceeded what was needed for power cogeneration at the facility) was also reported by interviewees to be sold to gas liquifiers/distributors (2 facilities); at one facility excess hydrogen was vented to the atmosphere. Three interviewees indicated that fuel cells using by-product hydrogen would only be feasible for generating supplemental power, unless hydrogen storage technologies were implemented for backup power.

Three interviewees indicated that they had considered and tested PEM fuel cells for converting excess process hydrogen into supplemental DC power for the process, but not for backup power uses. After testing, none of the facilities opted to install fuel cells due to lack of economic feasibility. The majority of interviewees (five facilities) indicated that they did not consider PEM fuel cells to be a cost effective option at this time due to high initial capital investment and the higher value that they currently receive for their by-product hydrogen (as a fuel source for on-site power cogeneration, or as a sold commodity). Two interviewees indicated that PEM fuel cells could possibly be more economically feasible at remote/isolated facilities with lack of access to grid power or that otherwise had stranded hydrogen due to market deficiencies. One interviewee indicated that PEM fuel cells had not been considered for critical power backup at this time because the reliability of fuel cell systems was unknown and they had proven technologies already in place.

Two interviewees cited the need for government (financial) incentives to drive the adoption of fuel cell technologies.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

Based on analysis of the chlor-alkali and sodium chlorate market segments, the chemical manufacturing sector is not an attractive near-term market opportunity for PEM fuel cells. Initial opportunities for PEM fuel cells in this market segment are likely to be grid parallel or grid independent applications utilizing the hydrogen available on-site for generating supplementary power for facility operation, and not backup power applications. Success in grid parallel and grid independent applications is likely, only if performance issues (increased power size, durability and efficiency) and capital costs can be addressed.

There are potential benefits of pursuing application of PEM fuel cells in this market sector; for instance, codes, standards, and procedures for handling hydrogen are better established than in residential or commercial applications. The potential to convert excess hydrogen into useful energy on-site is attractive, and (as demonstrated by the recent agreement between General Motors and Dow Chemical) there appears to be market interest in pursuing such an opportunity. However, primary research indicates that electrochemical companies already use excess hydrogen as fuel for steam/heat cogeneration or other process functions (e.g., dryers) in their manufacturing operations, and realize significant cost savings by doing so. The market also currently favors the sale of any excess by-product or waste hydrogen to gas liquefiers for purification and distribution or to petroleum refineries for use in the hydrocracking process; many such facilities are co-located to facilitate this arrangement. Conversations with representatives in the electrochemical industry indicated that use of by-product hydrogen in PEM fuel cell applications is, in general, not considered economically competitive at this time. In addition, present performance and cost characteristics of PEM fuel cells do not appear to meet user requirements.

For backup power applications, control systems backup is the best fit for PEM fuel cells. The chemical manufacturing segment presently uses UPS systems, batteries, and generators to provide backup for control systems. No apparent drivers for switching backup power sources at a control systems level were identified. Marketing research indicates that users in this segment are very satisfied with their present technologies. Since most facilities have redundant power sources, these backup systems often provide a second or even third level of protection, so there is limited interest in alternatives. Users select backup power systems based on various factors including capital costs, reliability, fuel availability, and a track record of others using them. Users in this segment are aware of PEM fuel cells for backup power; however, high capital costs and lack of reliability data are barriers to adoption.

Lack of technology fit, cost barriers, and other barriers, including low growth in the chlor-alkali market segment and stagnant growth in the sodium chlorate market segment, suggest that the chemical manufacturing segment does not offer compelling value for PEM fuel cells in the near term.

RESEARCH SUMMARY:
COMPUTER AND ELECTRONIC EQUIPMENT MANUFACTURERS

MARKET SEGMENT DESCRIPTION

The computer and electronics sector includes the manufacturing and distribution of a wide variety of electronic equipment, including computers and computer components, electronic storage devices, and other electrical components. Table e-1 identifies the SIC and NAICS classifications for the computer and electronics sectors.

Table e-1. SIC and NAICS Codes for Computer and Electronic Equipment Manufacturing.

2-Digit SIC Codes	35 – Industrial and commercial machinery and computer equipment
	36 – Electronic, electrical equipment and components, except computer equipment
4-Digit SIC Codes	3571 – Electronic computers
	3572 – Computer storage devices
	3575 – Computer terminals
	3577 – Computer peripheral equipment, not elsewhere classified (nec)
	3578 – Calculating and accounting equipment
	3579 – Office machines, nec
	3651 – Household audio and video equipment
	3661 – Telephone and telegraph apparatus
	3663 – Radio and television communications equipment
	3669 – Communications equipment, nec
	3671 – Electron tubes
	3672 – Printed circuit boards
	3674 – Semiconductors and related devices
	3675 – Electronic capacitors
	3676 – Electronic resistors
	3677 – Electronic coils and transformers
	3678 – Electronic connectors
	3679 – Electronic components, nec
NAICS Codes	333311 – Automatic vending machine manufacturing
	333313 – Office machinery manufacturing
	334111 – Electronic computer manufacturing
	334112 – Computer storage device manufacturing
	334113 – Computer terminal manufacturing
	334119 – Other computer peripheral equipment manufacturing
	334210 – Telephone apparatus manufacturing
	334220 – Radio and television broadcasting and wireless communications equipment manufacturing
	334290 – Other communications equipment manufacturing
	334310 – Audio and video equipment manufacturing
	334411 – Electron tube manufacturing
	334412 – Bare printed circuit board manufacturing
	334413 – Semiconductor and related device manufacturing
	334414 – Electronic capacitor manufacturing
	334415 – Electronic resistor manufacturing
	334416 – Electronic coil, transformer, and other inductor manufacturing
	334417 – Electronic connector manufacturing
	334418 – Printed circuit assembly (electronic assembly) manufacturing
	334613 – Magnetic and optical recording media manufacturing

The largest industry segments (by dollar volume) are the production of electronic computers and semiconductors. Electronic computers are machines that: store processing programs and data; are programmable; perform arithmetical computations; and are able to modify their own execution by logical decision during the processing run. Equipment that incorporates computers for functions such as measuring, displaying, or controlling process variables are classified with the end product (and not included here). The electronic computers segment includes electronic computers, computers (digital, analog, or hybrid), mainframe computers, minicomputers, and personal computers (microcomputers).

The computer and electronics sector includes establishments primarily engaged in manufacturing semiconductors and related solid-state devices. Important products of this business are semiconductor diodes and stacks, including rectifiers, integrated microcircuits (semiconductor networks), transistors, solar cells, and light sensing and emitting semiconductor (solid-state) devices.

Backup power is used in the manufacture of computers and electronics to prevent power outages and blackouts and also to prevent voltage dips and sags by supplying a constant flow of premium power. Manufacturing requires a constant flow of high quality power – voltage sags can negatively impact manufacturing operations as much as power outages.[187,188] The computer and electronics sector uses backup power for manufacturing equipment control systems, air compressors and ventilation systems, clean rooms, data centers, and R&D centers – equipment support and computer systems.

The two primary backup power technologies that are used in computer and electronic manufacturing are diesel generators and conventional UPS battery systems. Conventional UPS battery systems provide 90 to 94% efficiency. UPS units offer the benefit of speed in providing backup power; this is important when a typical outage lasts less than 0.1 second.[189] When the utility grid has a disturbance, UPS units can take as little as 2 to 4 milliseconds to recover, protecting manufacturing operations before damage is done. Other technologies being marketed to the manufacturing sectors include microturbines, flywheel power systems, and ultracapacitors.

MARKET SIZE

The computer industry (SIC Code 3571) includes an estimated 2,278 U.S. establishments and employs 90,762 people. Total annual sales in this industry are $196,557.41 million; average sales per establishment are $116.40 million. The semiconductor industry includes an estimated 2,706 U.S. establishments and employs 216,488 people. Total annual sales in this industry are $131,430.70 million; average sales per establishment are $67.50 million. Table e-2 illustrates the overall size of the computer and electronics industry.

[187] Deepak, D., R. Schneider, W. Brumsickle, D. Trungale, and T. Grant. 2002. Impact of Voltage Sag Correction in Critical Manufacturing Applications. Available at http://www.softswitch.com/docs/PQA%202002%20DySC.pdf [Accessed June 2006].
[188] Seymour, E., A. Pratt, R. Heckman, and D. Powell. 2004. Fabs Can Ride through Voltage Sags with Power-quality Targets. Solid State Technologies: International Magazine for Semiconductor Manufacturing. Available at www.advenergy.com/en/upload/File/Reprints/40340-144%20(Fabs%20can%20ride%20volt%20sags).pdf [Accessed June 2006].
[189] Sorkin, A. 2005. UPS: For When the Grid Goes Down. Distributed Energy, the Journal for Onsite Power Solutions. Available at http://www.distributedenergy.com/de_0511_ups.html [Accessed June 2006].

Table e-2. Number of Businesses in Various Computer and Electronic Equipment Manufacturing Sectors.[190]

SIC Code	SIC Description	Number of Businesses	Average Sales (Million $)	Total Sales (Million $)
3571	Electronic computers	2,278	116.4	196,557.4
3572	Computer storage devices	663	87.6	39,259
3575	Computer terminals	528	17	7,818.4
3577	Computer peripheral equipment, nec	2,363	45.5	86,622
3578	Calculating and accounting equipment	511	12.6	4,894.1
3579	Office machines, nec	618	22.7	9,382.1
3651	Household AV equipment	2,504	5.6	12,775
3661	Telephone and telegraph apparatus	1,610	35.1	38,428.9
3663	Radio and TV communications equipment	3,218	34	87,596.3
3669	Communications equipment, nec	1,436	11.3	13,005.7
3671	Electron tubes	125	7.1	728.2
3672	Printed circuit boards	1,716	31.8	46,205
3674	Semiconductors and related devices	2,706	67.5	131,430.7
3675	Electronic capacitors	154	26.6	3,109.5
3676	Electronic resistors	117	48.5	3,789.9
3677	Electronic coils and transformers	519	3.6	1,553.3
3678	Electronic connectors	455	64.9	20,953.8
3679	Electronic components, nec	4,395	4.9	18,768.4
	Total	**25,916**	**62.7**	**722,877.7**

In many cases, sellers (distributors and suppliers) of computers and electronics are not necessarily the manufacturers. Often, if a company retains management and operations of manufacturing, the manufacturing activities are located in Asia. China, Taiwan, and Singapore are among the common computers and electronics manufacturing countries. Key contract manufacturing companies include: Motorola, Sanmina SCI Corporation, Lenovo Group Limited, Solectron Corporation, Flextronics International Ltd, Jabil Circuit Inc, Celestica Inc., SYNNEX Corporation, and Kimball International Inc.

The rising cost of power is a concern among manufacturers. Due in part to rising power costs, Intel moved chipmaking operations from California to Ireland, New Mexico, and Arizona.[191] Some companies retain manufacturing operations in the U.S., but power costs are a driver for many businesses to move or outsource manufacturing overseas. Manufacturing services are often outsourced by companies such as HP and Compaq to contract manufacturers such as Sanmina, Jabil Circuit, and Lenovo. Larger computer and electronic companies who have manufacturing operations in the U.S. include: Apple Computer, Ariba, Advanced Micro Devices Inc., Cisco Systems, HP, Intel, Juniper Networks, Oracle Corporation, Sun Microsystems, and Texas Instruments.

Despite the U.S. trend toward outsourcing manufacturing operations to Asia, there is still some growth in domestic computer and electronic manufacturing. For example, in San Francisco, the electronic and computer manufacturing sector ballooned from a 6.1% share of Bay Area gross

[190] Dun and Bradstreet. Zapdata industry report. Available at www.zapdata.com [Accessed June 2006].
[191] Society of Manufacturing Engineers. 2001. Coping in California. Available at http://www.sme.org/cgi-bin/get-press.pl?&&20012443&GP&&SME& [Accessed June 2006].

domestic product (GDP) in 1994 to a 10.3% share in 2000 (in the middle of the dot-com bubble). It has since settled down to 6.9%.[192]

MARKET TRENDS

High-tech businesses are particularly vulnerable to power outages and blackouts due to the high cost of downtime and the need for an uninterrupted flow of high quality electricity in manufacturing (99.99999% reliability). Therefore, both power availability and power quality in electronics manufacturing have a significant effect on the quality and cost of electronic devices.

This has been cited in a number of manufacturing areas, including semiconductor manufacturing, PCB assembly, and system-level assembly. Due to the delicate manufacturing process, the semiconductor industry is particularly sensitive to power fluctuations. Power problems can cause large financial losses because of lost product and deferred production, costing the high-tech manufacturing sector anywhere from $30 billion to $119 billion every year.[193] Estimates suggest that the cost of downtime is approximately $0.5 million per hour in the electronics sector, and $1.3 million per hour in the information technology sector.[194] Power disturbances cost U.S. firms an estimated $30 billion annually in lost productivity and manufacturing processes. During the California energy crisis and blackouts in 2000, economists were projecting potential impacts of $75 million up to $100 million in Silicon Valley. One company noted that a 3-hr blackout cost $1 million per hour. In addition to loss of revenue and productivity, other consequences may include lost customers, decreased customer loyalty, non-compliance with regulatory requirements, legal implications, missing key audit requirements, loss of competitive advantage, and bad public image.

Some companies have been investigating small, modular energy generation and storage systems that can provide backup power during outages, hedge against energy price spikes, eliminate power quality problems, mitigate future emissions costs, and contribute to grid stability. There seems to be a growing market demand for smaller scale, fuel-flexible energy systems that can be deployed close to the point of use. A variety of products, including "Hybrid" and "SANUPS" units, are being developed that moderate voltage spikes and dips.

MGE UPS Systems, Inc. announced that MGE China is showcasing the first environmentally friendly fuel cell UPS in China for manufacturing and computer networking applications. The 3kVA UPS is powered by Ballard Power Systems' Nexa RM Series fuel cell modules and provides mission-critical process applications with extended run-time during power failures. This system has also been used in a project demonstrating the use of a fuel cell as a backup power source for an apartment building in New York.[195]

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[192] Bay Area Economic Forum. 2006. The Innovation Economy: Protecting the Talent Advantage. Available at http://www.bayeconfor.org/pdf/BAEP_February06web.pdf [Accessed June 2006].
[193] Electric Power Research Institute (EPRI). 1999. Electricity Technology Roadmap: 1999 Summary and Synthesis. Palo Alto, CA, EPRI.
[194] META Group, Inc. 2000. Quantifying Performance Loss: IT Performance Engineering and Measurement Strategies. Available at http://www.metagroup.com/us/displayArticle.do?oid=18750 [Accessed June 2006].
[195] MGE UPS Systems, Inc. 2004. MGE China Showcases Ballard® Fuel Cell Solution for Long Duration Backup Power – First Environmentally Friendly UPS in China to Provide Hours of Power Backup for Industrial and Networking Applications. Available at http://www.mgeups.com/news/pr/prus.htm?pr=71 [Accessed June 2006].

Environmental concerns are a driver for this industry to adopt alternative energy technologies. High-tech manufacturing may have interior emissions limitations due to building or manufacturing codes. Additionally, many manufacturing facilities are located in areas with emissions regulations that limit the use of diesel generators. For example, due to pollution caused by emergency diesel generators, these can be used a maximum of 200 hours per year in California. The Bay Area Air Quality Management District forbids turning on generators while the power is on. This ability to start generators only after the power goes off prohibits their use as an uninterrupted source of electricity.[196]

MARKET SEGMENT ANALYSIS

To identify the market opportunities for PEM fuel cells in the computer and electronics manufacturing industry, computer and electronics manufacturing and distribution firms were contacted: 47 organizations were contacted, and four complete survey responses were received. In addition, three brief interviews in lieu of responses to survey questions were conducted. Eleven organizations declined to answer, indicating that this information was confidential. Of these responses, three respondents were from small electronics manufacturing and distribution firms, while one respondent represented the semiconductor manufacturing division of a large computer and electronics company.

Respondents indicated that backup power was used for computer systems, emergency lighting, exhaust fans, life safety systems, and some manufacturing applications. The most critical applications requiring backup power were IT, manufacturing, exhaust fans, and life safety systems. Responses received from smaller manufacturers indicated a limited need for backup power, while larger manufacturers considered backup power to be more important. Two manufactures reported experiencing blackouts of < 60 seconds, of unknown frequency. Only one manufacturer knew the frequency at which power outages occurred but noted that this information was confidential, as any outage (or even a voltage sag) can cause manufacturing disruptions; the respondent indicated that outages would be very disruptive. Three of the four manufactures noted that blackouts of any duration (< 60 seconds to > 4 hours) would be disruptive to very disruptive. Two respondents indicated that, although they do not typically experience disruptions, they had experienced several in the last month. One indicated that, although exact information is confidential, such disruptions are rare. All respondents indicated that power outages could result in disruptions of production and/or distribution.

Three of the four respondents use UPS units to provide backup power; one of these uses batteries and generators as well. One respondent uses a natural gas generator. Sizes of backup units varied; one respondent uses UPS units of < 1 kW, while another uses units greater than 250 kW, with approximately 400 kW of UPS power/batteries per facility. Gas and diesel generators ranged from 35 to > 700 kW.

Respondents indicated that reliability was the most important factor in selecting a source for backup power. Two mentioned that fuel cost and availability were also important factors. Three of the four respondents indicated that the performance of their current backup system was very good. One did not respond but indicated that emissions from generators and maintenance on

[196] Bay Area Economic Forum. 2006. The Innovation Economy: Protecting the Talent Advantage. Available at http://www.bayeconfor.org/pdf/BAEP_February06web.pdf [Accessed June 2006].

UPS units were a concern. Of the respondents, three indicated that the reliability of current systems was good to very good, and that fuel availability and start up time were very good.

None of the respondents saw a growing need for backup power in this market, and one indicated that demand would continue for some time at its current rate.

One of the four respondents had considered alternatives to their current mode of operation. One larger manufacturing company had considered PEM fuel cells as a potential source of backup power. This respondent had no concerns with the use of hydrogen as a fuel; however, the respondent did not believe that PEM fuel cells could favorably compete with current alternatives due to high costs. The respondent indicated that dissatisfaction with the current mode of backup power, energy efficiency of PEM fuel cells, environmental concerns, availability of government incentives, and a positive track record of others using PEM fuel cells could be potential drivers for adoption. Their decision to purchase would be made by engineering representatives from different manufacturing sites, and would be based on return on investment. Other respondents from smaller companies made capital decisions based on other factors, including initial capital cost, payback period, and need.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

The opportunity for PEM fuel cells in this segment appears to be limited in the near-term. The computer and electronics manufacturing sector requires a consistent flow of high-quality power. The industry is extremely sensitive to blackouts and voltage sags, and there is a high cost associated with downtime. However, while the computer and electronics industries are large, many of the manufacturing functions are being outsourced overseas, and there does not appear to be a high growth rate of manufacturing operations in U.S. The potential fit for PEM fuel cells in this market segment is as backup power for specific computer systems, control systems, and emergency lighting in the near term. Facilities, however, require larger capacity backup technology than currently available PEM fuel cell units can supply. Limited information was gathered from surveys on the requirements for backup power in clean-rooms and manufacturing operations, as this information is considered confidential.

Environmental drivers are forcing manufacturing plants to consider alternatives to diesel generators. However, at this time, the size and durability of PEM fuel cells limit them from being considered as a suitable alternative. Manufacturers have introduced several products to address short outages and power quality problems. While users may be interested in protecting their networks from power quality problems, it does not appear that users are actively looking for alternatives to provide support for longer outages. Users seem very satisfied with their current backup power systems.

Marketing research did not identify a compelling value proposition for PEM fuel cells in this market segment. While no apparent barriers to PEM fuel cell adoption exist, it is likely that adoption will be driven by the reliability, quick start-up time, and capital and lifecycle costs of PEM fuel cells as compared to existing alternatives.

RESEARCH SUMMARY:
DATA CENTERS

MARKET SEGMENT DESCRIPTION

Nearly every medium-sized or larger company has some kind of data center that runs the applications that handle the core business and data necessary for the operation of the business. Data center services may be provided internally by an organization or bought from outside vendors. This market segment includes establishments primarily engaged in providing on-site management and operation of computer and data processing facilities on a contract or fee basis. These types of companies include data network operators, Internet and online services providers (e.g., web hosting services and co-location centers), and managed network services.

This analysis considers the potential for direct hydrogen PEM fuel cells for data center backup power. Table f-1 identifies the SIC and NAICS codes associated with this market segment.

Table f-1. Relevant SIC and NAICS Codes for Data Center Services.

2-Digit SIC Code	73 – Business services
4-Digit SIC Code	7376 – Computer facilities management services
NAICS Code	541513 – Computer facilities management services

A data center houses electronic equipment for the purpose of processing data for critical operations. Equipment housed in a data center typically includes critical computer systems and associated components as well as environmental controls (e.g., air conditioning, fire suppression), redundant/backup power supply, Internet and network connections, and security functions. Servers are the main form of equipment in a data center, often placed in racks of cabinets lined in single rows with corridors between them.

Data centers require reliable power for maximum network uptime. Backup power is a critical requirement of a data center in order to protect data and maximize uptime. Power loss, even for a few seconds, incurs high interruption costs for data centers and Internet service providers.[197] Power disruptions can result in data corruption, burned circuit boards, component damage, file corruption, and lost customers.[198] Studies suggest that U.S. industry interruption costs associated with system downtime average $1 million per hour.[199]

Backup power is typically provided by UPS and/or diesel generators. A Cisco Systems white paper recommends the following:[200]

- Multiple physically separate connections to public power grid substations
- Continuous power supply with backup UPS systems, with fuel (48 hours worth) for UPS-generators kept on the premises.

[197] Brown, A.S. 2003. Despite optimistic forecasts and steady progress in technology, widespread use of this alternative power source may still be more futuristic than realistic. necdigest™. Available at http://www.nfpa.org/itemDetail.asp?categoryID=561&itemID=18405&URL=Publications/necdigest/necdigest%20Magazine/necdigest®%20archives/Fall%202003/Fuel%20Cells&cookie%5Ftest=1 [Accessed July 2006].
[198] Pacific Northwest National Laboratory (PNNL). 2002. Electrical Power Interruption Cost Estimates for Individual Industries, Sectors, and U.S. Economy (PNNL-13797). Prepared for the U.S. Department of Energy under Contract DE-AC06-76RL01830.
[199] META Group, Inc. 2000. Quantifying Performance Loss: IT Performance Engineering and Measurement Strategies. Available at http://www.esolutionsgroup.ca/services/network_data.shtml [Accessed December 2006].
[200] Cisco Systems, Inc. 2004. White Paper Data Center: Best Practices for Security and Performance.

Traditional backup power sources for data centers include battery-based UPS systems and diesel generators. Secondary research indicates that these systems are typically large (1 to 2 MW) with an on-site fuel supply in case of extended outages (72 hours). Some data centers also have multiple power connections to the public grid for redundancy. For example, WestHost Inc., whose primary business is web hosting, has battery backup and 750 kV diesel generators with an underground fuel tank holding a 3 to 5 day supply of fuel to power its data center. Another web hosting service, AppSite, maintains a backup power system that includes two 2 MW generators, and 72 hours of backup fuel.

A number of other examples likewise indicate that data centers minimize the chance of power outage through backup systems designed with redundancy of power sources using diesel generators, battery-powered UPS, multiple grid power feeders, and a 72+ hour fuel supply.

MARKET SIZE

Larger companies may have several data centers, and large cities have data center buildings located in secure locations close to telecommunications services. Factors such as the rapid growth of the web, the increase in the use of networks to help geographically dispersed teams, and increasing server power have led to rapid growth in data centers and in their energy use.[201]

Potential fuel cell users in this market sector include hospitals and banks with large data center needs, as well as data center service providers like Sun Microsystems, Intel, Cisco, and others.

According to a survey of IT executives, companies are consolidating and centralizing data centers.[202] Data centers are being consolidated into a few central locations with increased capacity. More than half of all data centers are expected to expand or relocate by 2010.[203] As part of disaster recovery plans, companies are setting up secondary data centers. At the same time, companies are searching for ways to reduce their data center operating costs. These trends raise new issues for backup power.

The trend to centralize and consolidate has also caused an increased demand for servers (increasing at an average rate of 11% per year) and storage (increasing at a median rate of 22% per year), which brings greater demands for cooling in densely packed data centers.[204] As data centers increase capacity, heat output increases. Power and cooling are key issues of concern for data centers. The Green Grid, an association of IT professionals, has been formed to seek to lower the overall consumption of power in data centers around the globe.

Table f-2 provides market size statistics for SIC Code 7376, Computer Facilities Management Services.

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[201] Research News. 2006. Energy-Efficient Direct-Current-Powering Technology Reduces Energy Use in Data Centers By Up to 20 Percent. Available at http://www.lbl.gov/Science-Articles/Archive/EETD-DC-power.html [Accessed June 2006].
[202] Antonopoulos, A. M. 2006. The Four Main Data Center Trends. Network World. Available at http://www.networkworld.com/newsletters/datacenter/2006/0515datacenter1.html [Accessed June 2006].
[203] Data Center Knowledge. 2006. Five Predictions: Relocations and Outsourcing. Available at http://www.datacenterknowledge.com/archives/2006/03.html [Accessed June 2006].
[204] Mears, J. 2006. Consolidation and Growth – Trends in the New Data Center. Network World. Available at http://www.networkworld.com/weblogs/datacenter/012169.html [Accessed June 2006].

Table f-2. Market Size Statistics – Industry: Computer Facilities Management (SIC Code 7376).

Estimated Number of U.S. Establishments:	790
Number of People Employed in this Industry:	14,160
Total Annual Sales in this Industry:	$16,930.90 million
Average Number of Employees Per Establishment:	19
Average Sales Per Establishment:	$25.30 million

Source: www.zapdata.com, accessed June 2006.

MARKET TRENDS

Data communication applications worldwide spent an estimated $371.4 million on stationary lead-acid batteries in 2003, approximately 26% of the stationary lead-acid battery market. An annual growth rate of 9.3% is forecast through 2010, bringing estimated revenues from data communications' demand for lead-acid batteries to $693.2 million in 2010. The demand for stationary lead-acid batteries in the data center market segment is predicted to increase, threatening alternative competing backup power technologies (including UPS systems powered by fuel cells).[205]

However, there have been several fuel cell projects in this sector. In 2002, Chevron Energy Solutions installed a 200 kW phosphoric acid fuel cell (PAFC) at its ChevronTexaco data center in San Ramon, California.[206] The fuel cell, from UTC Power, supports critical data and retail transaction systems. It is designed to provide power to these critical systems without interruption in case of a power outage.[207]

Similar to the fuel cell installed at Chevron's San Ramon data center, a 200 kW PAFC from UTC Power supplies direct energy to a computer system center in Brazil. Likewise, a UTC Power 200 kW PAFC was installed in 1997 at a Hamilton Sundstrand data center in Connecticut. Three 200 kW PAFCs from UTC Power were installed in an office building in Fresno, California, in May 2004. The fuel cells provide power for computer server rooms, communications, building security, and other functions. In November 2000, two 200 kW PAFCs were installed at Ramapo College in Mahwah, New Jersey, to provide direct power and thermal energy to a dormitory and computer center.[208]

The primary driver for Chevron, in adopting a fuel cell at its San Ramon data center, was learning. They wanted to gain direct experience with stationary fuel cell technology and be able to evaluate the differences between fuel cells and generators and between fuel cells and UPS systems. Though not the case with Chevron, cost can be a factor in choosing a backup power source, but incentives (e.g., grants and rebates) could help make fuel cell projects cost competitive with other technologies.[209]

[205] Frost & Sullivan Inc. 2004. World Stationary Lead Acid Battery Markets.
[206] Research Reports International. 2004. Distributed Generation Case Studies, 3rd Edition.
[207] Fuel Cells 2000. 2005. Worldwide Fuel Cell Installations. Available at http://www.fuelcells.org/info/charts/FCInstallationChart.pdf [Last updated October 2005; accessed June 2006].
[208] Fuel Cells 2000. 2005. Worldwide Fuel Cell Installations. Available at http://www.fuelcells.org/info/charts/FCInstallationChart.pdf [Last updated October 2005; accessed June 2006].
[209] Research Reports International. 2004. Distributed Generation Case Studies, 3rd Edition.

MARKET SEGMENT ANALYSIS

To identify the market opportunities for direct hydrogen PEM fuel cells as backup power for data centers, seven data centers were contacted, and two responses were received.

Responses were received from one small data center service provider and from a data center operated by and for a large science and technology organization. Respondents indicated that backup power was used for servers, air-conditioning, lighting, telephone switching, and data center specific network switches. One respondent indicated that servers were the most critical applications and required continuous backup power. Respondents reported that they had experienced approximately two power outages in the past year. One respondent indicated that the outages lasted less than 60 seconds, while the other cited outages of approximately 3 to 5 minutes. Respondents indicated that any length of outage would be highly disruptive. One respondent indicated that an outage could result in a security breach and implementation of emergency management plans. Respondents stated that backup power was provided by both UPS systems and diesel generators. Sizes of backup power systems varied and were based on the type of application supported. Systems could be less than 5 kW to over 250 kW.

Respondents identified reliability, capital cost, lifetime of the unit, start-up time, ease of use, and fuel availability as very important factors in selecting a backup power system. Both respondents were fairly satisfied with their current backup power systems. One respondent indicated that they had no generator backup, and long outages could severely impact their operations. Respondents were split on the growing need for backup power in their market segment. One respondent had considered alternatives to their current mode of operation. Neither had considered PEM fuel cells as a smaller backup power solution. Decisions to purchase PEM fuel cells were made on the basis of initial capital cost and business justification. One respondent stated that government incentives were not considered in making purchasing decisions, and the other did not know if government incentives were considered.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

PEM fuel cells provide the benefits of low or zero emissions, high efficiency and reliability, siting flexibility, scalability, and ease of maintenance. Secondary research indicates that fuel cells can be reliable and efficient alternatives for mission critical applications such as data centers.[210] In addition, the size and projected growth of this market sector offers an attractive opportunity for PEM fuel cells. Users in this market segment appear to be fairly satisfied with their current mode of operation and there appears to be little interest in alternatives. No external drivers for pushing adoption of alternatives were identified in this market segment.

Marketing research did not identify a compelling value proposition for PEM fuel cells in this market segment. Near-term opportunities for PEM fuel cells will be as replacements to small battery systems, UPS systems, and generators. PEM fuel cells will have to compete with more established alternatives in this market segment and it is likely that small size, high capital costs, and lack of reliability data will limit application in the near-term.

[210] Gangi, J. 2004. Fuel Cells: Providing Customer Value Today. Distributed Energy, the Journal for Onsite Power Solutions. Available at http://www.distributedenergy.com/de_0411_fuel.html [Accessed June 2006].

RESEARCH SUMMARY:
ELECTRIC UTILITY SUBSTATIONS

MARKET SEGMENT DESCRIPTION

Electric utilities include establishments engaged in the generation, transmission, and/or distribution of electric energy for sale. This analysis considers the potential for PEM fuel cells for backup power of critical functions at electric utility substations. Table g-1 identifies the SIC and NAICS codes associated with this market segment.

Table g-1. Relevant SIC and NAICS Codes for Electric Utilities.

2-Digit SIC Code	49 – Electric, gas, and sanitary services
4-Digit SIC Code	4911 – Electric services
NAICS Code	221112 – Fossil fuel electric power generation

The electric industry commonly uses standard indices to track and benchmark reliability performance. These indices are termed CAIDI (Customer Average Interruption Duration Index), SAIDI (System Average Interruption Duration Index), and SAIFI (System Average Interruption Frequency Index). CAIDI measures average outage duration if an outage (greater than 1 minute) is experienced (i.e., average restoration time). SAIDI measures average outage duration per customer, and SAIFI measures how often a customer can expect to experience an outage. The indices are defined over a fixed time period, typically a year, and can be measured over an entire electric distribution system or over smaller portions of a system.[211] An industry benchmarking survey reported the CAIDI average as 320 minutes (5.3 hours), the SAIDI average as 95 minutes (1.6 hours), and the SAIFI average as 1.2 interruptions per customer.[212,213] The survey benchmarked reliability statistics with nearly 100 electric utilities across the nation.

Secondary research indicates that there is a need for standby or emergency power at battery substations to provide power to switching components and substation control equipment during AC power outages. Backup power is also needed for supervisory, monitoring, and indication functions at substations. Presently, there are more than 100,000 substation battery installations in the U.S.[214] Most battery strings employed for substation backup power are 120V DC, and typical loads are 5 to 30 amps.[215]

The dominant technology for substation backup technology is a vented, also called flooded, lead-acid battery. Typical heavy-duty flooded lead-acid battery banks provide 8 hours of backup to serve critical loads.[216] Vented lead-acid batteries are reported to generally meet the 15 to 20 year

[211] Rothwell, J. 2004. The Reliability Triangle. We Energies. Available at http://tdworld.com/mag/power_reliability_triangle/index.html [Accessed June 2006].
[212] Edmond Electric. 2006. System Reliability. Available at http://www.edmondok.com/Electric/elec_reliability.html [Accessed June 2006].
[213] City of Georgetown Texas. 2006. Reliability Stats. Available at http://www.georgetown.org/departments/gus/electric/reliabilitystats.php [Accessed June 2006].
[214] Eckroad, S., T. Key, and H. Kamath. 2004. Assessment of Alternatives to Lead-Acid Batteries for Substations. Available at http://www.battcon.com/PapersFinal2004/KamathPaper2004.pdf [Accessed December 2006].
[215] Davis, D. 2005. Fuel Cells: A Look at the Future for OSP and Substation Backup Power. Presentation at Advancements in Battery Technology & Power Management 2005.
[216] Electric Power Research Institute (EPRI). 2006. Alternatives to Substation Batteries. Available at http://www.epriweb.com/public/000000000001009083.pdf [Accessed June 2006].

life requirements of backup battery systems. Although maintenance routines are well-established, resources are needed to maintain and monitor lead-acid batteries.
A survey of electric utility practices found that valve-regulated lead-acid batteries are used significantly but that these are typically being replaced with vented lead-acid systems. Nickel-cadmium (NiCd) batteries are also used at a small number (5%) of installations.[217]

MARKET SIZE

Table g-2 provides market size statistics for SIC Code 4911, Electric Services. There are an estimated 9,404 establishments in the U.S. electric services industry, which generate total annual sales of $759,569.5 million, or an average of $180.5 million per establishment.

Table g-2. Number of Businesses in Electric Services Industry (4911).

SIC Code	SIC Description	Number of Businesses	Average Sales (Million $)	Total Sales (Million $)
4911-0000	Electric services	5,251	181,516	132,378.703
4911-9900	Electric services, nec	202	3,881	2,391.1
4911-9901	Distribution, electric power	1,642	85,107	110,555.102
4911-9902	Generation, electric power	2,119	176,364	502,420.906
4911-9903	Transmission, electric power	190	10,143	11,823.7
	Total	**9,404**	**457,011**	**759,569.5**

Sales figures are in millions. Source: www.zapdata.com, accessed June 2006.

Utilities worldwide spent an estimated $124.5 million on stationary lead-acid batteries in 2003; a moderate but stable 2.9% annual growth rate is predicted from 2000 to 2010. In 2003, utilities purchased 8.6% of 840.4 million stationary lead-acid batteries shipped worldwide, compared to other end-user applications. This percentage is expected to decline to 6.7% by 2010.[218]

Potential fuel cell users in this sector include DTE Energy, WE Energies, First Energy, Duke Energy (formerly Cinergy), American Electric Power (AEP), Avista Corporation, ConEdison, Minnesota Power, Mississippi Power Company, Pacific Gas & Electric, Southern California Edison, Sierra Pacific, TXU Energy, and others.

MARKET TRENDS

State mandates for renewable energy, such as those in California and New York, help drive the use of fuel cells and other alternatives. However, the lack of a regulatory policy encouraging alternative energy in most states has slowed the process of fuel cell adoption in the utility industry.[219]

An industry survey showed moderate interest in trying new technologies for backup power systems. Eckroad et al. analyzed alternatives to lead-acid batteries, including fuel cells, in electric utility substations.[220] A number of obstacles to fuel cell adoption remain, such as the need for supplemental power due to a lack of instantaneous response time, relatively untested

[217] Eckroad, S., T. Key, and H. Kamath. 2004. Assessment of Alternatives to Lead-Acid Batteries for Substations. Available at http://www.battcon.com/PapersFinal2004/KamathPaper2004.pdf [Accessed December 2006].
[218] Frost & Sullivan, Inc.. 2004. World Stationary Lead Acid Battery Markets.
[219] Stern, G.M. 2006. The Coming Fuel Cell Revolution. EnergyBiz Magazine. Available at http://energycentral.fileburst.com/EnergyBizOnline/2006-2-mar-apr/Fuel_Cell0306.pdf [Accessed June 2006].
[220] Eckroad, S., T. Key, and H. Kamath. 2004. Assessment of Alternatives to Lead-Acid Batteries for Substations. Available at http://www.battcon.com/PapersFinal2004/KamathPaper2004.pdf [Accessed December 2006].

performance, and additional refueling required. The authors concluded that any alternative technologies are years away from a significant level of market acceptance.
PEM fuel cells show potential for replacing conventional lead-acid batteries in backup energy systems. The cost of PEM fuel cells is roughly the same as traditional battery backup power.[221,222] The main advantage is that PEM fuel cells can provide power indefinitely, provided that hydrogen fuel is supplied. Fuel cells also offer the advantage of being scalable, and eliminating costly battery maintenance and replacement. PEM fuel cells can also be used to maintain batteries at full charge during outages, in preparation for relay/breaker closure once power is restored. This reduces the need for personnel to be dispatched during power outages. The smaller space requirement needed for fuel cells alleviates space shortages. PEM fuel cells have the ability to withstand extreme environmental conditions, eliminating the need for the environmentally controlled spaces that lead-acid batteries require to protect them from harsh weather conditions.

Several barriers to adoption of PEM fuel cell technology for backup power applications exist in this marketplace. A barrier to adopting PEM fuel cells is that they may need to be paired with complementary technology (e.g., batteries) to facilitate instantaneous response required for substation backup power. Another disadvantage of fuel cells in substation backup power applications is that they are relatively untested (i.e., 2- to 3-year demonstrated performance), although fuel cells are increasingly being demonstrated as alternative or supplementary backup power solutions at electric substations. Since PEM fuel cells are a relatively new technology whose reliability is still unproven, electric utilities are cautious in adopting fuel cells widely. Furthermore, capital costs for PEM fuel cells for substation backup can range from $15,000 to $50,000, making it unaffordable for some utilities. Additional challenges, such as delivering a hydrogen fuel supply and developing siting guidelines that facilitate the use of hydrogen and ensure safety, are being resolved.

In May 2005, Connecticut's Public Utilities Commission announced an agreement to conduct a 1-month demonstration of a Proton Energy Systems 15 kW regenerative fuel cell at an electric substation in Wallingford, Connecticut, next to Proton Energy Systems' office.[223] In Vancouver, Washington, Bonneville Power Administration has operated a ReliOn Independence 1000 PEM fuel cell at its Ross substation since April of 2004.[224] In 2001, Detroit Edison, which owns 14% of PlugPower, tested a PlugPower PEM fuel cell for backup power at a substation in Michigan. The hydrogen fuel cell served as a replacement for control batteries. Following the success of that pilot test, Detroit Edison proceeded to install a 5 kW GenCore direct hydrogen fuel cell, in parallel with the batteries, at one of its 600 substations.[225] In 2003 and 2004, ReliOn (under the

[221] Stern, G.M. 2006. The Coming Fuel Cell Revolution. EnergyBiz Magazine. Available at http://energycentral.fileburst.com/EnergyBizOnline/2006-2-mar-apr/Fuel_Cell0306.pdf [Accessed June 2006].
[222] Egbert, S.T. 2005. Raising the Bar on Substation Backup Power. Utility Automation & Engineering T&D. Available at http://uaelp.pennnet.com/articles/article_display.cfm?Section=ARCHI&C=Feat&ARTICLE_ID=243623&KEYWORDS=raising%20the%20bar&p=22 [Accessed June 2006].
[223] Fuel Cells 2000. 2005. Worldwide Fuel Cell Installations. Available at http://www.fuelcells.org/info/charts/FCInstallationChart.pdf [Last updated October 2005; accessed June 2006].
[224] Fuel Cells 2000. 2005. Worldwide Fuel Cell Installations. Available at http://www.fuelcells.org/info/charts/FCInstallationChart.pdf [Last updated October 2005; accessed June 2006].
[225] Stern, G.M. 2006. The Coming Fuel Cell Revolution. EnergyBiz Magazine. Available at http://energycentral.fileburst.com/EnergyBizOnline/2006-2-mar-apr/Fuel_Cell0306.pdf [Accessed June 2006].

former name Avista Labs) installed fuel cells at a substation in the northwestern U.S. to provide backup power for substation protection and control equipment.[226]

In May 2006, the Electric Power Research Institute (EPRI) issued a call for utilities to participate in a project to demonstrate and evaluate alternative technologies to traditional substation batteries.[227] Fuel cells are one of the alternative technologies to be tested as backup power at a host utility. The project will provide installation and design experience, field data, and lifecycle cost analysis to inform an evaluation of alternatives to lead-acid batteries.

MARKET SEGMENT ANALYSIS

Fourteen electric utilities were contacted to further determine requirements for backup power and the potential for application of fuel cells. Five interviews were conducted, and two responses were received from large electric utility companies. One was a large diversified energy company involved in the development and management of energy related businesses and services. The other company is involved in electric generation, transmission, and distribution. Functions typically requiring backup power, as identified by respondents, include substations and telecommunication sites. Critical backup power applications at substations include power control networks and relay protection at the substation. Respondents indicated that the impacts of power outages were minimal because critical systems are supported by redundant backup power systems. In case of backup power system failure, impacts can be devastating and could result in the implementation of emergency management plans and potentially losses in distribution.

Backup power is currently provided by batteries. The size of batteries used varies from 15 to 30 kW to over 250 kW. The number of backup power systems used varied significantly between users. One respondent reported approximately 1,000 backup power units. Systems were either nominal 48V consisting of two 24V lead-acid batteries or nominal 120V consisting of two 60V lead-acid batteries. When asked to rate the importance of various factors in selecting a backup power system, respondents identified reliability, annual operating and maintenance costs, start-up time, ease of use, fuel availability, and good experience with this type of system in the past as very important. Both respondents rated the performance of their current backup power systems as very good. One respondent elaborated that despite the good performance of battery systems, they are difficult to use, need extensive maintenance, and need to be located in vented rooms. Respondents rated the reliability, capital cost, lifetime, start-up time, ease of use, and fuel availability as very good for their current systems.

Both respondents indicated that they did not see a growing need for backup power in the next three years. Both respondents indicated that they had considered alternatives to batteries including fuel cells and natural gas and diesel fueled generators to provide extended run time. Both respondents were aware of PEM fuel cells for backup power. One respondent indicated that they had tested fuel cells and may consider installing fuel cells systems as backup to batteries to save cost and space in cities like New York. Batteries would serve as primary backup in case the grid went down and would then transfer load to the fuel cell. Both

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[226] Fuel Cells 2000. 2005. Worldwide Fuel Cell Installations. Available at http://www.fuelcells.org/info/charts/FCInstallationChart.pdf [Last updated October 2005; accessed June 2006].

[227] Electric Power Research Institute (EPRI). 2006. Alternatives to Substation Batteries. Available at http://www.epriweb.com/public/000000000001009083.pdf [Accessed June 2006].

respondents indicated that PEM fuel cells do not compete favorably with their existing backup power systems today but could in the future. Both respondents indicated that they were not concerned about using hydrogen as a fuel. One respondent indicated that they had concerns with the regulatory code written for battery backup, which specifies where the backup unit must be located (15 feet away from exposed switch gear), and noted that this may be a deterrent to the use of fuel cells. One respondent indicated that electric utilities were conservative and were not willing to adopt unproven technology. Both respondents indicated that incentives and the track record of others using PEM fuel cells would be important drivers for adopting the technology.

Respondents indicated that capital purchase decisions were made on the basis of initial capital cost and payback period. One respondent indicated that they took return on investment into consideration as well. One respondent indicated that lower budgets and the increasing cost of fuel were also important decision drivers.

Utilities with an interest in fuel cell technology were more willing (than other companies) to participate in interview discussions. Three utilities contacted, reported having tested fuel cells. One noted that the main barriers to adopting fuel cells are high cost and low performance. One utility had investigated the potential for using fuel cells to supplement battery backup at a substation, including receiving a vendor demonstration. The utility determined that fuel cells did not meet their requirements, citing cost as a factor in that decision.

Two utilities interviewed reported that they have no backup power at their substations. They have multiple feeds and switching arrangements that provide continuous power in case of outages. One utility also has a 10VA mobile transformer on a trailer that can be used in cases where they cannot switch to another substation.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

PEM fuel cells are well-suited for backup power applications at electric utility substations. However, electric utilities appear to be very satisfied with the performance of current backup power technologies. Electric utility respondents in this analysis indicated that power outages are not as disruptive to electric utility substation operations, primarily due to the availability of redundant power sources as well as reliable backup power sources that can maintain service or can facilitate relay breaker closing until AC power is restored. However, the threat of extended outages, as experienced in recent years during the Northeast blackout of 2003, and Hurricanes Rita and Katrina, has raised questions about the backup capacity of traditional batteries used for backup power. Electric utilities are investigating alternative sources to supply extended runtime to their critical sites as well as their remote sites. Characteristics desired by users in this market segment are high reliability, quick start-up time, wide fuel availability, and good experience with this type of system in the past.

Marketing research indicates that utilities are aware of PEM fuel cells, and recognize the advantages of PEM fuel cells over incumbent technologies. Despite this awareness, electric utilities appear to be slow adopters of PEM fuel cell technology. A few utilities have explored the possibility of using PEM fuel cells and have considered them as supplements to existing battery backup or as battery rechargers at substations. Users remain concerned about reliability, start-up time, lifetime, and capital cost of PEM fuel cells for backup power.

As users are fairly satisfied with current technologies, there is no significant driver for switching in this segment. Adoption of PEM fuel cells by users in this market segment is dependent on a track record of others using them. Furthermore, users in this market segment also appear to be price sensitive as capital purchase decisions are based on initial capital cost and the availability of government incentives. It is likely that in the near term, adoption will be limited to feasibility testing at remote substation sites or at substation sites where backup power systems are costly to maintain, until users are convinced of the reliability of PEM fuel cells for their application.

RESEARCH SUMMARY:
FOOD MANUFACTURING INDUSTRY

MARKET SEGMENT DESCRIPTION

The food manufacturing industry includes firms and associated establishments that manufacture or process foods and beverages for human consumption. It also includes other related products such as manufactured ice, chewing gum, vegetable and animal fats and oils, and prepared feeds for animals and fowl. Two areas – industries that use hydrogen, and industries that specialize in frozen foods – were selected for in-depth examination. Table h-1 lists the SIC and NAICS codes selected for this analysis.

One area of focus was on industries that use hydrogen, such as in the manufacture of edible fats and oils. It was assumed that fuel cell users who already use hydrogen may have infrastructure in place to facilitate the supply of hydrogen for backup power. Additionally, employees would be accustomed to working with hydrogen and would require minimal education and training. This segment includes starch and vegetable fats and oils manufacturing. Industries are engaged in one or more of the following: (1) wet milling corn and vegetables; (2) crushing oilseeds and tree nuts; (3) refining and/or blending vegetable oils; (4) manufacturing shortening and margarine; and (5) blending purchased animal fats with vegetable fats.

The other area of focus was on industries that specialize in frozen foods. The frozen food segment was chosen because it uses freezers and other equipment with large power requirements and high consequences if the equipment does not function properly or if there is a lack of power. This can extend to one or more of the following: fresh and frozen seafood processing, frozen fruits and vegetables processing, and ice cream and frozen dessert manufacturing.

Table h-1. Selected SIC and NAICS Codes for Food Manufacturing.

2-Digit SIC Code	20 – Food and kindred products
4-Digit SIC Codes	2024 – Ice cream and frozen desserts 2037 – Frozen fruits and vegetables 2038 – Frozen specialties, not elsewhere classified (nec) 2046 – Wet corn milling (refining purchased oil) 2074 – Cottonseed oil mills (processing purchased cottonseed oil) 2075 – Soybean oil mills (processing purchased soybean oil) 2076 – Vegetable oil mills, except corn, cottonseed, and soybean 2077 – Animal and marine fats and oils (fresh and frozen marine fats and oils) 2079 – Shortening, table oils, margarine, and other edible fats and oils, nec 2092 – Prepared fresh or frozen fish and seafood 2097 – Manufactured ice
NAICS Codes	311221 – Wet corn milling 311222 – Soybean processing 311223 – Other oilseed processing 311225 – Fats and oils refining and blending 311411 – Frozen fruit, juice, and vegetable manufacturing 311412 – Specialty food manufacturing 311520 – Ice cream and frozen dessert manufacturing 311712 – Fresh and frozen seafood processing

MARKET SIZE

The food processing and beverage industry accounts for about one-sixth of the U.S. manufacturing sector's activity.[228] In 2001, food and beverage manufacturing plants accounted for 13% of the value of shipments from all U.S. manufacturing plants. There are large numbers of food processing establishments (plants) in the U.S. – almost 29,000 owned by about 22,000 companies, according to the Census of Manufacturers.[229]

Generally, food processors (e.g., Tyson Foods (meats), Dairy Farmers of America (dairy products), and Tate & Lyle (sweeteners, sugar)) are located near farms, and specialize in one or two food segments. Many food industries are consolidating. As shown in Table h-2 below, overall the industry has increased the number of establishments, but the USDA reports that this gain primarily reflects increases in a few selected industries (e.g., salsa making) where the number of small producers has dramatically increased.

Table h-2. Consolidation of Businesses in the Food Manufacturing Industry.

Industry	Number of Businesses		
	1992	1997	Change
Meat	3,242	3,164	-78
Dairy	2,024	1,834	-190
Fruits and Vegetables	2,052	2,117	65
Grain Mill Products	2,618	2,531	-87
Bakery Products	3,152	3,384	232
Sugar	1,129	1,259	130
Fats and Oils	540	519	-21
Beverages	2,064	2,243	179
Other Prepared Foods	3,984	4,784	800
Total Food	**20,805**	**21,835**	**1,030**

Source: Census of Manufacturers, as cited in Harris, J., Kaufman, P., Martinez, S., and C. Price. 2002. The U.S. Food Marketing System, 2002. USDA/ERS. Agricultural Economic Report No. (AER811) Available at: http://www.ers.usda.gov/publications/aer811/ or http://www.ers.usda.gov/publications/aer811/aer811c.pdf. Accessed September 2006.

Food processing plants are located throughout the United States. The County Business Patterns (CBP) reports that, in 2000, California had the most food manufacturing plants (4,252), while New York (2,227) and Texas (1,739) were also leading food manufacturing states.[230]

Table h-3 characterizes the market for edible fats and oils. There are an estimated 183 establishments in this industry, employing over 7,783 people, and generating annual sales of $3,972.90 million. Key companies in this sector include: Bunge Limited, Cargill Foods, Cargill Soy Protein Solutions, and Cargill Industrial Oils & Lubricants.

Table h-4 characterizes the market for fresh or frozen fish and seafood. There are an estimated 555 establishments in this industry, employing over 22,336 people, and generating annual sales of $4,489 million. Key companies in this sector include: Icelandic USA, Inc., and American Seafoods Group, LLC.

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[228] Huang, K. 2003. Food Manufacturing Productivity and its Economic Implications. Available at http://www.ers.usda.gov/publications/tb1905/ [Accessed September 2006].
[229] U.S. Department of Agriculture, Economic Research Service. 2005. Food Market Structures: Food and Beverage Manufacturing. Available at http://www.ers.usda.gov/Briefing/FoodMarketStructures/processing.htm [Accessed September 2006].
[230] U.S. Department of Agriculture, Economic Research Service. 2005. Food Market Structures: Food and Beverage Manufacturing. Available at http://www.ers.usda.gov/Briefing/FoodMarketStructures/processing.htm [Accessed September 2006].

Table h-5 characterizes the market for ice cream and frozen desserts. There are an estimated 1,132 establishments in this industry, employing over 25,370 people, and generating annual sales of $5,354.20 million.

Table h-3. Number of Businesses in the Edible Fats and Oils Industry (2079).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)
2079-0000	Edible fats and oils	44	1,900	352.5
2079-0100	Margarine and margarine oils	1	100	63.5
2079-0102	Margarine-butter blends	3	13	1
2079-0103	Margarine, including imitation	6	979	77.3
2079-0104	Nut margarine	3	310	186.2
2079-0200	Shortening and other solid edible fats	6	556	23.2
2079-0201	Compound shortenings	4	526	99.6
2079-0203	Vegetable shortenings (except corn oil)	3	487	669.2
2079-9901	Cooking oils, except corn: vegetable refined	20	477	811.6
2079-9902	Cottonseed oil, refined: not made in cottonseed oil mills	1	6	2
2079-9903	Edible oil products, except corn oil	18	1,016	203.1
2079-9904	Oil, hydrogenated: edible	4	201	1,336.8
2079-9905	Oil, partially hydrogenated: edible	1	1	0.1
2079-9906	Olive oil	48	269	86.6
2079-9907	Peanut oil, refined: not made in peanut oil mills	1	7	1
2079-9908	Salad oils, except corn: vegetable refined	5	62	6.5
2079-9909	Soybean oil, refined: not made in soybean oil mills	7	400	14
2079-9910	Vegetable refined oils (except corn oil)	8	428	38.8
	Total	**183**	**7,738**	**3,972.9**

Sales figures are in millions. Source: www.zapdata.com. Accessed September 2006.

Table h-4. Number of Businesses in the Fresh or Frozen Seafood Industry (2092).

SIC	SIC Description	Number of Businesses	Total Employees	Total Sales ($)
2092-0000	Fresh or frozen packaged fish	207	8,173	920.5
2092-0100	Fresh or frozen fish or seafood chowders, soups, and stews	19	284	43.8
2092-0101	Chowders, fish and seafood: frozen	5	18	5.2
2092-0102	Soups, fish and seafood: frozen	1	1	0.2
2092-0200	Prepared fish or other seafood cakes and sticks	8	63	14.8
2092-0201	Crabcakes, frozen	5	30	23.9
2092-0203	Fishcakes, frozen	2	16	1.3
2092-9901	Crab meat, fresh: packaged in nonsealed containers	26	629	70.7
2092-9902	Crabmeat, frozen	9	155	166.1
2092-9903	Fish fillets	1	200	N/A
2092-9904	Fish, fresh: prepared	51	3,016	515.9
2092-9905	Fish, frozen: prepared	16	1,047	532.9
2092-9906	Seafoods, fresh: prepared	93	3,451	464.8
2092-9907	Seafoods, frozen: prepared	49	3,076	1,163.7
2092-9908	Shellfish, fresh: shucked and packed in	18	749	57.3

	nonsealed containers			
2092-9909	Shellfish, frozen: prepared	8	434	374.5
2092-9910	Shrimp, fresh: prepared	24	764	77.2
2092-9911	Shrimp, frozen: prepared	13	230	56.2
	Total	**555**	**22,336**	**4,489**

Sales figures are in millions. Source: www.zapdata.com. Accessed September 2006.

Table h-5. Number of Businesses in the Frozen Ice Cream and Dessert Industry (2024).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)
2024-0000	Ice cream and frozen deserts	674	12,950	3,054.1
2024-0100	Ice cream and ice milk	79	2,294	824.9
2024-0101	Ice cream, bulk	118	2,495	254.8
2024-0102	Ice cream, packaged: molded, on sticks, etc.	78	4,782	1,055.8
2024-0103	Ice milk, bulk	2	44	4.2
2024-0104	Ice milk, packaged: molded, on sticks, etc.	1	11	0.8
2024-0200	Dairy based frozen desserts	30	643	55.4
2024-0201	Custard, frozen	28	373	24.1
2024-0203	Sherbets, dairy based	1	0	N/A
2024-0204	Spumoni	1	3	0.5
2024-0205	Yogurt desserts, frozen	18	332	34.8
2024-0300	Nondairy based frozen desserts	13	431	11.1
2024-0301	Fruit pops, frozen	13	332	33.1
2024-0303	Ices, flavored (frozen dessert)	58	470	40.5
2024-0304	Juice pops, frozen	7	139	8.7
2024-0306	Rice-based desserts, frozen	1	4	5
2024-0307	Sorbets, non-dairy based	4	19	6.5
2024-0308	Tofu desserts, frozen	6	48	20
	Total	**1,132**	**25,370**	**5,434.2**

Sales figures are in millions. Source: www.zapdata.com. Accessed September 2006.

Table h-6 characterizes the market for frozen fruits and vegetables. These are establishments primarily engaged in freezing fruits, fruit juices, and vegetables, and which also produce important by-products such as fresh or dried citrus pulp. There are an estimated 299 establishments in this industry, employing over 29,807 people, and generating annual sales of $7,801.4 million.

Table h-7 characterizes the market for frozen specialties, which includes establishments primarily engaged in manufacturing frozen food specialties, not elsewhere classified, such as frozen dinners and frozen pizza. There are an estimated 613 establishments in this industry, employing over 41,447 people, and generating annual sales of $8,242.3 million.

Table h-6. Number of Businesses in the Frozen Fruits and Vegetables Market Industry (2037).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)
2037-0000	Frozen fruits and vegetables	80	4,439	469.9
2037-0100	Frozen fruits and vegetables	22	4,764	661
2037-0101	Citrus pulp, dried	2	11	1.7
2037-0102	Fruits, quick frozen and cold pack (frozen)	38	3,347	1,205.3
2037-0103	Potato products, quick frozen and cold pack	24	4,581	3,654.9
2037-0104	Vegetables, quick frozen & cold pack, excl. potato products	43	7,701	924
2037-0200	Fruit juices	50	2,332	382.3
2037-0201	Fruit juice concentrates, frozen	29	1,847	412.1
2037-0202	Fruit juices, frozen	11	785	90.1
	Total	**299**	**29,807**	**7,801.4**

Sales figures are in millions. Source: www.zapdata.com. Accessed September 2006.

Table h-7. Number of Businesses in the Frozen Specialties Market Industry (2038).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)
2038-0000	Frozen specialties, nec	270	22,503	4,224.4
2038-9901	Breakfasts, frozen and packaged	12	239	18.2
2038-9902	Dinners, frozen and packaged	33	4,473	518.3
2038-9903	Ethnic foods, nec, frozen	111	4,823	474.1
2038-9905	Lunches, frozen and packaged	5	114	2.2
2038-9906	Pizza, frozen	114	7,042	2,934.4
2038-9907	Snacks, incl. onion rings, cheese sticks, etc.	47	835	29.9
2038-9908	Soups, frozen	12	685	24
2038-9909	Spaghetti and meatballs, frozen	1	6	0.4
2038-9910	Waffles, frozen	7	277	16.5
2038-9911	Whipped topping, frozen	1	450	N/A
	Total	**613**	**41,447**	**8,242.3**

Sales figures are in millions. Source: www.zapdata.com. Accessed September 2006.

Table h-8 characterizes the market for manufactured ice, which addresses establishments primarily engaged in producing ice for sale. There are an estimated 616 establishments in this industry, employing over 6,757 people, and generating annual sales of $837 million.

Table h-8. Number of Businesses in the Manufactured Ice Market Industry (2097).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)
2097-0000	Manufactured ice	466	4,876	592.4
2097-9901	Block ice	72	990	128.1
2097-9902	Ice cubes	78	891	116.5
	Total	**616**	**6,757**	**837**

Sales figures are in millions. Source: www.zapdata.com. Accessed September 2006.

Total sales of frozen foods in the U.S. have continued to climb over the past several years, reaching more than $29.2 billion in 2003, 1.6% higher than in 2002. The frozen entrée category continues to be the largest within the frozen food market with more than $3.67 billion in annual sales. The frozen meat/seafood category and the hand-held entrées (non-breakfast) experienced the largest growth from 2002 to 2003, with sales of the meat/seafood category increasing by

8.4% and the hand-held entrées increasing by 7.9%. Juices/drinks experienced the largest decline within the frozen food market, with sales decreasing 13.2% from 2002 to 2003.[231]

Industry trends indicate that the growth in demand for frozen foods will continue. A survey conducted by the National Restaurant Association found that 96% of restaurant owners said they will use frozen food for their table service operations, while 100% will use frozen food for their quick service operations.

MARKET TRENDS

Refrigeration equipment is a major consumer of energy for certain sectors of the food industry. According to a 2001 market assessment, the engine-driven refrigeration market is growing, promising lower operating costs and enhanced reliability.[232] Engine-driven systems are often used for capacity expansions, particularly when expensive transformer upgrades may be required. The longer operating hours of refrigeration applications improve the economics of engine-driven equipment, especially when heat recovery is employed.

Figure h-1 presents refrigeration applications in sub-sectors of the food industry for small and large capacity refrigeration compressors. Primary applications include dairies, food processing, meatpacking, and refrigerated warehouses. In industries like frozen fish processing, processors may be found offshore on large factory ships. Many processors function as isolated facilities; the development of a dedicated on-site power source, such as a fuel-cell powered technology, is a potential consideration.

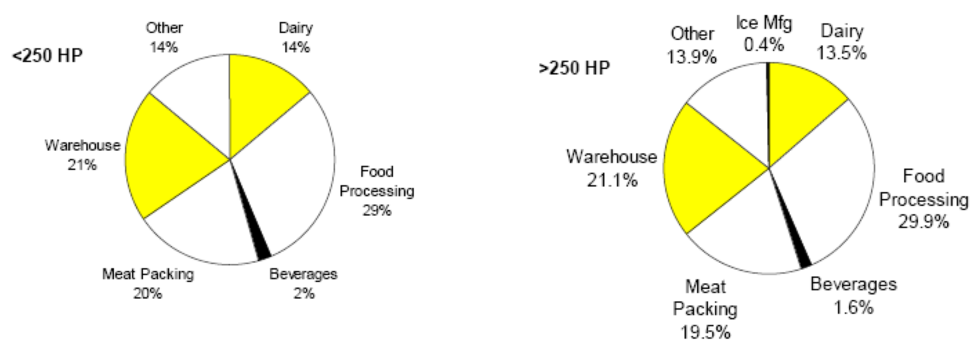

Figure h-1. Refrigeration Applications in Sub-sectors of the Food Industry.

Source: Onsite Energy Corporation for Oak Ridge National Laboratory for U.S. Department of Energy. 2001. Assessment of On-Site Power Opportunities in the Industrial Sector. Final Report, Contract No. 85X-TA008V.

Research has also indicated that the food processing sector represents an important market for on-site power generation and in particular for systems less than 50 MW in capacity. The food industry has had a peak steam draw of 53 million lbs per hour; it also has many small operations that use packaged boilers producing less than 25,000 lbs per hour. Energy end use is primarily for material handling, cooking, freezing, and refrigeration; more than $3.2 billion was spent on

[231] American Frozen Food Institute. 2006. Industry at a Glance. Available at http://www.affi.com/factstat-glance.asp [Accessed September 2006].

[232] Onsite Energy Corporation for Oak Ridge National Laboratory for U.S. Department of Energy. 2001. Assessment of On-Site Power Opportunities in the Industrial Sector. Final Report, Contract No. 85X-TA008V.

electricity in 1994. Since almost half of all the energy input is used for generating steam, CHP is also being pursued as an option for power supply. The most notable CHP opportunities in the food processing sector include meat preparation and packing, flour and grains, poultry, malt beverages, and fruit/vegetables processing and freezing processes.[233] CHP is well-positioned in this industry, operating in certain areas with a high potential for fuel cells, and would be a serious competitor in this market.

Although no fuel cell activity was identified in the food manufacturing sectors of focus for this analysis, a fuel cell project was identified at a bakery facility in Connecticut.[234] In response to a 2002 Connecticut Clean Energy Fund (CCEF) program designed to accelerate fuel cell commercialization, two fuel cells have been installed at the Pepperidge Farm bakery in Bloomfield, Connecticut. The project was designed to install commercially ready fuel cells in high-value applications to evaluate benefits, feasibility, and viability of use. Pepperidge Farm is partnering with FuelCell Energy Inc., which is providing a 250 kW direct fuel cell power plant to the bakery facility. The power plant will provide approximately 20% of the facility's base power.[235]

MARKET SEGMENT ANALYSIS

Three companies in the frozen foods sector were contacted; each indicated that there was no need for backup power in this industry.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

Limited information was available on the requirements for backup power in this market segment. Research indicates that this market does not have significant demand for sources of backup power supply. Some on-site generation is being supplied, primarily through CHP; however, neither primary nor secondary research indicated substantial near-term growth in the backup power market in this sector. It is likely that PEM fuel cells can be utilized as battery and UPS system replacements. Lack of near-term growth and minimal industry interest suggest that this is not a potential near-term market for PEM fuel cells.

[233] Onsite Energy Corporation for Oak Ridge National Laboratory for U.S. Department of Energy. 2001. Assessment of On-Site Power Opportunities in the Industrial Sector. Final Report, Contract No. 85X-TA008V.
[234] Food Processing Technology. 2006. Pepperidge Farm Bakery Plant, Bloomfield, CT, USA. Available at http://www.foodprocessing-technology.com/projects/pepperidge/ [Accessed September 2006].
[235] Fuel Cells Today. 2005. Fuel Cell Energy to Provide DFC Power Plant to Pepperidge Farm. Available at http://findarticles.com/p/articles/mi_m0OXF/is_2005_March_16/ai_n13454077.%20Accessed%20September%2029 [Accessed September 2006].

RESEARCH SUMMARY:
FEDERAL AGENCIES

MARKET SEGMENT DESCRIPTION

Federal agencies are considered to be the largest single energy consumer in the U. S. Energy used in federal buildings in 2004 accounted for 35.4% of the total federal energy bill. The federal government owns/operates over 500,000 buildings, including 422,000 housing structures (for the military) and 51,000 non-residential buildings. In fiscal year 2000, approximately $4 billion was spent on energy to heat, cool, light, and conduct operations in those 500,000 plus federal buildings. The DoD appears to be the largest consumer of energy in federal buildings (FY2004), accounting for 61.2% of total energy use in federal buildings and occupying 65.3% (FY2004) of the total floor space in federal buildings.[236]

While federal agencies are more likely to adopt grid parallel and grid independent sources of power due to their high energy needs, backup power may be needed for critical applications. The intent of this analysis, which focuses on a subset of potential federal users, was to identify applications and needs for backup power, as well as backup power trends, within these agencies. This particular subset of federal users was selected for two main reasons: (1) these agencies were deemed likely to have backup power needs, and (2) ample information was publicly available on the roles and activities of these agencies. Specific agencies that were considered for this analysis, along with their associated primary SIC and NAICS classifications, are provided in Table i-1. Table i-2 presents the primary roles of each agency selected for this analysis.

Table i-1. SIC and NAICS Codes for Selected Federal Agencies.

Agency	2-Digit SIC Code	4-Digit SIC Code(s)	NAICS Code(s)
DHS	97 – National security and international affairs	9711 – National security	928110 – National security
DOE	49 – Electric, gas and sanitary services	4911 – Electric services 4931 – Electric and other services combined 4955 – Hazardous waste management	213112 – Support activities for oil and gas operations 22112 – Electric power transmission, control, and distribution 221121 – Electric bulk power transmission and control 541620 – Environmental consulting services 541690 – Other scientific and technical consulting services 921190 – Other general government support 924110 – Administration of air and water resource and solid waste management programs
DOI	95 - Administration of environmental quality	9512 – Land, mineral, and wildlife conservation	924120 – Administration of conservation programs

[236] U.S. Department of Energy. 2006. 2006 Buildings Energy Data Book. Available at http://buildingsdatabook.eere.energy.gov/ [Accessed October 16, 2006].

Agency	2-Digit SIC Code	4-Digit SIC Code(s)	NAICS Code(s)
	and housing programs		
EPA	96 – Administration of economic programs	9631 – Regulation, administration of utilities	926130 – Regulation and administration of communications, electric, gas, and other utilities
FAA	45 – Transportation by air	4581 – Airports, flying fields, & services	488111 – Air traffic control
FCC	96 – Administration of economic programs	9621 – Regulation, administration of utilities	926130 – Regulation and administration of communications, electric, gas, and other utilities
FEMA	92 – Justice, public order and safety	9229 – Public order and safety, nec	922190 – Other justice, public order, and safety activities
FHWA	96 – Administration of economic programs	9621 – Regulation, administration of transportation	926120 – Regulation and administration of transportation programs
GSA	91 – Executive, legislative & general government, except finance	9199 – General government, nec	921190 – Other general government support
NASA	37 – Transportation equipment	3761 – Guided missiles and space vehicles	336414 – Guided missile and space vehicle manufacturing
NRC	96 – Administration of economic programs	9631 – Regulation, administration of utilities	926130 – Regulation and administration of communications, electric, gas, and other utilities
NWS	99 – Nonclassifiable establishments	9999 – Nonclassifiable establishments	921190 – Other general government support
USCG	92 – Justice, public order and safety	9229 – Public order and safety, nec	922120 – Police protection 926150 – Regulation, licensing, and inspection of miscellaneous commercial sectors 928110 – National security
USDA	96 – Administration of economic programs	9641 – Regulation of agricultural marketing	926140 – Regulation of agricultural marketing and commodities
USPS	43 – United States Postal Service	4311 – U.S. Postal Service	491110 – Postal service

nec - not elsewhere classified

Table i-2. Primary Roles of Selected Federal Agencies.

Agency	Description of Agency
DHS	This agency provides investigative and protective services intended to prevent attacks on the United States. Created in the wake of the 9/11 terrorist attacks, DHS includes units devoted to domestic nuclear detection, intelligence and analysis, management, operations coordination, policy, preparedness, and science and technology.
DOE	DOE's mission is to advance the national, economic, and energy security of the U.S.; to promote scientific and technological innovation in support of that mission; and to ensure the environmental cleanup of the national nuclear weapons complex. In support of this mission, the DOE has four primary goals: apply advanced science and nuclear technology to the nation's defense, promote a diverse supply of environmentally safe energy, conduct scientific research, and dispose of high-level radioactive waste.
DOI	The DOI manages one out of every 5 acres of land in the U.S. and is comprised of eight bureaus, including the National Park Service, U.S. Fish and Wildlife Service, and Bureau of Reclamation (BOR). The BOR was established in 1902 to construct dams, power plants, and canals throughout the western U.S.
EPA	This agency develops and enforces environmental policy and regulations throughout the country. Besides working to ensure compliance with federal environmental rules, the agency provides support for state environmental protection efforts. In addition, the EPA conducts research on environmental issues through a network of laboratories.
FAA	The FAA is responsible for overseeing air transportation in the United States. FAA focuses on air transportation safety, including the enforcement of safety standards for aircraft manufacturing, operation, and maintenance. It also manages air traffic in the U.S. through a network of towers at the nation's airports. It maintains radar systems, communication equipment, and air traffic security systems.
FCC	The FCC regulates interstate and international communications by radio, television, wire, satellite, and cable. The Communications Act of 1934 established the FCC as an independent US government agency directly responsible to Congress. Its jurisdiction covers the 50 states, the District of Columbia, and US possessions.
FEMA (part of DHS)	This agency is charged with building and supporting the nation's emergency management system. FEMA leads federal efforts to prepare for, respond to, and recover from disasters that overwhelm state and local resources.
FHWA	Part of the U.S. Department of Transportation (DOT), the FHWA offers funding and technical support for the construction and preservation of highways across the nation. FHWA's budget provides support for local and state governments, as well as national parks, national forests, Indian lands, and other federally-owned land.
GSA	In addition to acting as the government's landlord in obtaining office space for the federal workforce, the GSA also supplies equipment, telecommunications, and information technology products to its customer agencies. It carries out its mission through the Federal Technology Service, Federal Supply Service, Public Buildings Service, and regional offices throughout the country.
NASA	NASA is responsible for the public space program of the U.S., as well as long-term civilian and military aerospace research. Today, NASA conducts its work in four principle areas: 1) Aeronautics: providing new flight technologies that improve our ability to explore and which have practical applications on Earth; 2) Exploration Systems: creating new capabilities for, human and robotic exploration; 3) Science: exploring the Earth, moon, Mars and beyond; and 4) Space Operations: providing critical technologies for much of the rest of NASA through the space shuttle, the International Space Station, and mission support.
NRC	This agency oversees the civilian use of nuclear materials. Its regulatory oversight encompasses three primary components: commercial electric-power generation reactors and research/test reactors; nuclear materials in medical, industrial, and academic settings; and nuclear waste disposal.

Agency	Description of Agency
NWS	The NWS produces climate, hydrologic, and weather forecasts and warnings for the United States. Its mission also includes forecasting to protect life and property and to enhance the national economy. The NWS is now part of the Department of Commerce's National Oceanic & Atmospheric Administration (NOAA).
USCG (part of DHS)	The USCG guards the public, the environment, and the economic and security interests of the U.S. Its primary roles consist of promoting maritime safety; supporting national defense; providing maritime security; protecting natural resources; and facilitating maritime transport, commerce, and recreation.
USDA	Founded in 1862 by Abraham Lincoln, the USDA oversees a host of matters related to the nation's agricultural industries and food supply. Among many other functions, it provides training and scientific resources for farmers, monitors food safety, operates the Forest Service, and aids federal decision-making processes related to agricultural regulations and trade policies.
USPS	The USPS is responsible for handling cards, letters, and packages mailed throughout the United States. This independent government agency, which relies on postage and fees to fund its operations, delivers more than 210 billion pieces of mail a year to approximately 144 million addresses.

Source of agency information: Hoovers, Inc., fact sheets obtained from http://premium.hoovers.com.

At least one energy-dependent function is critical to many, if not all, of the agencies identified for this analysis: communications. Communications are critical both internally (e.g., radio towers that enable FEMA agents to remain in contact during a natural disaster or electronics that permit conversations between the space shuttle and earth-bound NASA technicians) and externally (e.g., equipment and radio towers that enable communication between air traffic control personnel and pilots). Maintaining communications to support the responsibilities described in Table i-2 requires that equipment and facilities remain operational at all times.

To support communications and other key functions, it appears that all federal agencies have a need for backup power for small- as well as large-scale applications (> 250 kW). In addition, specific backup power applications have been identified for particular agencies, as summarized below:

FAA

The FAA is responsible for a number of activities designed to ensure the safety and efficient operation of civil aviation. The FAA operates a network of airport towers, air route traffic control centers, and flight service stations. Using these facilities, the agency develops air traffic rules, assigns the use of airspace, and controls air traffic. Also, 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 communications equipment, radar facilities, computer systems, and visual display equipment at flight service stations.[237]

[237] Federal Aviation Administration. 2005. What We Do. Available at http://www.faa.gov/about/mission/activities/ [Accessed October 2006].

NRC

Backup power is necessary to maintain functionality of the NRC's public notification sirens in the event of a nuclear emergency; however, the agency does not yet have backup systems in place at many critical locations. As of 2005, only 27% of the NRC's 62 nuclear power emergency planning zones were prepared to remain fully operational in the absence of grid power.

In 2005, interest groups and local governments filed a public petition requesting that the NRC enforce battery backup requirements for vital emergency notification equipment so that the public can be promptly notified of a radiological emergency in the event of an accident or act of terrorism. The petition stated that grid failures due to lightning, hurricanes, ice storms, earthquakes, and mechanical failures in the electricity distribution system routinely cause a loss of power to community alerting systems near nuclear power stations. The petition requested that the sirens be supported with chargeable battery backup systems, preferably powered by photovoltaic solar arrays so as to ensure siren operation for the duration of any emergency. Supplements to the petition identified existing examples of solar-powered sirens at remote locations and requested retrofitting of entire siren systems with battery backup power. Despite the fact that relatively few of its emergency planning zones are equipped to function in the event of a power loss, the NRC denied the public petition.

In its denial of the petition, the NRC did not dispute the fact that many siren systems surrounding nuclear power stations would fail in the event of a radiological release coinciding with a power blackout. However, the agency's current emergency plan relies upon "local route notifications" wherein first responders (police and fire department personnel, etc.) travel in emergency vehicles through neighborhoods within ten-mile emergency planning zones and communicate instructions to residents using bullhorns.[238] Nevertheless, it appears that PEM fuel cells could be used in lieu of battery systems, should NRC eventually decide that all of its emergency siren systems should be equipped with backup power.

NWS

The NOAA Weather Radio (NWR) All Hazards is a nationwide network of radio stations broadcasting continuous weather information directly from a nearby National Weather Service (NWS) office. NWR is an "All Hazards" radio network, making it a single source for comprehensive weather and emergency information. NWR broadcasts NWS warnings, watches, forecasts, and other hazard information 24 hours per day. In conjunction with federal, state, and local emergency managers and other public officials, NWR also broadcasts warnings and post-event information for all types of hazards – including natural (e.g., earthquakes or avalanches), environmental (e.g., chemical releases or oil spills), and public safety (e.g., AMBER alerts or 911 Telephone outages).[239] Ensuring that NWR remains functional through the use of redundant transmitters and backup power was identified in a 2004 internal memorandum as a key priority

[238] Nuclear Information and Resource Service. 2005. NRC denies public petition for battery back up power to emergency sirens: Nuclear accident notification systems broadly vulnerable to grid power failures. Available at http://www.nirs.org/press/05-20-2005/1 [Accessed October 2006].

[239] NOAA, National Weather Service. 2006. NOAA Weather Radio All Hazards. Available at http://www.weather.gov/nwr/ [Accessed October 2006].

for the NWS from FY2007 through FY2011.[240] NWR is a prime example of a potential communication-related application for PEM fuel cells.

USCG

The USCG is responsible for operating and maintaining remote communications stations, radio navigation stations, weather stations, lighthouses, and lighted structures with audible warning signals to aid in navigation. Often, these sites draw power from older or unreliable power sources, which are costly to repair and frequently out-of-service.[241] Some of these sites are in environmentally-sensitive areas, and in many instances, historical or spatial restrictions limit the use of solar panels. The USCG appears to have a need for PEM fuel cells in lieu of older power sources and innovative but impractical solutions such as solar panels.

Backup power to federal agency activities, like those described above, is commonly supplied through diesel generators and/or batteries. Diesel generators are generally used for large, energy-intensive applications. Batteries are commonly used for smaller applications. For examples of specific backup power systems at various organizations, with a summary of primary research surveys and interviews, refer to the Market Segment Analysis section..

MARKET SIZE

The federal government spent $7.4 billion to consume 1 quadrillion Btu of site-delivered (end use) energy in 2000.[242] However, energy consumption in government buildings dropped 23% between 1985 and 2000 due to better energy management.[243] Detailed statistics on the amount of backup power consumed at federal facilities were not found.

Each federal agency included in this analysis is associated with distinctive sites and critical energy applications for which PEM fuel cells may be suitable. Limited information was available on the number of sites of application. Details on the number of facilities operated by various federal users are shown below, which may give some insight on the size of the various federal users.

DHS

Twenty-two federal agencies were combined to form the DHS. DHS components include the USCG, FEMA, the Secret Service, and the Transportation Security Administration. Due to this diversity, DHS-related facilities vary widely in size and are located throughout the U.S.

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[240] Johnson, D.L. 2004. FY07-FY11 Program Baseline Assessment: NWS Priorities. *Memorandum from D.L. Johnson to Mission Goal Team Leads and Program Managers*. Available at http://www.nws.noaa.gov/com/files/fy07-11_nws_priorities.pdf [Accessed October 2006].

[241] D'Entremont, J. 2001. Coast Guard looks at fuel cells as a new energy source: Cape Henry lights the way. Lighthouse Digest June 2001: 20.

[242] U.S. Department of Energy. 2006. Federal Energy Management Program. Available at http://www1.eere.energy.gov/femp/ [Accessed October 2006].

[243] The Alliance to Save Energy. 2005. Topics. Available at http://www.ase.org/section/topic [Accessed October 2006].

DOE

In addition to DOE Headquarters in Washington, D.C., the DOE operates approximately 14 regional operations offices that oversee activities in support of the missions assigned to the Department.[244] Also, the DOE owns 21 national laboratories and technology centers throughout the country, which employ more than 30,000 scientists and engineers.[245]

DOI

The DOI, through its Bureau of Reclamation (BOR), is the largest water distributor in the country. In total, the DOI provides water to 31 million citizens through 820 dams and reservoirs.[246] BOR also operates 58 hydroelectric power plants, which serve 6 million households. BOR has deployed multiple backup power systems at these plants to provide emergency power to systems such as plant protection, controls, security, communications, and lighting.

EPA

EPA occupies approximately 190 offices and laboratories nationwide. Approximately 57 of these are classified as large facilities (i.e., greater than 20,000 gross square feet in area): they include 29 major laboratory facilities, 10 regional offices, 6 large program offices, and 12 headquarters office buildings. The rest of EPA's facilities are smaller, special-purpose buildings and project offices scattered throughout the U.S. EPA facilities are owned by the Agency, owned or leased by the GSA and assigned to EPA, or leased directly by EPA.[247]

FAA

According the Central Intelligence Agency's World Factbook, there are currently 14,858 airports in the U.S.[248] As described above, the FAA is responsible for maintaining air traffic safety and facilitating air navigation at each of these facilities. Additionally, the FAA operates nine regional offices, one aeronautical center, one technical center, and field offices in each state and in several foreign countries.[249]

FCC

There are six operating bureaus and ten staff offices within the FCC.[250]

FEMA

FEMA, a component of DHS, has more than 2,600 full-time employees. They work at FEMA headquarters in Washington D.C., at regional and area offices across the country, the Mount Weather Emergency Operations Center, and the National Emergency Training Center in

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[244] U.S. Department of Energy. 2006. Operations offices. Available at http://www.doe.gov/organization/opsoffices.htm [Accessed October 2006].
[245] U.S. Department of Energy. 2006. National Laboratories and Technology Centers. Available at http://www.doe.gov/organization/labs-techcenters.htm [Accessed October 2006].
[246] U.S. Department of the Interior. 2006. Homepage. Available at http://www.doi.gov/ [Accessed October 2006].
[247] U.S. Environmental Protection Agency. 2006. EPA facilities. Available at http://www.epa.gov/greeningepa/facilities/index.htm#labs [Accessed October 2006].
[248] U.S. Central Intelligence Agency. 2006. Field Listing – Airports. The World Factbook. Available at https://www.cia.gov/cia/publications/factbook/fields/2053.html [Accessed October 2006].
[249] Federal Aviation Administration. 2006. Offices. Available at http://www.faa.gov/about/office_org/ [Accessed October 2006].
[250] Federal Communications Commission (FCC). 2006. About the FCC. Available at http://www.fcc.gov/aboutus.html [Accessed October 2006].

Emmitsburg, Maryland. FEMA also has nearly 4,000 standby disaster assistance employees who are available for deployment after disasters. FEMA often works in partnership with other organizations that are part of the nation's emergency management system.[251]

FHWA

FHWA consists of a headquarters office in Washington, DC; a division office in each State (including four metropolitan offices), the District of Columbia, and Puerto Rico; a resource center (with four locations); and three Federal Lands Highway division offices.[252]

GSA

GSA's management oversight covers $500 billion in federal assets, including approximately 8,300 buildings and 170,000 vehicles, and technology programs totaling more than $100 million. GSA National Headquarters is located in Washington D.C. Its 11 regional offices are located in Boston, Massachusetts; New York, New York; Philadelphia, Pennsylvania; Atlanta, Georgia; Chicago, Illinois; Kansas City, Missouri; Fort Worth, Texas; Denver, Colorado; San Francisco, California; Auburn, Washington; and Washington, D.C.[253]

NASA

NASA Headquarters in Washington, D.C. provides overall guidance and direction to the Agency, while 10 field centers and a variety of installations conduct the day-to-day work in laboratories, on airfields, in wind tunnels, and in control rooms.[254]

NRC

The NRC regulates commercial nuclear power plants that generate electricity. Currently, 104 nuclear power plants are licensed to operate in the United States. These plants generate about 20% of the nation's electrical power.[255] In addition, the NRC has four remote regional offices, located in larger cities, which operate as "command-and-control" centers by maintaining computer systems and communications with the power plants. These four offices are located in Philadelphia, Pennsylvania; Chicago, Illinois; Arlington, Texas; and Atlanta, Georgia.[256]

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[251] Federal Emergency Management Agency (FEMA). 2006. About FEMA. Available at http://www.fema.gov/about/index.shtm [Accessed October 2006].

[252] U.S. Department of Transportation, Federal Highway Administration. 2006. Contacts. Available at http://www.fhwa.dot.gov/whoweare/contacts.htm [Accessed October 2006].

[253] U.S. General Services Administration (GSA). 2005. GSA regions overview. Available at http://www.gsa.gov/Portal/gsa/ep/channelView.do?pageTypeId=8199&channelPage=/ep/channel/gsaOverview.jsp&channelId=-13362 [Accessed October 2006].

[254] National Aeronautics and Space Administration (NASA). 2006. NASA sites. Available at http://www.nasa.gov/about/sites/index.html [Accessed October 2006].

[255] U.S. Nuclear Regulatory Commission. 2006. Power reactors. Available at http://www.nrc.gov/reactors/power.html [Accessed October 2006].

[256] U.S. Nuclear Regulatory Commission. 2006. Region I. Available at http://www.nrc.gov/who-we-are/organization/rifuncdesc.html#funcdesc [Accessed October 2006].

NWS

The NWS has approximately 20 Central Weather Service offices; approximately 45 specialized data gathering and forecast centers; 10 regional headquarters and administrative support centers; and dozens of regional weather offices spread throughout the country.[257] Furthermore, NWS has approximately 884 Automated Surface Observing Systems (ASOS) sites.[258] There are 940 NOAA NWR transmitters, covering all 50 states, adjacent coastal waters, and U.S. territories.[259]

USCG

The USCG operates several hundred remote communications stations, radio navigation stations, weather stations, and lighted navigational aid (e.g., lighthouse) stations.[260]

USDA

In addition to USDA Headquarters in Washington, D.C., the Department maintains USDA Service Centers throughout the U.S. Each of these Service Centers serves a fairly limited geographic region (e.g., a county or metropolitan area) and is designed to be a one-stop resource for the services provided by three USDA agencies: the Farm Service Agency, the Natural Resources Conservation Service, and Rural Development. Each U.S. state and territory contains multiple USDA Service Centers; some states may contain dozens.[261]

USPS

The USPS operates an estimated 26,958 establishments in the U.S., employing over 709,000 individuals.[262]

MARKET TRENDS

The federal government is the largest energy consumer in the United States, with new mandates to meet increased demand, reduce peak operating costs, enhance energy security, and improve the reliability of electric power generation through the use of distributed generation (DG) and CHP technologies.[263] Recent federal mandates, including the Energy Policy Act of 2005 (EPAct 2005)[264] and Executive Order 13123,[265] require energy reduction and "greening initiatives" for federal operations. Individual federal agencies also may have internal goals for reducing energy costs and consumption.

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257 NOAA, National Weather Service. 2005. NWS organization. Available at http://www.weather.gov/organization.php?task=cwsu.php#task [Accessed October 2006].

258 Personal Communication between Rachel Sell (Battelle) and Tony Leonardo (National Weather Service), June 2006.

259 NOAA, National Weather Service. 2006. NOAA Weather Radio All Hazards. Available at http://www.weather.gov/nwr/ [Accessed October 2006].

260 U.S. Coast Guard Research and Development Center. 2003. Cape Henry Lighthouse Fuel Cell Evaluation, Final Report. Report No. CG-D-05-03. Available at www.rdc.uscg.gov/Reports/2003/CGD0503Report.pdf [Accessed October 2006].

261 United States Department of Agriculture. 2006. USDA Service Center Locator. Available at http://offices.sc.egov.usda.gov/locator/app?service=action/1/CountyMap/1/NavBar.HomeLink [Accessed October 2006].

262 Dun and Bradstreet. 2006. Zapdata industry report: U.S. Postal Service (4311). Available at http://www.zapdata.com [Last Accessed October 2006].

263 United States Combined Heat & Power (CHP) Association. 2006. CHP market studies. Available at http://uschpa.admgt.com/markets.htm#dist [Accessed October 2006].

264 The Library of Congress. 2005. H.R.6: Energy Policy Act of 2005. Available at http://thomas.loc.gov/cgi-bin/query/F?c109:6:./temp/~c109idTQ7y:e790842 [Accessed October 2006].

265 U.S. Department of Energy, CEQ NEPAnet. 1999. Executive Order 13123. Available at http://ceq.eh.doe.gov/nepa/regs/eos/eo13123.html [Accessed October 2006].

EPAct 2005 contains numerous provisions related to the use of clean, efficient, and renewable energy sources, including fuel cells, which affect federal agencies. Section 783 of the Act (Federal Procurement of Stationary, Portable, and Micro Fuel Cells) requires the head of any federal agency that uses electrical power from stationary, portable, or microportable devices to lease or purchase a fuel cell to meet certain energy savings goals, provided that the agency head is able to identify an appropriately efficient and reliable fuel cell to meet the agency's needs. The cost of leasing or purchasing stationary, portable, and microportable fuel cells is to be paid or shared by the DOE, in cooperation with the Hydrogen and Fuel Cell Technical Task Force and the Technical Advisory Committee. The DOE may use the GSA or other vendors to ensure cost-effective fuel cell purchases or lease arrangements.[266]

Executive Order 13123, passed in 1999, calls upon federal agencies to improve the energy efficiency of their buildings, promote the use of renewable energy, and reduce greenhouse gas emissions. This Order requires greater use of renewable energy by implementing renewable energy projects and by purchasing electricity from renewable sources. The goal for new renewable energy use by the federal government was set at 1,384 gigawatt-hours (GWh) by 2005. In 2003, federal agencies reported that they were purchasing or producing over 600 GWh of new renewable energy, or over 40% of that goal. The Order also requires federal facilities to achieve a 30 % reduction in greenhouse gas emissions by 2010, compared to 1990 levels. By FY 2001, carbon emissions from energy used in non-exempt federal facilities declined 19.4% compared to the 1990 base year. The federal government exceeded the 20% reduction goal established for FY 2000, relative to the 1985 base year. More recently in 2001, agencies reduced their gross square foot energy consumption by more than 23%, relative to the base. The government also saved more than $1.3 billion in 2001, on a constant dollar basis, relative to 1985, in reduced energy bills, much of which can be attributed to energy efficiency improvements.[267]

EPA is one example of a federal agency that has been working diligently to reduce its actual energy use, decrease its water use, and increase its green power purchases as it moves forward to meet Executive Order 13123 goals. Due to its green power purchases, EPA reduced its reported FY 2005 energy consumption by approximately 40% from its FY 1990 baseline, helping the Agency to far exceed its goal of a 20% reduction. DOE reporting guidelines allow agencies to net out green power purchases from reported energy consumption; without the green power credit, EPA's actual FY 2005 energy consumption was only 1.2 % below the baseline). EPA is nearing completion on multiple commissioning projects and mechanical equipment upgrades at its largest energy-using facilities and expects substantial energy consumption reductions to be reported in FY 2006. In meeting its future energy reduction goals, EPA expects to have a better balance between energy use reductions and green power purchases.[268]

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[266] The Library of Congress. 2005. H.R.6: Energy Policy Act of 2005. Available at http://thomas.loc.gov/cgi-bin/query/F?c109:6:./temp/~c109idTQ7y:e790842 [Accessed October 2006].
[267] Garman, D.K. 2003. Testimony of David K. Garman, Assistant Secretary, Energy Efficiency and Renewable Energy, Before the House Committee on Government Reform – Energy Efficiency Improvements in Federal Buildings and Vehicles. Available at http://www1.eere.energy.gov/office_eere/congressional_test_0312_203.html [Accessed October 2006].
[268] U.S. Environmental Protection Agency. 2006. Greening EPA: Results and Projections. Available at http://www.epa.gov/greeningepa/energy/results.htm [Accessed October 2006].

While fuel cells have not been widely adopted by federal agencies, several federal agencies have begun demonstrating fuel cell systems. Examples of fuel cell installation and demonstration activities at federal agencies are presented below.

DOI

The DOI's Bureau of Reclamation operates 58 hydroelectric power plants and has multiple backup power systems deployed at these plants to provide emergency power to systems such as plant protection, controls, security, communications, and lighting. In 2003, the BOR's Hydroelectric Research and Technical Services Group investigated backup power sources for use at BOR plants and determined that PEM fuel cell technology was the best choice for one of the Bureau's sites in Colorado.[269] Prior to this evaluation, all the DC backup power needs at the BOR had been met by batteries and/or engine-driven generators.[270]

A PEM fuel cell system was installed in October 2003 at the Pole Hill Power Plant near Loveland, Colorado, to replace an existing battery bank of 48V-DC batteries at a communication site. This site was selected because the existing battery bank was scheduled for replacement.[271] The site had extreme temperature ranges during the year (-25º C to 40º C), which demonstrated the fuel cell system's ability to operate in harsh environments. It was specified that the system should be able to provide extended backup power for up to 3 days of continuous operation. Testing continued for 3 months and was cycled 50 times, for a total run time of approximately 25 hours.

At the conclusion of this demonstration, the BOR concluded that it would not recommend the use of PEM fuel cells for primary or vital systems, such as power plant control and protection power, until a proven track record of performance is established. Instead, the BOR would consider the use of fuel cells for less critical systems, such as communications and monitoring systems. The BOR is considering additional sites for future PEM fuel cell applications and is planning to monitor the existing fuel cell system for 5 years, with completion of the project expected in fiscal year 2008.[272]

EPA

The mission of EPA's National Vehicle and Fuel Emissions Laboratory (NVFEL), operating since 1971 in Ann Arbor, Michigan, is to advance clean vehicle fuels and technologies. As part of major project to replace its aging and obsolete heating, ventilation, and air conditioning (HVAC) system with an energy-efficient alternative, NVFEL incorporated a 200 kW PAFC fuel cell into the initial design of the new HVAC system. The fuel cell's electrical and thermal outputs are connected to primary electrical and heating systems. The fuel cell serves part of the

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[269] Myers, N. and J. DeHaan. 2005. Fuel Cells: Will Fuel Cells Be Replacing Batteries at Your Facility? Presented at the Battcon Conference, May 2005. Bureau of Reclamation Hydroelectric Research and Technical Services Group, Denver, CO.

[270] U.S. Department of Energy, Federal Energy Management Program. 2005. Fuel Cells in Backup Power Applications. Technology Installation Review, DOE/EE-0310. Available at http://www1.eere.energy.gov/femp/pdfs/hydrogenfc_tir.pdf [Accessed October 2006].

[271] U.S. Department of Energy, Federal Energy Management Program. 2005. Fuel Cells in Backup Power Applications. Technology Installation Review, DOE/EE-0310. Available at http://www1.eere.energy.gov/femp/pdfs/hydrogenfc_tir.pdf [Accessed October 2006].

[272] U.S. Department of Energy, Federal Energy Management Program. 2005. Fuel Cells in Backup Power Applications. Technology Installation Review, DOE/EE-0310. Available at http://www1.eere.energy.gov/femp/pdfs/hydrogenfc_tir.pdf [Accessed October 2006].

base load of the facility, reducing electrical demand by nearly 200 kW. The new system became fully operational in March of 2001.[273]

FAA

In 2003, a 3 kW ReliOn PEM fuel cell unit (consisting of six smaller 500-W modular fuel cells) was installed at McChord Air Force Base in Tacoma, Washington. Sponsored by Construction Engineering Research Lab (CERL), a division of the U.S. Army Engineer Research and Development Center (ERDC), the fuel cells were installed as part of a 1-year demonstration project (through April 2004). The fuel cell system, which ran on unpressurized, industrial-grade hydrogen, backed up communications for an FAA radar system.[274] As part of the demonstration, the PEM fuel cell system responded to a loss in power and supplied backup power to a load bank located at an FAA-owned and operated radio transmitter and receiver (RTR) site. Over the demonstration period, the system was monitored for over 8,800 hours and accumulated over 1,100 successful starts, for a total system run time of 419 hours.[275]

NASA

NASA has been involved in fuel cell research and development for several niche applications. NASA's Glenn Research Center conducts research in energy storage technologies, including fuel cells, regenerative fuel cells, batteries, and flywheels, and has recently adopted PEM fuel cells. The Center conducted technology advancement programs on the Gemini PEM fuel cell and the Apollo alkaline fuel cell. It was responsible for advancing and qualifying primary fuel cell power technology for the Space Shuttle's onboard power system. It also developed the technology and supported advanced development activities for the alkaline fuel cells used in the Apollo missions and the Space Shuttle. The Center leads development of modular PEM fuel cell stack technology for use in Launch Vehicles. This technology provides increased peak-to-nominal power capability and improved reliability. Glenn is also leading the effort to evaluate and develop fuel cell and regenerative fuel cell energy storage systems for missions with long eclipse periods, such as Lunar/Mars bases, unmanned aerial vehicles, and high-altitude balloons. Totally passive components are the focus of this effort to minimize the weight, improve the energy density, and maximize the reliability of these systems.[276]

In 2005 Teledyne Energy Systems, Inc., engineered a PEM fuel cell power plant and delivered it to NASA's Glenn Research Center for testing in the Center's state-of-the-art fuel cell test facility. This fuel cell was noted to be the first high-fidelity, 12 kW PEM fuel cell hardware for space applications evaluated in a spaceflight-like environment.[277,278]

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[273] U.S. Environmental Protection Agency/U.S. Department of Energy. 2002. Laboratories for the 21st Century: Case Studies. The U.S. Environmental Protection Agency's National Vehicle and Fuel Emissions Laboratory, Ann Arbor, Michigan. Available at http://www.epa.gov/lab21gov/pdf/cs_nvfel_508.pdf [Accessed October 2006].

[274] Fuel Cells 2000. 2005. McChord Air Force Base, FAA radio transmitter-repeaters. Available at http://www.fuelcells.org/db/project.php?id=634 [Accessed October 2006].

[275] U.S. Department of Energy, Federal Energy Management Program. 2005. Fuel Cells in Backup Power Applications. Technology Installation Review, DOE/EE-0310. Available at http://www1.eere.energy.gov/femp/pdfs/hydrogenfc_tir.pdf [Accessed October 2006].

[276] National Aeronautics and Space Administration (NASA). 2006. NASA Glenn Research Center - Exploration Systems. Available at http://www.nasa.gov/centers/glenn/projects/exploration.html [Accessed October 2006].

[277] No author. 2006. NASA Fuel Cell Undergoing Tests. Fuel Cell Today (January 5, 2006). Available at http://www.fuelcelltoday.com/FuelCellToday/IndustryInformation/IndustryInformationExternal/NewsDisplayArticle/0,1602,7011,00.html [Accessed October 2006].

[278] Teledyne Technologies Incorporated. 2005. Teledyne delivers 12 kW PEM fuel cell power plant to NASA. Available at http://www.investquest.com/iq/t/tdy/ne/news/tdy080905pem.htm [Accessed October 2006].

USCG

The USCG began investigating the use of fuel cells in 1998 in an effort to meet energy objectives that called for a 20% reduction in facility energy costs from 1995 levels by 2005. The objectives further mandated that USCG minimize the use of petroleum fuels in all its facilities and platforms.[279] With funding from the Green Power Initiative of the Renewable Energy Trust (administered by the Massachusetts Technology Collaborative), DoD's Climate Change Fuel Cell Program, and Key-Span Energy, the USCG Research and Development Center installed one of the first fuel cells in the New England region in 2003. This fuel cell, a 250 kW FuelCell Energy Model DFC 300, is located at the USCG Air Station Cape Cod in Bourne, Massachusetts. Air Station Cape Cod is one of the largest USCG air stations on the East Coast, providing support for both fixed-wing aircraft and helicopters for search and rescue, maritime law enforcement operations, and other missions.

In addition to electric power, the Air Station Cape Cod fuel cell provides heat for domestic hot water for barracks and an associated galley and, at full 250 kW design output, has the potential to provide space heating for the entire building. In its first 12 months of operation (2003 to 2004), the fuel cell averaged an operating availability of 96.2% above its first year's expected design availability, producing a total of 1,392 megawatt-hours of electricity. Over the same year, approximately 1,832 million Btu of recovered heat was utilized for domestic hot water use, offsetting the purchase of nearly 26.3 million cubic feet of natural gas and resulting in a total net savings of almost $24,000 in operating expenses. Demonstrating a key benefit of fuel cell technology, in 2003 the fuel cell provided emergency power to the barracks and galley during several short grid outages, and in September 2003 was operated in a totally grid-independent mode as a precaution against potential grid power loss during a hurricane.[280] Air Station Cape Cod intends to operate the fuel cell as long as the economics are favorable.[281]

Another USCG-affiliated fuel cell demonstration took place at the Cape Henry Lighthouse in Virginia Beach, Virginia, in 2002. As noted above, the USCG operates several hundred remote communications, navigation, and weather stations with limited access to reliable, efficient power sources. Over the past few years, low-power fuel cell systems have emerged as a potential option in the suite of remote power technologies. To assess the potential of fuel cells in an operational marine environment, the USCG Research and Development Center installed and demonstrated a 3 kW, direct methanol fuel cell at the Cape Henry Lighthouse.

The Cape Henry installation was placed into service in March of 2002 and ran for approximately 6 months. Performance data such as fuel consumption, power output, and reliability were collected and compared with conventional energy technologies. An evaluation of costs, safety, training, fuel logistics, and other factors was conducted to assess the potential for future use of

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[279] U.S. Department of Energy, Federal Energy Management Program. 2005. U.S. Coast Guard Air Station Cape Cod demonstrates successful fuel cell. FEMP Focus – Summer 2005. Available at http://www.eere.energy.gov/femp/newsevents/fempfocus_article.cfm/news_id=9327 [Accessed October 2006].

[280] U.S. Department of Energy, Federal Energy Management Program. 2005. U.S. Coast Guard Air Station Cape Cod demonstrates successful fuel cell. FEMP Focus – Summer 2005. Available at http://www.eere.energy.gov/femp/newsevents/fempfocus_article.cfm/news_id=9327 [Accessed October 2006].

[281] U.S. Department of Energy, Federal Energy Management Program. 2004. Fuel Cell Demonstration at the U.S. Coast Guard Air Station Cape Cod. Case Study PNNL-SA-42044, August 2004. Available at http://www1.eere.energy.gov/femp/pdfs/fuel_cell_cs.pdf [Accessed October 2006].

fuel cells at other Coast Guard operational sites. Results of this demonstration were mixed, as several problems with fuel supply and overheating were observed. However, the technology appears to have significant promise and should be closely monitored by the USCG as manufacturers introduce more reliable systems.[282]

USPS

While no evidence was found to suggest that USPS has installed fuel cells for backup power, the agency has begun testing hydrogen fuel cell-powered vehicles. In September 2006 the USPS announced that it had agreed to extend a program with General Motors for another year of testing GM HydroGen3 minivans in Washington, DC, and Irvine, CA. The USPS already boasts 37,000 alternative-fuel vehicles in its fleet.[283]

MARKET SEGMENT ANALYSIS

To identify the market opportunities for direct PEM fuel cells as backup power for federal agencies, several agency representatives were contacted. In total, 13 federal agencies were contacted, seven responses were received, and nine interviews were conducted. A detailed summary of the contacts made and responses received from each agency is presented below.

DHS

Two DHS officials were contacted. No responses were received.

DOE

Three DOE national laboratories were contacted (Idaho, Brookhaven, and Lawrence Livermore National Laboratories). One complete survey response was received, and one interview was conducted.

The survey respondent identified a need for backup power for life safety systems (i.e., emergency lights, fire protection, and security), programmatic data protection, computer protection, and hospital certification. Life safety systems were cited as the most important application requiring backup power. The respondent's facility employs over 32 fixed emergency generators and numerous battery backup and UPS systems; systems range in size from < 5 kW to 1 MW. Four of the fixed generators are < 50 kW and support life safety needs in smaller facilities. The facility also utilizes a number of small portable generators in the 5 to 50 kW range that can be moved around the site to support various power needs during planned or forced power outages. UPS systems are typically owned by individual scientific departments in various locations around the site. The majority of these support data protection and allow the orderly shutdown of computer equipment in the event of a power outage.

The survey respondent indicated the frequency and impact of grid power outages at the national laboratory. Approximately four partial outages (lasting < 1 second) had occurred in the past year. Even short outages can be very disruptive to the national laboratory, if their large research machines are on-line. In the middle of winter, an extended outage could be devastating due to freeze damage. An estimated one to two grid power outages occur each year that are considered

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[282] U.S. Coast Guard Research and Development Center. 2003. Cape Henry Lighthouse Fuel Cell Evaluation, Final Report. Report No. CG-D-05-03. Available at www.rdc.uscg.gov/Reports/2003/CGD0503Report.pdf [Accessed October 2006].

[283] Hoovers, Inc. 2006. United States Postal Service fact sheet. Available at http://premium.hoovers.com/ [Accessed October 2006].

very disruptive. Possible consequences of power outages include: loss of lives, security breaches, implementation of emergency management plans, and disruptions in production.

The survey respondent indicated the importance of various factors in selecting a backup power system. The respondent cited reliability, ease of use use/maintenance, and good experience with a system as the most important factors in selecting a backup power system.

The survey respondent rated the overall performance of their current backup power systems as very good. The respondent indicated the greatest satisfaction with the following aspects of their current backup power systems: fuel availability, ease of use/maintenance, lifetime of the unit, and reliability. To ensure the performance and reliability of their emergency generators (to start and perform as required), the national laboratory conducts an extensive preventive maintenance program and testing program. The performance of UPS system is less certain because each department or division owns its own units and usually relies on outside services for maintenance.

The survey respondent anticipated a growing need for backup power among federal agencies in the next three years. However, the respondent had not considered alternatives to their current backup power systems and was not aware of PEM fuel cells as a backup power source.

The survey respondent reported that capital purchase decisions are made on the basis of need, funding availability, and priority. Purchasing decisions for backup power systems are made by the plant engineering division manager.

One national laboratory interviewed for this analysis reported using diesel generators for backup power and UPS systems for emergencies.

FAA

One FAA official was contacted in fiscal year 2006. No response was received from this individual. In fiscal year 2005, an individual from the FAA was contacted for information on the potential for PEM fuel cells at their facilities. Feedback received then is summarized below.

The FAA representative contacted in 2005 reported that FAA was a partner with DoD in a PEM fuel cell demonstration at a U.S. Air Force Base. Six 3 kW hydrogen fuel cells were installed in March 2002 and operated for 391 hours, providing backup power at a Radio Transmit and Receive (RTR) site. Specific loads powered included building lighting, building bay doors, and the building local area network (LAN) switch.

The respondent indicated that environmental concerns were very important in influencing the FAA's decision to conduct a PEM fuel cell demonstration. The respondent identified the following critical issues for the fuel cell application: reliability, start-up time, usability, and durability for use in an outdoor enclosure in a remote location.

The respondent reported that cost plays a role in influencing the decision to purchase fuel cells but that reliability, power quality, and durability (life) of a system are more important. The respondent noted that the reliability of fuel cells is an important benefit that affects the purchasing decision. The respondent indicated that downtime of an RTR site can have a significant impact at larger airports, costing up to $1 million per day.

The respondent discussed other alternative technologies for backup power and indicated that photovoltaic and wind power would be considered as alternatives to batteries. The respondent commented that generators and batteries are expensive and indicated a desire to move away from these systems due to the maintenance required. The respondent reported that capital purchasing decisions are made using centralized energy management.

The respondent reported that the FAA was very pleased with the performance of the fuel cell system and has purchased additional fuel cell systems for installation at other sites. The fuel cells were easy to use, and remote monitoring facilitated maintenance of the system.

When asked to identify the primary barriers that impede wide-scale commercialization of PEM fuel cells, the respondent indicated that the most important barriers were the durability of PEM fuel cells and the need for a reformer. The respondent also identified the following as important barriers to wide-scale commercialization of PEM fuel cells: balance of plant issues, fuel supply, service infrastructure, lack of storage technologies, lack of national policy on fuel cells, national/state/local incentives for adoption, lack of funding for development, and lack of a champion for fuel cell commercialization.

FEMA

State agencies affiliated with FEMA were contacted as part of the Emergency Response market segment. No federal FEMA officials were contacted.

DOT

One DOT official was contacted. One interview was completed.

The interviewee commented on sources of power used at DOT facilities. The government has set goals for increasing the percentage of renewable energy used at government facilities. Currently, 0.9% of power used at DOT facilities is renewable energy, a considerable portion of which is geothermal energy. The interviewee also noted that DOT does not own many of its buildings but rents or uses GSA space.

The interviewee was not aware of PEM fuel cells as a source of backup power and did not anticipate that PEM fuel cells would be considered at government facilities because their percent use is presently very low. However, with incentives, the interviewee expected PEM fuel cells to be considered as an alternative backup power source. The interviewee cited radar as one application of backup power.

NASA

Five NASA officials were contacted. One complete survey response was received, and one interview was conducted.

The survey respondent represented a NASA research center with critical backup power needs for research, operations, communication, and data collection and storage. The facility utilizes batteries, UPS systems, and diesel and propane generators for backup power. These systems range in size from < 5 kW to > 250 kW. Based on the size and diverse nature of the work performed at the research center, there is no typical size of backup power system.

The survey respondent reported one to two power outages across the entire lab in the past year, and four to six in isolated areas. These power outages were estimated to last from 1 second to 2 hours. The respondent indicated that any power outage, whether 1 second or 4 hours in duration, would be very disruptive without backup power. The respondent estimated that one grid power outage that is considered very disruptive occurs each year. Potential consequences of power outages at the respondent's facility include: implementation of emergency management plans, disruptions in production, disruptions in distribution, and loss of research data.

The survey respondent rated the overall performance of their current backup power systems as very good. The respondent indicated the greatest satisfaction with the following aspects of their current backup power systems: reliability, capital cost, lifetime of the unit, annual operating cost (fuel and maintenance), start-up time, and fuel availability. The respondent noted concerns with the reliability of their current backup power systems and operating costs for a sufficient amount of standby power.

The survey respondent rated the importance of several factors in selecting a new backup power system. Reliability, capital cost, lifetime of the unit, annual operating cost (fuel and maintenance), emissions, start-up time, ease of use/maintenance, and fuel availability were all considered very important factors in selecting a backup power system. Good experience with a system was considered less important than the above factors. The respondent cited reliability, capital cost, annual operating cost, and ease of use/maintenance as the most important.

The survey respondent reported that capital purchase decisions for backup power systems are made on the basis of initial capital cost, payback period, and return on investment. Government incentives are not considered in making a purchasing decision. Purchasing decisions for backup power systems are made by high- and low-voltage power system managers.

The survey respondent anticipated a growing need for backup power among federal agencies in the next 3 years. The respondent agreed to be contacted again for further information.

The survey respondent was aware of PEM fuel cells as a source of backup power and had considered fuel cells as an alternative. However, the respondent felt that the capital cost of fuel cells was still too high for them to compete favorably with their existing backup power systems. The respondent also cited concerns about using hydrogen as a fuel. The respondent identified factors that would drive a decision to purchase PEM fuel cells, including: the cost of not having electricity, or having a power failure; dissatisfaction with the current mode of backup power; energy efficiency of PEM fuel cells as compared to alternatives; environmental concerns; and a track record of others using the PEM fuel cell system.

An interview was also conducted with a representative of the NASA Johnson Space Center. The interviewee commented on NASA's present use of fuel cells and potential opportunities for the use of PEM fuel cells in the near future. Currently, NASA is primarily interested in the use of fuel cells on spacecraft and is working to certify them under various conditions of use. NASA has returned to using alkaline fuel cells that were used in the Apollo flights and expects to use them on future missions as well. PEM fuel cells are one of various energy technologies used on-board the spacecraft. NASA is considering the capture of hydrogen from rocket propellant for use in PEM fuel cells; however, this is presently just a proposal to conduct research.

The interviewee noted that NASA has also shown interest in using PEM fuel cell vehicles at various sites, and one 2-week test using a fuel cell vehicle was conducted. NASA would consider converting fleets to fuel cell vehicles, if funding were available. Terrestrial applications of PEM fuel cells for backup power exist; however, these are lower priority and are greatly dependent on the availability of funds.

The interviewee discussed potential drivers for the adoption of PEM fuel cells. The interviewee stated that mandates are necessary to drive PEM fuel cell adoption. Budgets are tight, particularly for more expensive, unproven alternatives without clear benefits. No funding is presently available for fuel cell development. The interviewee could recall only one mandate from 1976 for NASA to assist in the understanding of the science behind fuel cells. The interviewee expected the recent increase in the price of gasoline to drive mandates (with funding support) for fuel cells.

NRC

Two NRC officials were contacted. One interview was conducted.

The interviewee described backup power at the approximately 104 nuclear power plants operating in the U.S. A nuclear plant typically has multiple, large emergency diesel generators on site for emergency power. For example, one plant has five separate 4,400 kW units. Nuclear power plants have some backup power needs for communications and security issues, which are normally fed from the emergency diesel generators, but might have a need for an independent backup power source. Nuclear plants also employ dedicated battery circuits (battery banks). The main reason for backup power at nuclear power plants is safety, to control plant shutdown, and to keep the plant cool. There are a myriad of regulatory requirements to meet that driver.

The interviewee commented on potential applications for PEM fuel cells at nuclear power plants. He suggested that fuel cells could possibly replace the following current battery applications:

- Emergency power for communications (e.g., walkie talkies recharged by fuel cells in lieu of batteries)
- Emergency instrumentation and control equipment used during loss of power (to monitor the reactor)
- The interviewee was uncertain about the backup power source for emergency sirens. He speculated that it was tied to the battery backup for instrumentation and control equipment.

The interviewee estimated that each nuclear plant has five vital batteries that offer potential for fuel cell technology (i.e., replacement by a fuel cell). Each battery could provide emergency power of approximately 700 amps in the first minute, < 500 amps in the first 30 minutes, and 300 amps for up to 6 hours.

The interviewee explained that NRC is the regulator, not the operator, of nuclear power plants. NRC is responsible for assuring that nuclear power plants operate safely and meet federal regulations, but NRC does not purchase or maintain backup power units for nuclear power plants. NRC has four remote regional offices (similar to command and control centers), located in large U.S. cities, and maintains communication with nuclear power plants. The interviewee was not aware of fuel cells being used at NRC offices.

Purchases of backup power systems for nuclear power plants are made by plant operators, not NRC. There are about 12 or 24 operators for the approximately 100 plants in the U.S. Fairly large corporations operate a number of nuclear sites. The interviewee cited Entergy as an example. Entergy operates 11 nuclear units at nine plant sites in seven states.

NWS

One NWS official was contacted. One complete response was received.

The respondent described the primary drivers for backup power to support the maintenance of weather data collection platforms and weather data dissemination. Hurricane Isabel (2003), Hurricane Charley (2004), and Hurricanes Katrina and Rita (2005) resulted in an identified need for an uninterrupted supply of meteorological and climatologic data. Two mission-critical weather systems were identified as vulnerable to failure during severe weather events (i.e., 40+ mph winds, tropical cyclones, winter storms, and local thunderstorms). This vulnerability was due to commercial and telecommunication outages.

The respondent indicated the frequency and impact of power outages at Automated Surface Observing System (ASOS) sites (owned by NWS and FAA) and NWS NOAA weather radio (NWR) sites. Each site may experience several minor power outages annually. Outages caused by severe weather events occur approximately once a year. Outages lasting from 1 second to 4 hours are not uncommon. Outages of 1 second duration are not considered disruptive; however, longer outages (e.g., 1 to 4 hours) are very disruptive. The respondent indicated that power outages could result in loss of lives, disruptions in distribution (of data), and loss of data.

ASOS sites currently have UPS systems to address the temporary short-term loss of grid power. The UPS system is capable of supplying backup AC power under full load for a minimum of 10 minutes. The primary purposes of the UPS system, as identified by the respondent, are to provide uninterrupted operation during minor power outages and fluctuations, to filter facility power (i.e., during power surges), and to allow uniform (orderly) shutdown of an ASOS in a prolonged power outage. In its current configuration, the UPS is not designed to sustain operations for prolonged power outages, and backup engine generators are needed.

NWR locations currently do not have UPS units to address the short-term loss of grid or have the ability to filter facility power. Backup engine generators are needed for NWR sites.

To address the deficiencies identified above, the respondent reported that NWS is currently procuring 238 backup power generators in the 11 to 12 kW range and 40 generators in the 20 to 22 kW range. The generators will be liquid propane vapor compatible engine generators or hydrogen fuel cells that convert liquid propane vapor to hydrogen gas. Both types of systems must meet the standard for stationary engine generators (UL 2200).

The respondent rated the importance of several factors in selecting a backup power system. Reliability, capital cost, lifetime of the unit, annual operating cost (fuel and maintenance), emissions, start-up time, ease of use/maintenance, and fuel availability were all considered very important factors in selecting a backup power system. The respondent cited reliability, lifetime, and capital cost as the most important factors.

The respondent was not very well satisfied with the performance of the agency's existing backup power systems. ASOS sites do not currently have a UPS that can provide 10 minutes of backup power, and NWR sites do not have NWR-owned UPS units; some NWR sites are supported by non-NWS-owned standby generators. The respondent rated the reliability, annual operating cost (fuel and maintenance), emissions, start-up time, and fuel availability of existing backup power units as very good; capital cost, lifetime of the unit, and ease of use/maintenance were rated not so good.

The respondent was aware of PEM fuel cells as a source of backup power but did not think they were likely to compete favorably with existing backup power systems due to cost. The respondent did not have any concerns with using hydrogen as a fuel. The respondent identified several factors that would drive a decision to purchase PEM fuel cells for backup power, including the cost of not having electricity, or having a power failure; dissatisfaction with the current mode of backup power; energy efficiency of PEM fuel cells as compared to alternatives; environmental concerns; availability of government incentives; and track record of others using the PEM fuel cell system.
The respondent provided information on the capital purchase decision process within NOAA. Many factors contribute to government procurement decisions, including initial capital cost, payback period, and return on investment. Government incentives are also considered in making a purchasing decision. Purchasing decisions for backup power systems are made by the chief of the maintenance branch.

USCG (part of DHS)
Two USCG officials were contacted. One complete response was received, and one interview was conducted.

The respondent represented an island Integrated Support Command facility whose primary functions are search and rescue and law enforcement. The respondent identified a need for backup power to operational units, such as telephones, computers, and other equipment needed for lifesaving operations. The most critical applications requiring backup power were cited as security communication and computers. Specifically, the facility's communication center (CommCenter) is a critical application that requires backup power to be able to respond to off-shore emergency calls (up to 500 miles) and provide alerts in case of terrorist threats.

The respondent indicated the frequency and impact of power outages at the island facility. One outage had occurred in the first 5 months of 2006. The facility experienced four to five outages in 2005, including a failure of the high-voltage line running through the island, which caused a loss of power to the entire island for a few hours. A typical outage lasts between 5 minutes and 1 hour. The respondent reported that outages lasting greater than 1 hour would be highly disruptive without backup power; an estimated one to four power outages that are considered disruptive occur each year. Outages at the facility could potentially result in loss of lives, security breaches, decreased ability to implement emergency management plans, and other disruptions (e.g., sewage removal).

Backup power for the facility is currently provided by batteries, six diesel generators, and three main UPS units. In addition, each computer server has its own UPS unit for backup power (individual computers do not have backup power). Diesel generators support telephones and computers as well as a sewage lift station on the island. A UPS unit (100 to 250 kW) can provide backup power to the facility's CommCenter for 10 minutes.

The respondent rated the importance of several factors in selecting a backup power system. Capital cost, lifetime of the unit, emissions, and start-up time were considered important factors; reliability, annual operating cost, ease of use/maintenance, fuel availability, and good experience with a system were not as important. The respondent cited lifetime of the unit, emissions, and start-up time as the most important factors in selecting a backup power system.

The respondent rated the overall performance of existing backup power systems as very good, although there were concerns noted with maintenance (i.e., finding parts for old machinery). The respondent also indicated a desire to replace diesel generators with an alternate source of backup power.

The respondent was not aware of PEM fuel cells as source of backup power, but has considered a waste heat system fueled by propane as an alternate backup power source. The respondent did not have concerns about using hydrogen as a fuel. The respondent identified potential applications for alternative backup power sources in the 5 to 30 kW power range, the relevant size range for PEM fuel cells. Backup power for security lighting and camera systems on the island, comprised of two circuits of 17 kW each, may be candidate applications for fuel cells.

The respondent anticipated a growing need for backup power in the next 3 years but was not certain of the size of the potential market for PEM fuel cells (i.e., the total number of USCG facilities that would have smaller backup power needs).
The respondent provided information on the procurement process at the USCG facility. Capital purchase decisions are made on the basis of return on investment and other future energy savings, in addition to lifetime of the unit; maintenance costs are not considered in making purchase decisions (to the dismay of the respondent). Capital purchase decisions are made by the Civil Engineering Unit.

The interviewee commented on a 3 kW fuel cell installed at a USCG lighthouse. The USCG considered the potential for fuel cell power at remote applications, and based upon the lighthouse installation, concluded that fuel cell technology was not ready for Coast Guard installations due to cost, maintainability, and other factors.

USDA

Two USDA officials were contacted. One interview was completed.

The interviewee was not aware of fuel cells being used at USDA facilities but mentioned that USDA is considering renewable energy in the form of ethanol and wind. The interviewee noted that USDA facilities are leased, and the lessor may make the purchasing decisions for backup power systems. The interviewee was uncertain whether current backup power systems consisted of generators or other sources.

EPA

Twenty EPA officials were contacted. Three completed responses were received from three EPA research laboratory facilities, and two interviews were conducted with EPA staff.

Respondents reported critical business operations requiring backup power. All three respondents identified computer operations; two identified critical laboratory equipment (e.g., for analysis, refrigeration, and storage); two identified emergency operations or life safety functions; and one identified security.

Respondents reported that between one and six power outages had occurred in the past year. These outages typically lasted less than 3 minutes, but respondents indicated that all outages (whether 1 second or 4 hours) would be very disruptive. Power outages could potentially result in loss of lives, security breaches, implementation of emergency management plans, or disruptions in production at respondents' facilities.

Two respondents use batteries, UPS systems, and generators for backup power. One respondent could not provide details of EPA's backup power system due to security considerations. Both respondents reported using a diesel emergency power generator (one of size 375 kW, and the other 1,200 kW), one to three UPS units approximately 50 kW and larger, and numerous local UPS units. One respondent also reported using a 200 kW PAFC (connected in parallel) for backup power, but noted that it may be decommissioned due to operational costs, parts availability, and reliability.

Respondents were asked to rate the importance of various factors in selecting a backup power system. All three respondents rated reliability, lifetime of the unit, start-up time, and fuel availability as very important factors; two respondents also cited capital cost, emissions, and ease of use/maintenance as very important factors in selecting a backup power system. Good experience with a system was considered important by all three respondents. Annual operating cost was considered important or very important by two respondents, but not so important by one respondent. When asked to identify the three most important factors in selecting a backup power system, respondents cited reliability (two respondents), annual operating cost (one respondent), capital cost (one respondent), lifetime of the unit (one respondent), and ease of use/maintenance (one respondent).

Respondents commented on the performance of their current backup power systems. One respondent rated the performance of the facility's current backup power systems as very good and noted no concerns. Another respondent indicated concerns with the facility's backup diesel generator, including its reliability, emissions, and parts availability; start-up time was also not considered very good.

Respondents varied in their opinions of whether the need for backup power would increase in the next three years. Two respondents anticipated a growing need for backup power among federal research laboratories, and one did not.

Two respondents had considered alternative sources of backup power, including photovoltaic and solid oxide fuel cells, bi-fuel, and co-generation. Two respondents were aware of PEM fuel cells as a power source for backup power applications. Two respondents stated that PEM fuel cells were not likely to compete with existing backup power systems because of high capital costs. However, one respondent commented that EPA's mandate to utilize innovative technology may justify the higher operating and capital costs of fuel cells. One respondent indicated that a decision to purchase PEM fuel cells would be driven by dissatisfaction with the current mode of backup power, energy efficiency of PEM fuel cells as compared to alternatives, environmental concerns, and availability of government incentives.

Respondents commented on the capital purchase decision process in their organizations. Two reported that decisions are made on the basis of initial capital cost and payback period. One respondent indicated that capital purchase decisions are made on the basis of payback period and return on investment. One respondent noted that interaction and installation with existing equipment are also considered. Two respondents indicated that government incentives were considered in making a purchasing decision, while one respondent indicated that they were not. All three respondents reported that procurement decisions are a consolidated effort involving several individuals. At one respondent's facility, an independent analysis is sought before a purchase is initiated.

An interview was conducted with EPA representatives to discuss potential applications for fuel cells at EPA facilities and drivers for adoption. EPA has considered adopting alternative power technologies for new buildings and laboratories and expressed an interest in fuel cells. Drivers for fuel cell adoption at EPA facilities include: a desire to increase the use of alternative technologies, and growth in the number of EPA facilities. However, the size of current PEM fuel cell products may limit adoption.

One EPA division interviewed in this analysis reported having no backup power (UPS or generators).

USPS

One USPS official was contacted. No response was received.

GSA
Two GSA officials were contacted. One interview was completed.

An interview was conducted with a large federal facility participating in a 5 kW PEM fuel cell demonstration project. In an effort to pursue alternative energy sources, the fuel cell was installed as a backup generator (in place of a gasoline-powered generator) for the facility's telecommunications system.

The interviewee noted that the facility's telecommunications system was the only application that currently provides an opportunity for PEM fuel cells. No other applications fit the size range and have a steady load. The interviewee expected that PEM fuel cells could be adopted at other GSA facilities where applications offer the right fit.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

As large consumers of electricity, there is significant potential for the application of PEM fuel cells in grid parallel, grid independent, and backup power applications. Furthermore, federal users are interested in alternative technologies that can reduce their energy consumption and help meet their energy efficiency goals. Primary drivers for adoption of energy alternatives are the commitment to energy efficiency, environmental concerns, interest in novel technologies, and commitment to energy security. While users in this sector are primarily looking for ways to offset their grid electricity consumption, there has also been some interest in alternative technologies to increase reliability and runtime for backup power applications. Federal users including FAA, USCG, BOR, and NOAA have even considered PEM fuel cells as alternatives. While these users are satisfied with the performance of PEM fuel cell technologies there is some dissatisfaction with the capital costs of the systems.

Legal directives such as EPAct 2005 and Executive Order 13123 are likely to drive the long-term use of alternative energy sources such as PEM fuel cells. Also, primary research indicates that some agencies would welcome alternatives to current energy technologies, such as diesel generators, due to emissions and other concerns. Marketing research also suggests that, due to cost, reliability, and durability issues, it is likely that PEM fuel cells will be adopted in the near term by government users in backup power applications.

The early opportunities for PEM fuel cells in the federal market segment are with those users that require reliable backup power to support their communications infrastructure. The FAA, USCG, and NOAA are particularly good candidates as they are looking for alternatives to support communication at remote locations, are looking for alternatives to generators, or are interested in alternatives that can provide longer runtimes. While there is significant interest in alternatives, for most federal users, capital expenditure on facility related infrastructure is low priority unless mandated at this time. With shrinking budgets federal agencies find it difficult to budget and finance energy investments. In the near term, it is likely that the availability of funding will drive the adoption of PEM fuel cells with federal users.

RESEARCH SUMMARY:
GROCERY STORES

MARKET SEGMENT DESCRIPTION

This market segment encompasses stores commonly known as supermarkets, food stores, and grocery stores, primarily engaged in the retail sale of a wide range of food products, including canned and frozen foods; dry goods, such as tea, coffee, spices, sugar, and flour; fresh fruits and vegetables; and fresh and prepared meats, fish, and poultry. Table j-1 identifies the SIC and NAICS classifications that cover this market segment.

Table j-1. SIC and NAICS Codes for Grocery Stores.

2-Digit SIC Code	54 – Food stores
4-Digit SIC Code	5411 – Grocery stores
NAICS Code	445110 – Supermarkets and other grocery (except convenience) stores

This market was considered for the application of fuel cells because of the size of the market, the need for constant, reliable power to maintain food quality, especially for refrigerated or frozen items, and the often 24/7 nature of the business. Secondary research indicates that backup power is most directly needed for emergency lighting, refrigerator and freezer cases, and point of sale cash registers.

There are no standards or requirements mandating the use of backup power in grocery stores, so the decision is made on a chain-by-chain or store-by-store basis. Some grocery chains choose to only supply backup power to stores located in areas with unreliable grid power or that often experience outages due to adverse weather such as icy conditions in the north or hurricanes in the south. Smaller stores and specialty stores often have no backup power and merely close when power outages occur.

Backup power, when supplied, is usually in the form of generators with some additional help from UPS systems in computer equipment. Information on the size of typical backup systems in grocery stores is limited to anecdotal evidence. Publix Grocery stores, a chain located primarily in the southern U.S. states, recently announced a plan to use backup generators in its hurricane-zone stores.[284,285] Following the 2004 hurricanes (including Hurricane Wilma) that cut access to power and spoiled over $60 million dollars worth of goods, Publix is spending $100 million to install 500 kW generators at every store in hurricane-prone areas. The company's plans are to install 400 stationary and mobile generators in hurricane-prone store locations and 175 quick-connecting docking stations in stores in lower-probability hurricane areas.

[284] Gray Television Group, Inc. 2006. Publix put backup generators at its hurricane zone stores. Available at http://www.wjhg.com/home/headlines/2919421.html [Accessed September 2006].
[285] Publix Asset Management Company. 2006. Publix Purchases Generators as Part of Business Recovery Plan. Available at http://www.publix.com/about/newsroom/NewsReleaseItem.do?newsReleaseItemPK=1857 [Accessed September 2006].

MARKET SIZE

Current data on the grocery store market are provided below. SIC Code 5411, covering the grocery store industry, is represented by Table j-2. These statistics indicate that there are an estimated 164,981 grocery establishments in the U.S. These establishments employ over 2.6 million individuals and are responsible for total annual sales exceeding $620 billion.

Table j-2. Number of Businesses in Grocery Stores Industry (5411).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)
5411-0000	Grocery stores	59,292	618,113	85,798.797
5411-0100	Supermarkets	5,109	166,975	62,614.199
5411-0101	Supermarkets, chain	10,643	914,078	344,044.406
5411-0102	Supermarkets, greater than 100,000 square feet (hypermarket)	123	15,300	1,502
5411-0103	Supermarkets, independent	2,187	90,411	14,608.1
5411-0104	Supermarkets, 55,000 - 65,000 square feet (superstore)	31	3,187	1,417.7
5411-0105	Supermarkets, 66,000 - 99,000 square feet	24	1,710	2,533.2
5411-0200	Convenience stores	31,144	162,652	17,620.801
5411-0201	Convenience stores, chain	17,307	141,496	36,581.699
5411-0202	Convenience stores, independent	11,420	62,315	9,343
5411-9901	Cooperative food stores	399	7,355	898
5411-9902	Delicatessen stores	7,810	39,351	3,169.9
5411-9903	Frozen food and freezer plans, except meat	160	2,343	159.6
5411-9904	Grocery stores, chain	2,304	152,417	16,334
5411-9905	Grocery stores, independent	17,028	225,731	26,391.801
	Total	**164,981**	**2,603,434**	**623,017.188**

Sales figures are in millions. Source: www.zapdata.com, accessed September 2006.

Grocery stores have very low net profit margins, traditionally barely 3% of sales, and must move a large number of goods.[286] Various factors are cited as contributing to the slim profit margins, including the perishable nature of a large portion of a grocer's stock, fierce competition from low price, non-traditional competitors (including warehouse clubs and dollar stores), mature markets, steep start-up costs, and antitrust limitations. The supermarket industry is relatively mature, and not projected to grow substantially, although there may be a growth in the demand for backup power, as indicated by Publix's recent investment in generators.

Supermarkets and grocery stores consume large amounts of energy, consuming more electricity per square foot than any other type of commercial building.[287] Grocery stores spend approximately $4.1 billion annually on electricity alone in the United States and Canada. On average, the annual utility bill for a supermarket is roughly equal to its profit. For a major chain, efficiency improvements that cut energy costs by 10 % could be worth tens of millions of dollars.

[286] Hoovers, Inc. 2006. Industry Record: Grocery Retail. Available at http://premium.hoovers.com/subscribe/ind/overview.xhtml?HICID=1535 [Accessed September 2006].
[287] E Source. 1998. E Briefing: Highlights of reports issued under E SOURCE's supplemental research services. EB-98-2. Available at http://www.esource.com/members/e_cd/pdfs/EB9802.pdf [Accessed September 2006].

MARKET TRENDS

No evidence of fuel cell activity in the U.S. grocery market segment could be identified; however, certain players in the grocery industry are showing increased interest in alternative energy sources.

One natural foods chain, Whole Foods, recently announced their plan to use wind power, and become the largest buyer of wind energy credits in North America.[288] It plans to purchase credits equal to 100% of its projected energy use for 2006, making Whole Foods the only Fortune 500 company to purchase renewable energy credits to offset 100% of its electricity use. One credit represents one megawatt-hour of electricity from renewable sources.

Specialty and organic markets such as Whole Foods are becoming increasingly popular, and traditional grocery stores are offering more specialty foods and organic products in addition to their traditional fare. This move, as well as the move to the use of renewable energy resources, is part of a larger movement by all Fortune 500 companies trying to project a "greener" image.[289] Although there are no regulatory drivers to promote the use of alternative energy sources, or to institute backup power systems, grocery companies are responding to public demand for improved environmental performance. Image enhancement is one of the most common benefits reported by ENERGY STAR participants. Image maintenance as a responsible corporate citizen through improved energy efficiency often minimizes community opposition to opening new stores. Once stores are opened, a positive environmental image contributes to increased sales and enhanced community relations.[290]

MARKET SEGMENT ANALYSIS

Twenty-seven grocery stores or related retail food organizations were contacted to further determine requirements for backup power and the potential for application of PEM fuel cells in the supermarket sector. Five informal interviews were conducted, with three additional complete responses to the survey. Three survey responses were collected representing a large grocery chain, a warehouse club, and a natural foods and specialty foods chain. In addition, three smaller specialized food chains were interviewed but did not complete the survey.

From the interviews conducted, it was noted that the smaller, niche stores tend not to have backup power, while larger grocery stores have at least partial backup and often full backup in areas with grid unreliability or a history of more common power outages (i.e., with the potential for greater loss of income). One smaller store decided against installing backup generators due to the cost of installing transfer switches in existing stores and the capital cost of procuring generators. All the smaller stores indicated that in the instance of extended power outages in which power was not restored in a matter of minutes, the stores were simply closed. In these stores, if keeping food cold during an outage is a concern, then the stores arrange for delivery of dry ice. One interviewee, the Director of Energy Management of a large chain of stores, indicated that the company had installed either generators or battery backup systems in all its

[288] Horovitz, B. 2006. Whole Foods Goes With the Wind. USA Today (January 9, 2006). Available at http://www.usatoday.com/money/industries/food/2006-01-09-whole-foods-usat_x.htm [Accessed September 2006].
[289] Horovitz, B. 2006. Whole Foods Goes With the Wind. USA Today (January 9, 2006). Available at http://www.usatoday.com/money/industries/food/2006-01-09-whole-foods-usat_x.htm [Accessed September 2006].
[290] Innovest Strategic Value Advisors, Inc. 2002. Energy Efficiency & Investor Returns: The Retail Food Sector. Available at http://files.harc.edu/Sites/GulfcoastCHP/Publications/EnergyEfficiencyRetailFood.pdf [Accessed September 2006].

stores to power emergency lighting and emergency management controllers. New generators installed are typically 50 kW in size, with some older units in the 25 kW size range. The interviewee indicated that looking across stores, power outages were less than 1% of total run time. Most stores were fairly satisfied with grid electricity, except in certain areas with power availability issues like Southern California. The interviewee identified the frozen and refrigerated products section within the grocery store as most severely impacted by power outages. Backup power primarily relies on the use of generators and UPS systems that are easy to operate by the various personnel within the stores. Grocery store respondents noted an interest in renewable and environmentally friendly alternative power sources but indicated that cost would be an issue in widespread adoption.

Of the three survey respondents, two were large grocery chains and one was a large grocery and retail chain. Respondents indicated that backup power was used to power complete store operations in certain high-risk markets like Florida. Respondents indicated that the functions most critical to their business operations include refrigeration, point of sale, and emergency lighting.

One respondent indicated that they had experienced approximately 37 grid outages at their facility in the past 12 months, while the other two respondents indicated they did not keep track of such information. Two large grocery store representatives noted that outages typically lasted from a few seconds to several hours. One respondent noted that outages could last days in Florida and Louisiana. Two respondents indicated that outages longer than 1 hour were very disruptive. All three respondents indicated that power loss results in the implementation of emergency management plans and disruptions in production and distribution.

All three respondents indicated they had either batteries or generators for backup power. One large retail and grocery chain indicated they had generators at only 5% of their facilities and in most cases did not have backup power. The size of backup power systems used in low-risk stores ranged from 15 to 60 kW to over 250 kW for one large grocery store. The same large grocery store indicated that they had systems > 1 MW. Backup power systems used by the large retail and grocery store were sized from 5 to 15 kW to over 250 kW. The respondent from this large retail and grocery store indicated that the company had 450 UPS systems at 9 kW and 50 generators at 50 kW at each facility. One respondent, who noted that each of the company's stores had approximately 139 backup systems, indicated that the size of the systems was not readily available.

All three respondents identified reliability and fuel availability as the most important factors is selecting a backup power system. Respondents also identified lifetime of unit, ease of use, and good experience with the type of system as important factors. Capital cost was identified as a very important factor by only one respondent. All three respondents who use some form of backup power indicated that their systems were good. One respondent indicated that backup systems currently in place were a maintenance problem. Only two respondents provided information on the performance of their backup power systems. Respondents indicated that fuel availability, ease of use, annual operating cost, start-up time, and lifetime of unit were very good. They also indicated that reliability, capital cost, and operation and maintenance costs were good.

Two respondents indicated that they envisioned a growing need for backup power in their sector. One respondent had considered alternatives like solar, wind turbines, and fuel cells for backup power. Another respondent had not considered alternatives for backup power but had briefly installed a microturbine for testing. All three respondents had heard of PEM fuel cells; however, only two had heard of them for backup power. All three respondents indicated that they did not think that PEM fuel cells would compete favorably with existing technologies. They identified the fact that systems are very expensive, high lifecycle costs, and lack of fuel as factors that would impact adoption. One respondent had concerns of using hydrogen as a fuel. Factors cited that would drive decisions to adopt PEM fuel cells included the energy efficiency of PEM fuel cells compared to alternatives, environmental concerns, availability of government incentives, and track records of others using PEM fuel cells. Two respondents indicated that decisions to procure backup power systems were made based on return on investment. One noted that decisions were made based on initial capital cost and payback period. One respondent indicated that decisions were also made based on grid vulnerability. Two respondents indicated that they would consider government incentives when making a purchase decision.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

The grocery industry, particularly the emerging specialty and organic market segment, has an interest in environmentally friendly energy alternatives, including in fuel cells. There is potential for application of PEM fuel cells at high-risk stores as replacements to smaller generators (50 kW). No regulatory market drivers that impact a need for backup power or the consideration of environmentally friendly alternatives were identified in this market segment. The market opportunity for PEM fuel cells will be limited to sensitive energy markets prone to energy outages like the gulf coast. However, market indications show that grocery stores have very small profit margins with which to invest in expensive alternatives like fuel cells. Cost is a significant barrier for an industry with low profit margins. Furthermore, fuel availability is a critical factor for making purchasing decisions in this sector. As a result it is likely that the grocery market segment will be a potential mid-term market opportunity when capital cost and fuel availability can be addressed.

RESEARCH SUMMARY: HOSPITALS

MARKET SEGMENT DESCRIPTION

The healthcare market sector includes various establishments involved in all aspects of care for individuals. These establishments include hospitals, rehabilitation and long-term care facilities, psychiatric facilities, surgical facilities, urgent care operations, and retirement care centers. Table k-1 identifies the SIC and NAICS codes for the healthcare industry. While there are a wide variety of healthcare specialties within this market sector, for the purposes of this discussion the focus is on hospitals as the primary candidate for potential fuel cell users. Other related healthcare markets provide similar care and have similar power concerns. It is assumed that a number of the same issues for backup power in the hospital market hold true in other healthcare facilities. Also, other health services may be part of a larger hospital system and form an integrated healthcare delivery network. Such an integrated network typically consists of several hospitals, nursing homes, home care agencies, hospices and ambulatory care units, and other affiliated healthcare entities.[291]

Table k-1. SIC and NAICS Codes for the Healthcare Industry.

2-Digit SIC Code	80 – Health services
4-Digit SIC Codes	8052 – Intermediate care facilities 8062 – General medical & surgical hospitals 8063 – Psychiatric hospitals 8069 – Specialty hospitals, excluding psychiatric
NAICS Codes	622110 – General medical and surgical hospitals 622210 – Psychiatric and substance abuse hospitals 622310 – Specialty (except psychiatric and substance abuse) hospitals 623110 – Nursing care facilities 623210 – Residential mental retardation facilities 623311 – Continuing care retirement communities

The healthcare sector requires critical power to support a wide variety of functions within a hospital campus. The reliability of the electrical power systems that serve hospitals is very important. Not only do power outages in the hospital industry cause potential for loss of revenue and an inconvenience to hospital staff and patients, but hospitals also provide a number of services for which reliable power is a necessity for the preservation of human life. These critical services include surgical, radiological, life support, intensive care, and emergency care.[292] Hospitals also contain a large amount of technical and diagnostic equipment that requires power. Furthermore, the trend in the U.S. healthcare system toward a standardized health information infrastructure for electronic medical records and computerized charting of patients means that, to access information necessary for the quality care of patients, power must constantly be supplied to the computer systems that contain the medical information.[293] In addition to these specialized needs, like many large building complexes, hospitals have a variety of typical power needs such

[291] Energy and Environmental Analysis, Inc. (Energy Nexus Group). 2003. Task 2.1 Report: National Account Sector Energy Profiles. Available at http://files.harc.edu/Sites/GulfCoastCHP/MarketAssessments/NationalAccountSectorEnergyProfiles.pdf [Accessed December 2006].
[292] Wikimedia Foundation, Inc. 2006. Hospital. Available at http://en.wikipedia.org/wiki/Hospitals [Accessed December 2006].
[293] Wikimedia Foundation, Inc. 2006. Health Informatics. Available at http://en.wikipedia.org/wiki/Medical_informatics [Accessed December 2006].

as heating, air conditioning and ventilation systems, computer systems, food service, laundry, and other services.

Hospitals are usually given priority status within the utilities infrastructure and are therefore one of the first to receive service for restoration of power during outages.[294] Still, power outages are a possibility, and there are state laws and national standards that require that hospitals and emergency services maintain a backup power supply. Hospitals must have emergency power testing programs in place to meet the requirements of the National Fire Protection Association (NFPA), as well as standards established by accreditation organizations such as the Joint Commission on Accreditation of Healthcare Organizations (JCAHO). The JCAHO operates voluntary accreditation programs for hospitals and other healthcare services and is responsible for certifying hospitals as having met the condition of participation required for reimbursement under the federal Medicare program.[295,296] The NFPA and JCAHO programs include requirements for generator load testing, also commonly known as 30%.[297]

In recent news, the JCAHO issued new requirements for emergency electrical power testing.[298] The Revised Standard EC.7.40 now requires organizations to test their emergency generators at least once every 36 months for a minimum of 4 continuous hours. This test is in addition to the current requirement to test emergency generators 12 times each year for 30 continuous minutes. This additional requirement is based on a new NFPA requirement designed to assure health care organizations that their emergency generators will operate during extended power outages. The new requirement is effective January 1, 2007, and organizations must have performed this test by July 1, 2007, in order to be in initial compliance. JCAHO stated that the revision is "based on recent briefings by experts and debriefing with organizations that have sustained extended electrical utility power outages."[299]

The NFPA and JCAHO mandate that all hospitals use emergency diesel generators to back up utility-supplied power. While these requirements ensure that hospitals regularly test emergency generator systems, they do not address the transitional gap between utility and generator power (or lag time until a diesel generator comes fully online).

MARKET SIZE

According to the latest statistics from the American Hospital Association,300 there are a total of 5,759 registered hospitals in the U.S. Table k-2 presents the breakdown of the types of hospitals reported by AHA.

[294] Wikimedia Foundation, Inc. 2006. Hospital. Available at http://en.wikipedia.org/wiki/Hospitals [Accessed December 2006].
[295] Wikimedia Foundation, Inc. 2006. Hospital. Available at http://en.wikipedia.org/wiki/Hospitals [Accessed December 2006].
[296] American Society for Healthcare Engineering. 2006. Joint Commission on Accreditation of Healthcare Organizations. Available at http://www.ashe.org/ashe/codes/jcaho/index.html [Accessed December 2006].
[297] American Society for Healthcare Engineering. 2006. Managing Hospital Emergency Power Systems – Testing, Operation and Maintenance. Available at http://www.ashe.org/ashe/products/pubs/pdfs/mg2003stymiest.pdf [Accessed December 2006].
[298] American Society for Healthcare Engineering. 2006. Homepage. Available at http://www.ashe.org/ [Accessed December 2006].
[299] American Society for Healthcare Engineering. 2006. Advisories and Alerts. Available at http://www.ashe.org/ashe/codes/advisories/index.html [Accessed December 2006].
[300] American Hospital Association. 2006. Fast Facts on US Hospitals. Available at http://www.aha.org/aha/resource_center/fastfacts/fast_facts_US_hospitals.html [Accessed June 2006].

Table k-2. Types of Hospitals in the U.S., 2004.[301]

Type	Number
Number of U.S. community** hospitals	4,919
Number of nongovernment not-for-profit community hospitals	2,967
Number of investor-owned (for-profit) community hospitals	835
Number of state and local government community hospitals	1,117
Number of federal government hospitals	239
Number of nonfederal psychiatric hospitals	466
Number of nonfederal long term care hospitals	112
Number of hospital units of institutions (prison hospitals, college infirmaries, etc.)	23
Total Number of All U.S. Registered* Hospitals	**5,759**

Updated November 14, 2005.
**Registered hospitals* are those hospitals that meet AHA's criteria for registration as a hospital facility. Registered hospitals include AHA member hospitals as well as nonmember hospitals.
***Community hospitals* are defined as all nonfederal, short-term general, and other special hospitals. Other special hospitals include obstetrics and gynecology; eye, ear, nose, and throat; rehabilitation; orthopedic; and other individually described specialty services. Community hospitals include academic medical centers or other teaching hospitals if they are nonfederal short-term hospitals. Excluded are hospitals not accessible by the general public, such as prison hospitals or college infirmaries.

According to the most recent energy expenditure information from the U.S. Energy Information Administration (EIA)'s 2003 Commercial Buildings Energy Consumption Survey (CBECS), there are 129,000 U.S. buildings in the combined healthcare industry that account for 3,163 million square feet of total floorspace.[302] Table k-3 presents information on total electricity consumption and expenditures for the combined healthcare industry compared to all U.S. buildings.

Table k-3. Total Electricity Consumption and Expenditures in U.S. Buildings, 2003.[303]

	All Buildings* Using Electricity			Electricity Consumption			Electricity Expenditures
				Primary	Site		
	Number of Buildings (thousands)	Floorspace (million square feet)	Floorspace per Building (thousand square feet)	Total (trillion Btu)	Total (trillion Btu)	Total (billion kWh)	Total (million dollars)
All	4,404	63,307	14.4	9,168	3,037	890	69,032
Healthcare	129	3,163	24.6	748	248	73	4,882
Inpatient	8	1,905	241.4	539	178	52	3,198
Outpatient	121	1,258	10.4	209	69	20	1,684

Released: June 2006

MARKET TRENDS

The new requirements for emergency electrical power testing discussed above, combined with efforts to demonstrate fuel cells in the healthcare industry, are potentially important trends that could open the door for PEM fuel cells as a backup power source for hospitals.

[301] American Hospital Association. 2006. Fast Facts on US Hospitals. Available at http://www.aha.org/aha/resource_center/fastfacts/fast_facts_US_hospitals.html [Accessed June 2006].
[302] Energy Information Administration, Office of Energy Markets and End Use. 2006. Form EIA-871A of the 2003 Commercial Buildings Energy Consumption Survey. Available at http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/2003set1/2003html/b1.html [Accessed December 2006].
[303] Energy Information Administration, Office of Energy Markets and End Use. 2006. Forms EIA-871A, C, and E of the 2003 Commercial Buildings Energy Consumption Survey. Available at http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/2003set10/2003excel/c13.xls [Accessed December 2006].

No installations of PEM fuel cells for backup power at hospitals were found through secondary data. However, there have been several demonstrations of PAFCs at hospitals through the DoD PAFC Demonstration program. Most of these fuel cell installations (listed below) were grid parallel applications for peak-shaving or for quality power assurance, and several were set up to provide CHP.[304]

1. St. Francis Hospital in Hartford, Connecticut, installed a 200 kW PC25 PAFC natural gas fuel cell that provides power security to an operating room and is interconnected with the hospital's distribution and air conditioning system.
2. In December 2000, a 200 kW PAFC natural gas fuel cell was installed at North Central Bronx Hospital in Bronx, New York. The fuel cell supplies supplemental power and backup power. The installation was funded through the U.S. DoD Climate Change Fuel Cell Program.
3. In 1999, South County Hospital in Wakefield, Rhode Island, installed a 200 kW PC25 PAFC natural gas fuel cell. The fuel cell provides electricity and heat, produces one-third of the hospital's electricity during peak hours (saving $60,000 to $90,000/year), and also provides backup power for the hospital's critical loads.
4. In July 1997, a 200 kW PC25C PAFC natural gas fuel cell was installed at the Barksdale Air Force Base hospital in Bossier, Louisiana. The fuel cell, which operated until October 2002, was grid connected; total estimated thermal utilization was approximately 90%.
5. Edwards Air Force Base hospital in Palmdale, California, demonstrated a 200 kW PC25C PAFC natural gas fuel cell from July 1997 to July 2002. The fuel cell was grid connected and produced a high grade thermal output that was utilized by a space heating loop. Total estimated thermal utilization was approximately 23%.
6. A natural gas 200 kW PC25C PAFC was installed at Laughlin Air Force Base Hospital in Del Rio, Texas, from September 1997 until November 2002. The installation was part of the U.S. DoD PAFC Demonstration Program. The fuel cell was grid connected at an existing electrical transformer (no emergency backup). Thermal output was utilized by a space heat/cool reheat loop and domestic hot water (DHW) loop; estimated thermal utilization was approximately 75%.
7. A 200 kW PC25C PAFC natural gas fuel cell was installed at the Jacksonville, Arkansas, Little Rock Air Force Base hospital from October 1997 until December 2000. The installation was part of the DoD PAFC Demonstration Program. The fuel cell was grid connected at an electrical panel, and thermal output was used by a space conditioning recirculation loop. Total estimated thermal utilization was approximately 85%.
8. In another DoD PAFC Demonstration Program installation, a 200 kW PC25B PAFC natural gas fuel cell was installed at the Twentynine Palms Marine Corp Base Naval Hospital in Twentynine Palms, California. Use of the natural gas fuel cell lasted from June 1996 to May 2000. The fuel cell was grid connected at an existing subpanel. However, a grid independent connection was established at a new electrical subpanel. Thermal output was utilized by DHW loops with an estimated thermal utilization of 60%.
9. At the Naval Air Station Naval Hospital in Jacksonville, Florida, a 200 kW PC25C PAFC natural gas fuel cell was installed from April 1997 to April 2002 as part of the DoD PAFC Demonstration Program. The fuel cell was grid connected at an existing electrical panel

[304] Fuel Cells 2000. 2005. Worldwide Fuel Cell Installations. Available at http://www.fuelcells.org/info/charts/FCInstallationChart.pdf [Accessed December 2006].

(no emergency backup), and thermal output was utilized by a DHW loop with an estimated thermal utilization of 56%.

10. Another 200 kW PC25C PAFC natural gas fuel cell was installed at the Marine Corp Base Camp Pendleton Naval Hospital in Oceanside, California, from October 1995 to January 2002. The installation was part of the DoD PAFC Demonstration Program. The fuel cell was grid connected at an existing panel. Thermal output was utilized for DHW storage with thermal utilization estimated at 75%.

MARKET SEGMENT ANALYSIS

To identify the market opportunities for direct PEM fuel cells, 35 healthcare organizations were contacted. Many organizations expressed interest; five survey responses were received, and two interviews were conducted.

Responses were received from two large and three medium-sized hospitals. Four respondents in this category were government hospitals. Respondents indicated that backup power in hospitals was required for a variety of applications including life support equipment, critical equipment, life safety equipment, communications systems, blood bank refrigerators, urgent care areas, emergency lighting, and specific zones within the facility. Respondents indicated that all backup power applications were critical to their business operations. Two hospitals indicated that life support equipment and medical equipment were especially critical applications requiring backup power.

In terms of number of power outages during the past year, responses varied among respondents. Two respondents reported two outages, and one reported experiencing six to ten outages. One respondent indicated that no outages occurred but they experienced numerous power sags. Respondents indicated that power interruptions lasted from < 60 seconds to over 4 hours. Respondents rated the impact of power interruptions and indicated that short interruptions were disruptive but extended interruptions (greater than 1 hour) were very disruptive. In the past year, one respondent had experienced two very disruptive power outages. According to respondents, power outages at hospitals can result in implementation of emergency management plans, loss of life, and security breach.

Backup power is currently supplied through a combination of UPS, batteries, and generators. One respondent indicated that they also have alternate feeds from the grid to ensure continuous and reliable power. The size of backup systems used by respondents varied from < 5 kW to over 1MW. Respondents rated reliability, start-up time, ease of use, fuel availability, and good experience with system in the past as the most important factors in selecting a backup power system. Four respondents rated their current backup power systems as very good, while one respondent did not provide an answer. All five respondents reported very high levels of satisfaction with various performance factors of their current systems, including reliability, start-up time, capital cost, operation and maintenance costs, lifetime, annual operating costs, emissions, ease of use, and fuel availability.

Respondents were split on the potential for growth in backup power requirements for hospitals. Two respondents anticipated a growing need, while two respondents did not. None of the respondents had considered alternative sources of backup power. Only two respondents had heard of PEM fuel cells as a backup power source, and both believed that PEM fuel cells could compete favorably with existing backup power systems. Of these two respondents, one was concerned about using hydrogen as a fuel source.

Respondents indicated that a combination of factors would drive their decision to purchase PEM fuel cells, including the cost of not having electricity, energy efficiency of PEM fuel cells compared to alternatives, track record of others using PEM fuel cells, environmental concerns, and government incentives. Four respondents indicated that capital purchase decisions were made on the basis of initial capital costs. Two respondents also indicated that decisions were made based on equipment reliability. One respondent indicated that certification requirements, life safety, and support needs were considered in making a purchasing decision. Only one respondent indicated that they considered government incentives when making purchasing decisions. Respondents reported that decisions to procure systems were typically made by engineers.

Interviewees indicated that backup power is provided in three main areas: critical (which includes surgeries, patient care, ventilators, and other essential care to preserve life), life safety (which includes emergency and other lighting, lighting of exit signs), and equipment (which supports other hospital facilities, including the air handler and emergency elevators).

Interviewees indicated that power outages were not a major problem for their hospital complexes, but backup power is a requirement for accreditation. Backup power is supplied primarily through the use of diesel and natural gas generators, with support from some UPS systems. Alternatives such as fuel cells had not been widely investigated by interviewees, and little was known about them. Because generators are required and are tested regularly, interview respondents have not had a compelling reason to seek alternative energy sources for backup power.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

Based on this analysis, hospitals are not thought to represent a near-term opportunity for PEM fuel cells. Hospitals currently use generators and UPS systems to meet their backup power requirements and do not appear to be dissatisfied with the performance of their existing systems. It also appears that a substantial part of their backup power needs are met with large systems, beyond the current capacity of PEM fuel cells. While there is some experience with fuel cells in this sector, demonstration projects have focused on providing baseload power to healthcare facilities using PAFC systems; research indicates that none of these have employed PEM fuel cells.

At the same time, the landscape for backup power in the healthcare sector is changing. New accreditation standards are expected to change the way backup power is used, as it increases annual operating time associated with testing backup systems. If PEM fuel cells can be demonstrated to provide an economic or performance advantage over existing systems in smaller power output, niche applications, this could spur interest in PEM systems as these increased operating requirements are implemented. The size of the market and the backup power demand for at least some applications with lower power output requirements are promising market characteristics. Even though past fuel cell projects in this sector have focused on baseload power, such demonstrations may help develop user confidence in fuel cell use as a viable power source in this sector. Changes in this market should be monitored as it may represent a viable mid-term market for PEM fuel cells.

RESEARCH SUMMARY:
METALS PROCESSING AND REFINING

MARKET SEGMENT DESCRIPTION

The metal refining and processing market segment includes the processing and refining of aluminum, steel, and other metals. Metal refining and processing addresses a variety of activities, including: foundry operations (including for aluminum and steel), metal production (aluminum, steel, and other products), casting (including die casting), extruding, rolling and drawing, and wire drawing. Table l-1 identifies the SIC and NAICS codes associated with this market segment.

Table l-1. Relevant SIC and NAICS Codes for Metals Processing and Refining.

2-Digit SIC Code	33 – Primary metal industries
4-Digit SIC Codes	3312 – Blast furnaces and steel mills 3313 – Electrometallurgical products 3315 – Steel wire and related products 3316 – Cold finishing of steel shapes 3317 – Steel pipe and tubes 3321 – Gray and ductile iron foundries 3322 – Malleable iron foundries 3324 – Steel investment foundries 3325 – Steel foundries, not elsewhere classified (nec) 3331 – Primary copper 3334 – Primary aluminum 3339 – Primary nonferrous metals, nec 3341 – Secondary nonferrous metals 3351 – Copper rolling and drawing 3353 – Aluminum sheet, plate, and foil 3354 – Aluminum extruded products 3355 – Aluminum rolling and drawing, nec 3356 – Nonferrous rolling and drawing, nec 3357 – Nonferrous wiredrawing and insulating 3363 – Aluminum die-castings 3364 – Nonferrous die-castings except aluminum 3365 – Aluminum foundries 3366 – Copper foundries 3369 – Nonferrous foundries, nec 3398 – Metal heat treating 3399 – Primary metal products
NAICS Codes	324199 – All other petroleum and coal products manufacturing 331111 – Iron and steel mills 331112 – Electrometallurgical ferroalloy product manufacturing 331210 – Iron and steel pipe and tube manufacturing from purchased steel 331221 – Rolled steel shape manufacturing 331222 – Steel wire drawing 331312 – Primary aluminum production 331314 – Secondary smelting and alloying of aluminum 331315 – Aluminum sheet, plate, and foil manufacturing 331316 – Aluminum extruded product manufacturing 331319 – Other aluminum rolling and drawing 331411 – Primary smelting and refining of copper 331419 – Primary smelting and refining of nonferrous metal (except copper

	and aluminum) 331421 – Copper rolling, drawing, and extruding 331422 – Copper wire (except mechanical) drawing 331423 – Secondary smelting, refining, and alloying of copper 331491 – Nonferrous metal (except copper and aluminum) rolling, drawing, and extruding 331492 – Secondary smelting, refining, and alloying of nonferrous metal (except copper and aluminum) 331511 – Iron foundries 331512 – Steel investment foundries 331513 – Steel foundries (except investment) 331521 – Aluminum die-casting foundries 331522 – Nonferrous (except aluminum) die-casting foundries 331524 – Aluminum foundries (except die-casting) 331525 – Copper foundries (except die-casting) 331528 – Other nonferrous foundries (except die-casting) 332618 – Other fabricated wire product manufacturing 332811 – Metal heat treating 332813 – Electroplating, plating, polishing, anodizing and coloring

Metal Casting

Die casting is an old process of injecting molten metal into a steel die under high pressure. The metal, aluminum, zinc, magnesium, or sometimes copper, is held under pressure until it solidifies into a net shape metal part. In modern applications, using computerized controls, die casters produce precision and high-strength products at a rapid rate.

Metal casting plays a critical role in the success of U.S. manufacturing through the production of high quality castings. Castings are used in 90% of all finished manufactured products. Die casting, which produces over one-third of all metal castings, is an important segment of the larger metal casting industry. Over 500 die casters manufacture thousands of non-ferrous castings for applications in automotive, computer, medical, and other industries. Die casters contribute over $7.3 billion to the nation's economy annually and provide over 63,000 jobs directly and indirectly. While larger firms are world leaders, 58% of these companies have fewer than 100 employees. The average power requirements of a metal casting plant are in the 1 MW range.

Steel Mills/Steel Products

Those facilities included in the steel products sector tend to be slightly smaller, both in terms of their power demand and average number of employees, and have slightly lower load factors. The steel mills sub-industry includes large integrated steel mills and smaller "mini-mills." The average power requirements for steel mills are in the 50 MW range, and for steel products, in the 3 to 4 MW range. [305] Large power consumption equipment in steel mills includes blast furnaces, electric arc furnaces, and coke plants.

[305] Arthur D. Little, Inc. 2000. Opportunities for Micropower and Fuel Cell/Gas Turbine Hybrid Systems in Industrial Applications. Volume I (Main Text). Final Report to Lockheed Martin Energy Research Corporation and the DOE Office of Industrial Technologies.

Primary Aluminum and Aluminum Refining
Aluminum originates as an oxide called alumina, and because aluminum itself does not occur in nature as a metal, the processing of aluminum requires electricity to extract. The aluminum industry can be broken down into two distinct sub-industries: primary aluminum and aluminum products. Within the aluminum industry, the dominant differences between the two sub-industries are facility size (in terms of megawatts used). Primary aluminum production facilities have power requirements over 100 MW, while aluminum products plants have power requirements around 4 to 5 MW.

The U.S. aluminum industry is the world's largest producer of primary aluminum, annually producing about $39.1 billion in products and exports. The U.S. industry operates over 300 plants in 35 states, produces more than 23 billion lbs of metal annually, and employs over 145,000 people. Aluminum products include castings, extrusions, mill products, and other aluminum fabricated products. Top markets for the industry are transportation, beverage cans, packaging, and building construction.

Backup Power
A constant flow of power is important to ensure full utilization of the production facilities described above. Blackouts and/or loss of power can impact production and company performance, creating delays in filling demand. Blackouts can also cause equipment failures; for instance, blackouts in foundries can inflict permanent damage on furnaces, pots (used to pour metal), and other equipment. Longer power outages are often of greater concern. As a result, backup power is used for a variety of applications in metals refining and processing. These include:

- **Foundry and Furnaces** – Heating, melting, and extracting metal require very high temperatures. These establishments are primarily engaged in: manufacturing hot metal, pig iron, and silvery pig iron from iron ore and iron and steel scrap; converting pig iron, scrap iron, and scrap steel into steel; and hot-rolling iron and steel into basic shapes, such as plates, sheets, strips, rods, bars, and tubing. This area also includes merchant blast furnaces and by-product or beehive coke ovens.
- **Automation and Robotics** – For instance, the pots pouring metal in foundry operations need to be controlled and maintained at certain temperatures.
- **Processing and Controllers** – Some furnaces are controlled by a computerized system that permits control capabilities and a variety of energy management strategies. Documentation includes a variety of operating logs and specific event recording such as power failure, missing energy pulses, tap changes, and load shedding and restoring. This may also include plant shutdown in the case of power outages.
- **Casting** – Cast metals require processes for melting, grinding, and coating systems, as well as automation for pouring and molding, and cooling systems (to keep wax molds cool).

Several technologies are currently being used to provide backup power in the metals industry, including gas turbine and diesel generators, UPS systems, and gas-powered flywheels. Energy-intensive process industries, including steel mills, may use generators during emergency outages and natural disasters, or to supplement grid power. A variety of options, including aeroderivative gas turbine generation (up to 22 MW) and linked 1 MW diesel systems are used for additional power supplies. UPS systems are used for backup power in metal refining.

MARKET SIZE

Table l-2 presents the size of various market segments in the metals processing and refining industry.

Table l-2. Number of Businesses in Metals Processing and Refining Market Segments.[306]

SIC Code	Industry Segment	Type	Number of Businesses	Total Sales ($M)
3312	Blast furnaces and steel mills	Steel mills	2,513	94,669.10
3313	Electrometallurgical products	Steel products	86	2,556.70
3315	Steel wire and related products	Steel Products	843	4,507.40
3316	Cold finishing of steel shapes	Steel products	242	9,081.20
3317	Steel pipe and tubes	Steel products	565	10,512.60
3321	Gray and ductile iron foundries	Metal casting	597	8,407.70
3322	Malleable iron foundries	Metal casting	30	67.90
3324	Steel investment foundries	Metal casting	221	4,872.80
3325	Steel foundries, nec	Metal casting	462	3,835.30
3331	Primary copper	Other	46	174.20
3334	Primary aluminum	Primary aluminum	183	8,142.00
3339	Primary nonferrous metals, nec	Other	264	2,823.90
3341	Secondary nonferrous metals	Other	373	10,135.80
3351	Copper rolling and drawing	Other	208	9,564.90
3353	Aluminum sheet, plate, and foil	Aluminum products	216	30,311.70
3354	Aluminum extruded products	Aluminum products	392	6,928.70
3355	Aluminum rolling and drawing, nec	Aluminum products	186	2,756.40
3356	Nonferrous rolling and drawing, nec	Other	303	4,662.50
3357	Nonferrous wiredrawing and insulating	Other	602	19,921.00
3363	Aluminum die-castings	Metal casting	395	9,015.30
3364	Nonferrous die-castings except Aluminum	Metal casting	255	913.90
3365	Aluminum foundries	Metal casting	565	3,005.10
3366	Copper foundries	Metal casting	422	1,904.30
3369	Nonferrous foundries, nec	Metal casting	325	1,086.70
3398	Metal heat treating	Other	778	1,571.30
3399	Primary metal products	Other	551	2,068.90

A report by Arthur D. Little, Inc. assesses the backup power market for metals refining and processing. The report estimates the fraction of power demand within each industry that is likely to be installed as backup power (see Table l-3).

[306] Dun and Bradstreet. 2006. Zapdata Industry Report. Available at http://www.zapdata.com [Accessed July 2000].

Table l-3. Estimated Demand for Backup Power Generation Equipment.[307]

Industry	Dominant Backup Power Needs	Estimated Backup*	Total Power Demand
Primary Aluminum	Shutdown, extraction processes	30%	8,500 MW
Aluminum Products	Shutdown	5%	1,000 MW
Metal Casting	Shutdown	5%	2,000 MW
Steel Mills	Shutdown, pumps	10%	5,700 MW
Steel Products	Shutdown	5%	1,500 MW

*Estimated percentage of total power demand.

In addition to the backup power needs in Table l-3, backup power sources, such as UPS, are used to provide premium power to the industries listed in Table l-4 below.

Table l-4. Dominant Premium Power Needs.[308]

Industry	Dominant Premium Power Needs	Assumed Premium Power*
Primary Aluminum	Controls (UPS)	1%
Aluminum Products	Controls (UPS)	5%
Steel Mills	Controls (UPS), avoided grid penalties	5%
Steel Products	Controls (UPS)	1%

*Estimated percentage of total power demand.

MARKET TRENDS

The industry is concerned about the cost and reliability of grid power, and companies are investigating options for both backup and on-site power (e.g., distributed, off-grid).[309] Particularly in California, companies have been looking to build on-site power, as grid power is not particularly reliable. On-site power can be isolated from the grid so that it can act as backup power if necessary. Other states are investigating on-site power as well. A key driver for investments in on-site power will be the cost of outside power. At $0.07 per kW, on-site power is less attractive; however, when grid power was $0.23 per kW, on-site power was highly attractive. Currently, grid power costs are hovering around $0.14 to $0.15 per kW; therefore, the decision to build on-site power depends on how much power a facility requires, economies of scale, the economics of the power source, and other factors.

One fuel cell demonstration project is taking place in the metalworking industry. In 2005, the California Cast Metals Association (CCMA), TST Inc., Alliance Power, Otto H. Rosentreter Company, Southern California Gas Company, FuelCell Energy, and South Coast Air Quality Management District teamed up to site 500 kW fuel cells (two DFC300 systems that run on natural gas) at an industrial metalworking facility to provide baseload power. The project also includes the installation of four 60 kW Capstone microturbines to work in conjunction with the fuel cells. The fuel cells were able to provide 300 kW of power during Southern California's rolling blackouts in June 2006.

[307] Arthur D. Little, Inc. 2000. Opportunities for Micropower and Fuel Cell/Gas Turbine Hybrid Systems in Industrial Applications. Volume I (Main Text). Final Report to Lockheed Martin Energy Research Corporation and the DOE Office of Industrial Technologies.
[308] Arthur D. Little, Inc. 2000. Opportunities for Micropower and Fuel Cell/Gas Turbine Hybrid Systems in Industrial Applications. Volume I (Main Text). Final Report to Lockheed Martin Energy Research Corporation and the DOE Office of Industrial Technologies.
[309] American Society of Mechanical Engineers. 2000. Rent-a-power plant. Mechanical Engineering (June).

Changes in the industry may affect the need for backup power. It has been suggested that U.S. operations are shifting from manufacturing to service and management. While output continues to rise, the number of die casting businesses and employees has fallen across North America. One study of end-use markets showed an expansion in casting shipments for 2004 with considerable gains in aluminum and steel. The study forecasts that demand for casting would rebound in 2004 and in subsequent years; while imports would rise to new highs and keep the expansion of shipments by domestic foundries at modest levels. However, other studies indicate that the number of die-casting businesses in North America will continue to fall, and that by 2013, the industry expects total employment to decline by as much as 40%. Die casting businesses are reacting to these trends in a number of ways, such as forming global partnerships and finding lower-cost off-shore sources for tooling.[310]

Pressure facing industry from environmental regulations may influence the need for backup power as well. For instance, a failure in the UPS, and subsequent failure of the backup systems at an alumina refinery plant, caused a cloud of fly-ash to be released. This created a breach in license operations, due to an infringement of clean air regulations. EPA has begun work on the development of area source emission standards for iron and steel foundries that could include all facilities not covered by the Iron & Steel Maximum Achievable Control Technology (MACT) requirements finalized in 2004. It is possible that these standards could spur the use of backup power to avoid compliance breaches resulting from power outages.

MARKET SEGMENT ANALYSIS

In the metals refining and processing industry, 11 companies were contacted, and four responses were received. Of the respondents, two were small metal soldering and manufacturing companies, one was a large steel foundry and manufacturing company, and one was a professional association representing foundry operations and die casting.

Two respondents reported that they use backup power, and the professional association indicated that a large portion of their constituents use backup power. Critical functions include heating metals pots on manufacturing lines and cooling wax molds used for casting metal. Backup power for computers and automation was also considered important.

Respondents indicated that they had experienced one to six blackouts in the previous year. Manufacturing facilities noted blackouts lasting from < 60 seconds up to 1 hour; additionally, rolling blackouts had triggered longer power outages ranging from 1 to 4 hours. Companies indicated that disruptions of less than 3 minutes were minimally disruptive, while disruptions greater than 1 hour were considered very disruptive. Three companies indicated that they had experienced one to two disruptive power outages over the last year. All companies indicated that disruptive power outages could result in disruption of production and distribution. Other potential impacts of power outages included equipment damage and safety hazards.

Two respondents (one large manufacturing company and one professional organization) indicated that the primary source of backup power was diesel and natural gas generators, with sizes ranging from 30 to 150 kW. One manufacturing company reported using UPS units of < 5 kW. Respondents typically had one to two backup power units per facility. Respondents

[310] North American Die Casting Association. 2005. U.S. Die Casting Industry Fact Sheet: Manufacturing & Die Casting Statistics.

unanimously indicated that reliability was a very important attribute of backup power; two respondents indicated that other very important attributes included start-up time and ease of use. Capital cost and fuel availability were also considered important. All respondents who currently use backup power indicated that the performance of their current backup power system was good to very good; no concerns were noted. When asked to rate current backup systems, three respondents indicated that fuel availability was very good, two noted that reliability was very good, and two noted that start-up time was very good. Capital cost and operation and maintenance costs were considered to be good to very good by all respondents. Of the four respondents, only the professional association anticipated a growing need for backup power, indicating that, while about 0.5% of the market is currently using backup power, this would increase to 10% over the next 3 years.

Only one of the four respondents was aware of PEM fuel cells as a potential source of backup power; this respondent indicated that PEM fuel cells would favorably compete with other forms of backup power. The respondent also believed that PEM fuel cells could be excellent for providing base load power for facilities, although a fuel cell in the range of 250 kW could be used to provide backup power as well. Factors cited as potentially driving the adoption of PEM fuel cells included the cost of not having electricity (i.e., the cost of a power failure), dissatisfaction with the current mode of backup power, and the energy efficiency of PEM fuel cells as compared to alternatives. Most did not know what criteria would be used to purchase new backup power units, or who would make such decisions, although one respondent indicated that it was based on initial capital cost.

POTENTIAL OPPPORTUNITIES FOR PEM FUEL CELLS

There are numerous applications for backup power in the metals processing and refining market segment. Backup power units currently being used range in size from < 5 kW to 250 kW. While the market size is attractive, it is unclear whether there is sufficient growth potential to support this sector as a target market for fuel cell backup power. There are numerous, highly distributed facilities in this industry each with their own backup power needs. The overall demand for backup power in aluminum, steel, and metal casting is estimated to be 5 to 30% of overall power requirements; metal refining and processing facilities typically require 5 to 20 MW per facility. The potential market for backup power for blast furnaces and steel mills alone could range as high as 3,750 MW to 15,000 MW. However, the U.S. metals refining and processing market is slowly shrinking as businesses move overseas. Primary research seems to suggest low domestic growth potential for backup power in this industry.

Users in this market segment are interested in alternatives as reliability to operations is a necessity. Although respondents did not consider environmental factors to be a key driver for the purchase of a backup power system, regulatory requirements concerning emissions from this industry are becoming more stringent. While PEM fuel cells offer no distinct advantage over low-wattage UPS units in terms of emissions, they do offer this advantage over diesel-powered generators. Initial capital cost of alternatives also appears to be a factor when selecting and purchasing a backup power system in this market segment. This may impact the potential for adoption of PEM fuel cells in the near term.

It appears that in the near term, PEM fuel cells may be considered as replacements to UPSs and small diesel generators. This market will be limited in the near term as adoption of PEM fuel cells in the metals refining and processing industry will depend on several factors, including the competitiveness of PEM fuel cells with existing technologies, the reliability of PEM fuel cells, and the impact of environmental regulations on demand for backup power sources in this sector.

RESEARCH SUMMARY:
MINING

MARKET SEGMENT DESCRIPTION

The mining industry includes SIC Codes 12 and 10 for coal and metal mining companies. This does not include those facilities involved in oil and gas exploration and production, or mining of non-metals (e.g., gravel). Table m-1 identifies the SIC and NAICS classifications that represent coal and metal mining.

Table m-1. SIC and NAICS Codes for Coal and Metal Mining.

2-Digit SIC Codes	12 – Coal mining 10 – Metal mining
4-Digit SIC Codes	1222 – Bituminous coal underground mining 1231 – Anthracite mining (hard coal) 1241 – Coal mining services 1011 – Iron ores 1021 – Copper ores 1031 – Lead and zinc ores 1041 – Gold ores 1044 – Silver ores 1061 – Ferroalloy ores, except vanadium 1081 – Metal mining services 1094 – Uranium-radium-vanadium ores 1099 – Miscellaneous metal ores, not elsewhere classified (includes platinum)
NAICS Codes	21211 – Coal mining 212112 – Bituminous coal underground mining 212210 – Iron ore mining 212234 – Copper ore and nickel ore mining 212231 – Lead ore and zinc ore mining 212221 – Gold ore mining 212222 – Silver ore mining 213114 – Support activities for metal mining 212291 – Uranium-radium-vanadium ore mining 212299 – All other metal ore mining

Mining companies use backup power to support several functions at mine sites. According to a recent study by Arthur D. Little, backup power is a critical need, integral to normal operation in the mining industry.[311] Safety, pumping, and shutdown concerns are the primary drivers behind the demand for backup power in this industry. The greatest need for backup power may be in underground mines where human lives are at risk when systems fail. Functions often supported with backup power in mines include:

- Ventilation systems
- Hoists, for getting people out of mines

[311] Arthur D. Little, Inc. 2000. Opportunities for Micropower and Fuel Cell/Gas Turbine Hybrid Systems in Industrial Applications. Volume I (Main Text). Final Report to Lockheed Martin Energy Research Corporation and the DOE Office of Industrial Technologies.

- Communications devices, such as telephones and signaling devices (must contain a backup power supply to be approved for use in coal mines)
- Emergency lighting
- Mine pumps.

Total power demand for the mining industry is estimated at 18,000 MW, with the average facility size estimated to be 2 MW. The fraction of this power demand that is likely to be installed as backup power is estimated at 10%. This suggests that backup power requirements for an average facility would be about 200 kW.[312]

Currently, diesel generators are the primary source of backup power for mines. There is not usually a need for UPS systems, except for monitoring systems, which are used in some mines to monitor carbon monoxide and methane levels, and to detect heat or fire.

The U.S. Mine Safety and Health Administration (MSHA) administers safety and health standards that govern the nation's mines. As part of MSHA's escape and evacuation planning requirements for underground mines, each mine is required to provide a statement of availability of emergency power, telecommunications, and ventilation.

MARKET SIZE

Assuming a total power demand for the industry of 18,000 MW, and an estimated 10 % of which is likely to be installed as backup power (based on figures provided in the Arthur D. Little study), the total demand for backup power in the mining industry might be estimated at 1,800 MW.

Data on the overall mining industry size, including the number of businesses operating in each subsector, are presented in Tables m-2, m-3, and m-4 below. It should be noted that some mining companies operate across multiple subsectors and therefore may be included in more than one of the tables below.

[312] Arthur D. Little, Inc. 2000. Opportunities for Micropower and Fuel Cell/Gas Turbine Hybrid Systems in Industrial Applications. Volume I (Main Text). Final Report to Lockheed Martin Energy Research Corporation and the DOE Office of Industrial Technologies.

Table m-2. Number of Businesses in Bituminous Coal and Lignite-Surface Mining Industry (1221).[313]

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)*
1221-0000	Bituminous coal and lignite-surface mining	300	13,510	9,065.8
1221-0100	Bituminous coal surface mining	132	6,067	5,922.7
1221-0101	Auger mining, bituminous	25	261	29.4
1221-0102	Culm bank mining	2	5	0.6
1221-0103	Strip mining, bituminous	129	3,520	1,015.8
1221-0104	Strip mining, lignite	8	74	37.7
1221-0105	Surface mining, bituminous, nec	86	7,430	9,129.7
1221-0106	Surface mining, lignite, nec	9	1,037	272.5
1221-0200	Bituminous coal and lignite loading and preparation	13	155	754.6
1221-0201	Coal preparation plant, bituminous or lignite	60	3,238	611.5
1221-0202	Unit train loading facility, bituminous or lignite	8	161	15.6
	Total	**772**	**35,458**	**26,855.9**

*Sales figures are in millions.

Table m-3. Number of Businesses in Underground Coal Mining Industry (1222).[314]

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)*
1222-0000	Bituminous coal-underground mining	268	17,320	15,878
1222-9901	Underground mining, semianthracite	1	100	12.8
1222-9902	Underground mining, semibituminous	6	113	165.5
1222-9903	Underground mining, subbituminous	12	1,489	233.6
	Total	**287**	**19,022**	**16,289.9**

*Sales figures are in millions.

Table m-4. Number of Businesses in Metals Industry (1011, 1021, 1031, 1041, 1044, 1061, 1094, 1099).[315]

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)*
Iron Ores				
1011-0000	Iron ores	29	1,637	55.9
1011-0100	Iron ore mining	31	2,598	2,147.6
1011-0101	Open pit iron ore mining, nec**	5	2,036	24.7
1011-0102	Open pit taconite mining	4	1,308	0.5
1011-0103	Underground iron ore mining	3	19	2.6
1011-0200	Iron ore preparation	4	18	0.3
1011-0201	Iron ore beneficiating	3	12	0.9
1011-0202	Iron ore pelletizing	4	16	33.8
	Subtotal	**83**	**7,644**	**2,266.2**
Copper Ores				
1021-0000	Copper ores	45	2,101	346.6
1021-0100	Copper ore mining and preparation	21	3,857	13,079.4
1021-0101	Copper ore milling and preparation	5	935	2.8
1021-0102	Open pit copper ore mining	17	2,407	3,184.6
1021-0103	Underground copper ore mining	5	950	428.3
	Subtotal	**93**	**10,250**	**17,041.699**

313 Dun and Bradstreet. 2006. Zapdata industry report. Available at http://www.zapdata.com [Accessed May 2006].
314 Dun and Bradstreet. 2006. Zapdata industry report. Available at http://www.zapdata.com [Accessed May 2006].
315 Dun and Bradstreet. 2006. Zapdata industry report. Available at http://www.zapdata.com [Accessed May 2006].

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)*
Lead and Zinc Ores				
1031-0000	Lead and zinc ores	15	1,063	3.5
1031-0100	Lead ores mining	9	1,297	1,231
1031-0101	Cerussite mining	1	2	0.3
1031-0200	Zinc ores mining	6	351	42.8
1031-0203	Willemite mining	1	1	0.2
	Subtotal	**32**	**2,714**	**1,277.8**
Gold Ores				
1041-0000	Gold ores	122	8,501	1,079.1
1041-0100	Gold ores mining	130	3,924	5,172.9
1041-0101	Open pit gold mining	24	902	211.9
1041-0102	Placer gold mining	20	233	11.6
1041-0103	Underground gold mining	31	573	46.5
1041-0200	Gold ores processing	8	17	1.8
1041-0201	Gold bullion production	3	10	1.2
1041-0202	Gold ore milling	7	45	6
1041-0203	Gold recovery from tailings	3	20	5.2
	Subtotal	**348**	**14,225**	**6,536.4**
Silver Ores				
1044-0000	Silver ores	13	308	15.2
1044-0100	Silver ores mining	5	323	1.1
1044-0101	Open pit silver mining	1	3	0.1
1044-0102	Placer silver mining	2	23	9.7
1044-0103	Underground silver mining	3	7	0.2
1044-0200	Silver ores processing	3	5	0.2
1044-0202	Silver ore milling	3	8	0.2
1044-0203	Silver recovery from tailings	8	20	1.8
	Subtotal	**38**	**697**	**28.5**
Ferroalloy Ores, Except Vanadium				
1061-0000	Ferroalloy ores, except vanadium	7	433	86.8
1061-0200	Manganese ores mining	1	2	0.2
1061-0300	Molybdenum ores mining	10	1,119	276
1061-0400	Tungsten ores mining	3	8	4.8
1061-9901	Cobalt ore mining	1	2	0.3
1061-9902	Columbite mining	2	7	1
1061-9904	Huebnerite mining	1	12	1.7
1061-9905	Nickel ore mining	3	7	0.8
	Subtotal	**28**	**1,590**	**371.6**
Uranium-radium-vanadium Ores				
1094-0000	Uranium-radium-vanadium ores	14	257	100
1094-9903	Radium ore mining, nec	1	5	0.1
1094-9905	Uranium ore mining, nec	37	551	1,653.9
1094-9906	Vanadium ore mining, nec	1	0	N/A
	Subtotal	**53**	**813**	**1,754**
Metal Ores, nec				
1099-0000	Metal ores, nec	19	62	5.9
1099-0100	Aluminum and beryllium ores mining	2	8	0.7
1099-0101	Aluminum ore mining	14	205	94.5
1099-0102	Bauxite mining	10	285	543.7
1099-0104	Beryllium ore mining	2	1,863	196.8

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)*
1099-0200	Palladium group ores mining	3	1,266	507.8
1099-0300	Platinum group ores mining	2	6	0.8
1099-0400	Rare-earth ores mining	3	23	2
1099-0501	Rutile mining	1	9	0.9
1099-0502	Titaniferous-magnetite mining	1	1	0.1
1099-0503	Titanium ore mining	1	10	1.1
1099-9904	Mercury ore mining	1	4	0.4
1099-9906	Thorium ore mining	1	4	N/A
	Subtotal	**60**	**3,746**	**1,354.6**

*Sales figures are in millions.

MARKET TRENDS

The demand for backup power in the mining industry is expected to increase in future years, in light of recent mining crises that have drawn national attention. For example, the Sago Mine Explosion, which occurred on January 2, 2006, has heightened awareness of the need for appropriate underground mine rescue equipment and technology.316 In underground mines, lives may be at stake when critical systems for ventilation, evacuation, and communications fail.

Title 30 of the Code of Federal Regulations (CFR) establishes rules that support the use of emergency power equipment in underground mines. Regulations established under 30 CFR § 57.11053 require mine operators to provide copies of their escape and evacuation plans to MSHA, which must be reviewed and updated at least once every 6 months. Among other requirements, the plan must include "a statement of the availability of emergency communication and transportation facilities, emergency power and ventilation and location of rescue personnel and equipment."[317] While emergency power sources are not required for escape hoists, a regulation under 30 CFR § 57.19111 requires that either fixed ladders be provided that reach as near the shaft of the mine, or "an escape hoist powered by an emergency power source shall be provided."

MARKET SEGMENT ANALYSIS

To identify the market opportunities for direct PEM fuel cells to provide backup power in mining operations, three mining companies were contacted, and one response was received. One MSHA representative also participated in a brief interview.

The single respondent organization was a medium-sized platinum mining company. The company uses limited backup power, which supplies a communications system and personnel hoist, in its mines. The company does not provide backup power for its ventilation system because it would require 3 MW of power. The respondent considered the most important applications of backup power in mines to be pumping (in mines with the potential for flooding and thus the need to ensure that the mine does not flood in case of a power failure), communications systems, and escape hoisting. The respondent reported that the consequences of power outages include loss of life, disruptions in production, and disruptions in distribution.

[316] Mine Safety and Health Administration. 2006. Sago Mine Information Single Source Page. Available at http://www.msha.gov/sagomine/sagomine.asp [Accessed August 2006].
[317] Mine Safety and Health Administration. 2006. Title 30 Code of Federal Regulations. 30 CFR § 57.11053 Escape and evacuation plans. Available at http://www.msha.gov/30cfr/57.11053.htm [Accessed October 2006].

The respondent estimated that the company has experienced two power failures during the past year, and they have had a few planned outages. One unplanned outage lasted 12 hours, and another lasted more than 24 hours. The respondent indicated that any outages > 1 second are considered very disruptive. A power failure trips all electronic systems (e.g., the hoist), and many need to be restarted, a process which can take up to several hours.

The company currently uses diesel generators to meet its backup power requirements. One of the company's mines utilizes two 2-MW generators, which is sufficient power for the entire mine operation. A second mine utilizes one 750 kW generator.

The respondent identified reliability, emissions, ease of use, and past experience with the system as very important factors in making a decision to purchase a backup power system. Of these, the respondent considered reliability and emissions to be the most important factors.

Reliability and emissions are the primary concerns the company has with the performance of its current backup power systems. Although the company has had some issues with failure of its backup power systems to start when needed, the respondent indicated that the company is fairly satisfied with the performance of its current backup power systems. Favorable characteristics of the company's current backup power systems, as indicated by the respondent, are ease of use, operation and maintenance costs, and fuel availability.

The respondent expects to see growth in the future demand for backup power in the mining sector. Because of the Sago Mine disaster, the respondent reported that the federal government is expected to promulgate new requirements for backup power at the nation's mines.

The respondent stated that the company has not considered alternatives to diesel generators for backup power (other than larger sized systems). The company is familiar with PEM fuel cells and believes that PEM fuel cells will compete for backup power in this industry at some point, though the respondent did not indicate a timeframe.

The respondent did not have any concerns with the use of hydrogen as a fuel, primarily due to the company's past experience with an experimental hydrogen-powered vehicle. The company performed a field test with a Zero Emission Utility Solution (ZEUS), developed by the National Institute for Occupational Safety and Health (NIOSH), in 2004. The respondent noted that, while he personally did not have concerns with a hydrogen-powered vehicle, some employees of the company were concerned about safety.

The respondent stated that capital purchase decisions in this company were made based on a return on investment assessment. Government incentives are considered in capital purchase decisions.

The respondent agreed to be contacted again for further information.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

Limited information was available to assess the potential for PEM fuel cells as a backup power source in the mining industry. Based on secondary research, PEM fuel cells appear to fit the size requirements for backup power at typical mines. However, the single data point in this analysis suggests that PEM fuel cells would be too small to provide adequate backup power. Current PEM products for backup power could meet the lower estimate for power size requirements described in the Arthur D. Little study (200 kW) but not the higher estimate provided by the mining company interviewed for this analysis (2 MW).

The primary value proposition that PEM fuel cells offer over the current technology is the opportunity to reduce emissions in a sector where diesel emissions are very closely monitored and regulated. PEM fuel cells offer clean emissions as well as reliability, factors which were valued over cost and other factors by the respondent interviewed in this analysis. In addition, new safety regulations being discussed may increase requirements for backup power in the mining sector.

RESEARCH SUMMARY:
NATIONAL AND STATE PARKS

MARKET SEGMENT DESCRIPTION

A national or state park is a reserve of land that is typically protected from human development and environmental alteration. National or state parks typically consist of spacious areas known for their exceptional scenic or natural characteristics; these areas often have significant ecological, geological, archeological, historical, recreational, or other such values. The federal government generally is responsible for the administration of national parks, while state or local governments are responsible for operating and maintaining state parks. State parks are often, but not always, smaller than national parks. This analysis considers the potential for PEM fuel cells for backup power at national and state park facilities. Table n-1 identifies the primary SIC and NAICS classifications associated with this market segment.

Table n-1. SIC and NAICS Codes for National and State Parks.

2-Digit SIC Code	95 – Administration of environmental quality and housing programs
4-Digit SIC Code	9512 – Land, mineral, and wildlife conservation
NAICS Code	712190 – Nature parks and other similar institutions

National and state parks do have a need for backup power. These parks have education and resort facilities that need to sustain lodge operations in the event of power supply interruption to provide services such as heating, ventilation, and air conditioning systems, electricity, water supplies (both for drinking and fire protection), kitchen services, and lighting. Parks have campground and visitor facilities, stores with retail point-of-sale systems, and computerized central reservation systems that also require power. Park facilities often are located in remote areas, and providing utility power to these facilities can be difficult. Above-ground power lines may be prohibited because of their aesthetic impacts, and below-ground power line easements are difficult to obtain in some parks. As a result, many parks use generators not only for backup power but for their primary power supply, as well.[318]

Backup power is presently provided by diesel and propane generators, photovoltaic array systems, and battery backup technologies.[319]

MARKET SIZE

Current market size data for national and state parks are provided below. Table n-2 provides data on the primary SIC code related to national and state parks (9512 - Land, Mineral, and Wildlife Conservation). Because parks offer forestry services, SIC codes that are likely to be associated with national or state parks include 0851 (Forestry services). Market information on these related SIC codes is provided in Table n-3; note that only a small portion of the organizations associated with these services could reasonably be expected to work in national or state park facilities. In Tables n-2 and n-3, only those eight-digit SIC specialties deemed relevant to national and states parks are shown.

[318] National Park Service. 2003. Greening the National Park Service: Greening Case Studies. Available at http://www.nps.gov/renew/case.htm [Accessed July 2006].
[319] National Park Service. 2003. Greening the National Park Service: Greening Case Studies. Available at http://www.nps.gov/renew/case.htm [Accessed July 2006].

Table n-2. Number of Potential Users – Industry: Land, Mineral, and Wildlife Conservation (9512).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)*
9512-0000	Land, mineral, and wildlife conservation	4,955	137,204	1
9512-0200	Land conservation agencies	1,048	39,442	0.2
9512-0201	Land management agency, government	448	16,152	N/A
9512-0400	Land, mineral, and wildlife conservation, level of government	4	419	N/A
9512-0401	Land, mineral, and wildlife conservation, federal government	20	295	N/A
9512-0402	Land, mineral, and wildlife conservation, state government	110	631	N/A
9512-0403	Land, mineral, and wildlife conservation, county government	79	402	N/A
9512-0404	Land, mineral, and wildlife conservation, local government	72	698	N/A
9512-9901	Conservation and stabilization agency, government	153	2,900	0.8
9512-9902	Recreational program administration, government	3,151	57,520	1
	Total	**10,040**	**255,663**	**3**

Sales figures are in millions. Source: www.zapdata.com, accessed July 2006.

Table n-3. Number of Potential Users – Industry: Forestry Services (0851).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)*
0851-0000	Forestry services	3,387	15,250	578.5
0851-0100	Forest management services	461	2,353	115.3
0851-9901	Fire fighting services, forest	760	4,642	197.5
0851-9902	Fire prevention services, forest	212	1,337	46.8
	Total	**4,820**	**23,582**	**938.1**

Sales figures are in millions. Source: www.zapdata.com, accessed July 2006.

The National Park Service (NPS) is the federal agency responsible for administration of national parks. The NPS, which partners with other governments and private organizations to manage its land, oversees approximately 390 units within the National Park System; these units include national parks, national monuments, national historic sites, national recreation areas, national rivers, national battlefields, and national scenic trails. The National Park System covers over 84 million acres of land in the United States and its territories.[320]

National and state parks generate revenues primarily through fees collected from visitors but also receive funding from federal and state governments. The most popular NPS units in 2005 include Blue Ridge Parkway (nearly 18,000,000 recreational visits), Golden Gate National Recreation Area (over 13,000,000 recreational visits), and Great Smoky Mountains National Park (over 9,000,000 recreational visits).[321] In FY 2005, the NPS earned approximately $287,715,000 in revenue derived from the public and $52,949,000 in revenue from federal sources. The total cost of services provided by the NPS for FY 2005 was $3,000,536,000.[322]

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[320] U.S. Department of the Interior, National Park Service. 2005. Annual Report: Fiscal Year 2005. Available at http://www.doi.gov/pfm/annrept/nps_05_par.pdf [Accessed July 2006].
[321] National Park Service, Public Use Statistics Office. 2005. 2006 Statistical Abstract. Available at http://www2.nature.nps.gov/stats/abst2005.pdf [Accessed July 2006].
[322] U.S. Department of the Interior, National Park Service. 2005. Annual Report: Fiscal Year 2005. Available at http://www.doi.gov/pfm/annrept/nps_05_par.pdf [Accessed July 2006].

State parks, though typically smaller in size, are much more plentiful than national parks and are also heavily utilized. There were 5,842 state park areas in 2004, comprising over 13 million acres.[323] State parks represent less than 2% of the property devoted to outdoor recreation nationwide but host nearly 30% of all visitors at state and federal outdoor recreation areas. In 2001, 735 million people reported visiting state parks. There are multiple facilities that may require primary and/or backup power at these parks. The following statistics, compiled by the National Association of State Park Directors, characterize the state park industry in 2004 by summarizing key features and activities reported by all state parks during that year:[324]

- 208,849 campsites ranging from primitive to multiple hookups
- 6,492 cabins and cottages
- 124 lodges (with 6,865 rooms) in 25 states
- 129 golf courses
- 48 ski slopes
- 309 marinas
- 293 swimming pools
- 99 stable operations
- $345.7 million spent on capital improvements and land acquisition
- $690.9 million expended for capital expenditures
- Average share of the state budget: 0.24%.

Both national and state parks maintain large work forces. The NPS has approximately 20,000 direct employees. In 2004, state parks employed 20,603 full-time personnel and an additional 33,295 part-time and seasonal personnel.[325]

MARKET TRENDS

Efforts are underway to replace fossil fuel-based power sources in parks with alternative energy sources.[326,327] Existing technologies, particularly diesel generators, are being replaced by environmentally friendly alternatives such as photovoltaic and wind-based technologies. No information was found on performance or user satisfaction; however, wind technologies have been identified as ideally suited for use in the National Park System.[328,329]

[323] The National Association of State Park Directors. 2004. State Park Facts. Available at http://isu1.indstate.edu/naspd/statistics_sub.asp [Accessed July 2006].
[324] The National Association of State Park Directors. 2004. State Park Facts. Available at http://isu1.indstate.edu/naspd/statistics_sub.asp [Accessed July 2006].
[325] The National Association of State Park Directors. 2004. State Park Facts. Available at http://isu1.indstate.edu/naspd/statistics_sub.asp [Accessed July 2006].
[326] National Park Service. 2003. Greening the National Park Service: Greening Case Studies. Available at http://www.nps.gov/renew/case.htm [Accessed July 2006].
[327] U.S. Department of the Interior. 2004. Statement of Joseph Alston, Superintendent of Grand Canyon National Park, National Park Service, Before the House Resources Subcommittee on National Parks, Recreation and Public Lands of the House Committee on Resources, on the Use of Hydrogen Fuel Cell Technology in the National Park System. Available at http://www.doi.gov/ocl/2004/FuelCell.htm [Accessed July 2006].
[328] U.S. Department of Energy, National Renewable Energy Laboratory. 1998. New Wind Energy Technologies Are Cost-Effective in Federal Applications. DOE/GO-10098-583. Available at http://www1.eere.energy.gov/femp/pdfs/WindTF.pdf [Accessed July 2006].
[329] Xanterra Parks & Resorts. 2006. Renewable Energy. Available at http://www.xanterra.com/Renewable-Energy-378.html [Accessed July 2006].

Anthony Eggert, Associate Research Director of the Hydrogen Pathways Research Program at the University of California-Davis Institute of Transportation Studies, testified before the House Hearing on the Use of Hydrogen Fuel Cell Technology in the National Park Service on May 15, 2004.[330] In his testimony, Mr. Eggert cites a number of benefits and challenges associated with the demonstration of hydrogen and fuel cell technologies within the NPS. Benefits include the high visibility of NPS properties to national and international visitors; the ability to replace heavily polluting diesel generators with technologies that have substantially lower pollutant emissions; and the management structure of the NPS, which includes a highly trained workforce. Challenges include the absence of an inexpensive hydrogen feedstock due to the lack of natural gas pipelines into many parks and strict construction, siting, and permitting controls that would make developing a new hydrogen infrastructure difficult. [331]

The NPS has a vested interest in environmental programs. Through its Green Energy Parks Program, the NPS has initiated many efforts to foster environmental stewardship throughout the National Park System. Several hydrogen fuel cell systems have been installed at various units within the National Park System, as summarized below, and numerous other fuel cell initiatives have been planned:[332]

- The first pure hydrogen fuel cell was installed in 1999 at Golden Gate National Recreation Area's Kirby Cove Campground. The 0.5 kW system was fairly reliable, and when coupled with a solar photovoltaic system, provided clean electricity to a trailer site reserved for an NPS volunteer campground host. When the services of a campground host were deemed no longer necessary, the fuel cell system was removed.[333]
- Experiments have been conducted with PEM fuel cells to power various functions at the Golden Gate National Recreation Area and Yellowstone and Yosemite National Parks.[334]
- Opened in May of 2004, the Exit Glacier Nature Center at Kenai Fjords National Park is powered by a 5 kW, solid-oxide fuel cell. The remote Nature Center is not served by utility power, and park officials had previously relied on diesel generators for electricity. The fuel cell, which runs on hydrogen generated by propane, is used to flush toilets, power videos and other interactive exhibits, and provide heat.[335]
- In 2002, a 4.5 kW hydrogen fuel cell was demonstrated at the west entrance of Yellowstone National Park. The system was used to heat offices and power entrance kiosks; however, the system was later removed from the park after being deemed too difficult to maintain.[336]

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[330] Eggert, A. 2004. Hearing on the Use of Hydrogen Fuel Cell Technology in the National Park Service. Available at http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1067&context=itsdavis. [Accessed July 2006.[

[331] Eggert, A. 2004. Hearing on the Use of Hydrogen Fuel Cell Technology in the National Park Service. Available at http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1067&context=itsdavis. [Accessed July 2006.[

[332] National Parks Conservation Association. 2004. Alternate Fuel Source Tapped at Kenai Fjords. Available at http://www.npca.org/magazine/2004/fall/news3.html. [Accessed July 2006.]

[333] U.S. Department of the Interior. 2004. Statement of Joseph Alston, Superintendent of Grand Canyon National Park, National Park Service, Before the House Resources Subcommittee on National Parks, Recreation and Public Lands of the House Committee on Resources, on the Use of Hydrogen Fuel Cell Technology in the National Park System. Available at http://www.doi.gov/ocl/2004/FuelCell.htm. [Accessed July 2006.]

[334] National Parks Conservation Association. 2004. Alternate Fuel Source Tapped at Kenai Fjords. Available at http://www.npca.org/magazine/2004/fall/news3.html. [Accessed July 2006.]

[335] National Parks Conservation Association. 2004. Alternate Fuel Source Tapped at Kenai Fjords. Available at http://www.npca.org/magazine/2004/fall/news3.html. [Accessed July 2006.]

[336] National Parks Conservation Association. 2004. Alternate Fuel Source Tapped at Kenai Fjords. Available at http://www.npca.org/magazine/2004/fall/news3.html. [Accessed July 2006.]

MARKET SEGMENT ANALYSIS

Twenty-five individuals affiliated with state or national parks were contacted in an attempt to gather information on requirements for backup power and the potential for fuel cell use in national and state parks. Two interviews were conducted, and one complete survey response was received. Interviewees were enthusiastic about the potential use of fuel cells and the opportunity to test them as an alternative, environmentally friendly, energy source. Interviewees also expressed enthusiasm over the opportunity to educate the public on new alternative energy sources that help protect natural resources and aid in reducing emissions. Various park services use fuel cells for backup power and even for prime power in more remote locations.

One completed survey was received from a regional energy manager serving 60 national parks and 7 state parks. The respondent indicated that backup power was required for museums and curatorial centers, waste water treatment, utility water systems, fire protection, radio and telephone systems, dispatch centers, fire/rescue/law enforcement operations, hospitality, housing and administrative units onsite. The respondent indicated that power outages were not as disruptive but could result in loss of drinking water and release of sewage. The respondent indicated that backup power was currently being met through generators, which vary in size depending on the application, but range from 5 kW to > 250 kW. The respondent indicated that reliability, emissions, lifetime of unit, and good experience with this type of system in the past were the most important factors when selecting a backup power system. The respondent's primary concerns regarding current systems were emissions and the high cost of owning and operating the systems. The respondent had considered alternatives, including propane, for diesel generators. The respondent was aware of PEM fuel cells for backup power but was skeptical of their performance. The respondent had no concerns about hydrogen as a fuel and cited the primary drivers for purchasing fuel cells as: environmental concerns, government incentives, and a track record of others using them. The respondent indicated that a variety of factors were considered when making purchasing decisions, including initial capital costs, payback period, and return on investment.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

Both state and national parks seem to have significant interest in the installation of alternative technologies, including fuel cells. Users in this market segment are considering alternatives to diesel generators, and are looking for environmental friendly alternatives. While the market is small and growth is limited, there is potential for application of PEM fuel cells at various sites within the national park system (e.g. remote lodging facilities, communication systems). While users are interested in alternatives, the primary barrier is likely to be the cost of the systems. Park budgets are tight, and existing fuel cell installations have been sponsored by other agencies and programs. National parks are currently weathering a funding crisis, with the NPS reported to be under-funded by as much as $600 million per year. National park advocacy groups indicate that the parks are getting just two-thirds of the funding they need, leading to severe staffing shortages and deteriorating park facilities.[337] Without outside funding, there is little chance that park systems could afford such installations on their own in the near-term, given their extreme budget constraints. Adoption in NPS will be dependent on availability of funds and will likely be a mid-term opportunity.

[337] Lovgren, S. 2004. U.S. National Parks Told to Quietly Cut Services. National Geographic News. Available at http://news.nationalgeographic.com/news/2004/03/0319_040319_parks.html [Accessed July 2006].

RESEARCH SUMMARY: ORIGINAL EQUIPMENT MANUFACTURERS (OEMs) AND SUPPLIERS

MARKET SEGMENT DESCRIPTION

The original equipment manufacturing (OEMs) and supply industry includes the manufacture and supply of a range of transportation-related equipment. This analysis focuses primarily on the manufacture and assembly of motor vehicles and car bodies. OEMs and suppliers include establishments primarily engaged in manufacturing or assembling complete passenger automobiles, trucks, commercial cars and buses, and special purpose motor vehicles which are for highway use. It also includes the manufacture and supply of chassis and passenger car bodies, as well as various parts and accessories. Other transportation-related equipment manufacturing (not specifically addressed in this report) includes aerospace vehicles, railroads, ships, and boats as well as motorcycles and armored cars. Table o-1 identifies the SIC and NAICS classifications that cover original equipment manufacturers and suppliers.

Table o-1. SIC and NAICS Codes for Original Equipment Manufacturers and Suppliers.

2-Digit SIC Code	37 – Transportation equipment
4-Digit SIC Code	3711 – Motor vehicles and car bodies
NAICS Code	336111 – Automobile manufacturing

The U.S. is the world's largest marketplace for motor vehicles because of the size and affluence of its population. According to the U.S. Department of Transportation, approximately 230 million motor vehicles - nearly 136 million automobiles, 95 million trucks, and 777,000 buses were registered in the United States in 2003.

In 2004, about 9,400 establishments manufactured motor vehicles and parts; these ranged from small parts plants with only a few workers to huge assembly plants that employ thousands. Table o-2 below shows that 68.9% of establishments in the industry manufactured motor vehicle parts including, electrical and electronic equipment; gasoline engines and parts; brake systems; seating and interior trim; steering and suspension components; transmission and power train parts; air-conditioners; and motor vehicle stampings, such as fenders, tops, body parts, trim, and molding. Other establishments specialized in manufacturing truck trailers; motor homes; travel trailers; campers; and car, truck, and bus bodies placed on separately purchased chassis.[338]

Globalization of the industry has boosted competition among U.S. motor vehicle manufacturers, prompting innovations in product design and in the manufacturing process. Manufacturers have rapidly designed and produced new models aimed at niches in the market. Firms also must be fast and flexible in implementing new production techniques, such as replacing traditional assembly lines with modern systems using computers, robots, and interchangeable platforms. Plants designed for production flexibility put resources in the right place at the right time, allowing manufacturers to shift to new models quickly and efficiently.

[338] Bureau of Labor Statistics, U.S. Department of Labor. 2006. Career Guide to Industries, 2006-07 Edition, Motor Vehicle and Parts Manufacturing. Available at http://www.bls.gov/oco/cg/cgs012.htm [Accessed May 2006].

MARKET SIZE

Table o-2 characterizes the market for OEMs and suppliers for the manufacture of motor vehicles and car bodies. There are an estimated 2,022 establishments in the U.S., employing 280,242 people. Total annual sales in this industry are $457,793.4 million, with average sales per establishment of $273.0 million.

Table o-2. Number of OEMS and Suppliers – Manufacture of Motor Vehicles and Car Bodies (3711).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)*
3711-0000	Motor vehicles and car bodies	465	89,024	41,892.602
3711-0100	Automobile assembly, including specialty automobiles	619	115,225	388,082.188
3711-0101	Ambulances (motor vehicles), assembly of	47	1,958	216.1
3711-0102	Automobile bodies, passenger car, not including engine, etc.	122	8,212	138.8
3711-0103	Cars, armored, assembly of	31	393	144
3711-0104	Cars, electric, assembly of	26	114	20.1
3711-0105	Chassis, motor vehicle	123	6,040	1,476.4
3711-0106	Hearses (motor vehicles), assembly of	6	273	105.8
3711-0107	Patrol wagons (motor vehicles), assembly of	3	77	8.1
3711-0108	Station wagons (motor vehicles), assembly of	1	1	0.1
3711-0109	Taxicabs, assembly of	10	41	3.7
3711-0200	Truck and tractor truck assembly	80	20,901	17,351.4
3711-0201	Motor trucks, except off-highway, assembly of	12	11,336	632.3
3711-0202	Truck tractors for highway use, assembly of	27	2,330	2,226.8
3711-0203	Trucks, pickup, assembly of	37	3,134	10.4
3711-0300	Military motor vehicle assembly	30	826	1,972.7
3711-0301	Amphibian motor vehicles, assembly of	3	51	12.6
3711-0302	Personnel carriers (motor vehicles), assembly of	17	82	6.7
3711-0303	Reconnaissance cars, assembly of	6	22	1.8
3711-0304	Scout cars (motor vehicles), assembly of	5	70	0.4
3711-0305	Universal carriers, military, assembly of	1	2	0.1
3711-0400	Bus and other large specialty vehicle assembly	30	1,576	128.2
3711-0401	Brooms, powered (motor vehicles), assembly of	3	18	1.8
3711-0402	Buses, all types, assembly of	67	8,903	1,816.1
3711-0403	Fire department vehicles (motor vehicles), assembly of	84	5,009	875.5
3711-0404	Mobile lounges (motor vehicle), assembly of	10	157	8.8
3711-0405	Motor buses, except trackless trollies, assembly of	6	1,652	270.4
3711-0406	Motor homes, self contained, assembly of	20	1,034	132.5
3711-0407	Road oilers (motor vehicles), assembly of	2	8	0.7
3711-0408	Snow plows (motor vehicles), assembly of	34	587	42.7
3711-0410	Street sprinklers and sweepers (motor vehicles), assembly of	15	769	164.7
3711-0411	Wreckers (tow truck), assembly of	80	417	48.8
	Total	**2,022**	**280,242**	**457,793.406**

Sales figures are in millions. Source: www.zapdata, accessed September 2006.

Motor vehicle assembly plants use energy throughout the plant for many different end-uses. The main energy types used on-site are electricity, steam, gas, and compressed air. Total energy expenditures in the transportation equipment manufacturing industry as a whole (NAICS Code

336) were estimated at $3.6 billion in 1999.[339] In vehicle assembly plants categorized in SIC Code 3711, about $700 million is spent on energy. An estimated two-thirds of the budget for assembly plants is spent on electricity.[340] Electricity use in vehicle assembly plants has increased over time from 8.6 terawatt hours (TWh) in 1987 to 10 TWh in 1995, while the average specific electricity consumption per car has decreased from almost 1000 kW hours per car in 1987 to 860 kW hours per car in 1995. However, there are large variations among individual plants.[341]

Table o-3 provides an estimate of the typical electricity end-use distribution in vehicle assembly plants, based on studies of such plants in the U.S. About 70% of all electricity is used in motors to drive different pieces of equipment in the plant.

Table o-3. Distribution of Electricity Use in Vehicle Assembly Plants.[342]

End-Use	Share of Electricity Use (%)	Estimated Electricity Consumption in 1995 (kW Hours/Car)	Average Electricity Applied in Analyses in this Study (kW Hours/Car)
HVAC	11-20%	95-170	160
Paint Systems (e.g., Fans)	27-50%	230-320	260
Lighting	15-16%	130-140	130
Compressed Air	9-14%	80-120	120
Materials Handling/Tools	7-8%	60-70	60
Metal Forming	2-9%	20-80	30
Welding	9-11%	80-95	80
Miscellaneous	4-5%	35-45	20
Total	**100%**	**730-1040**	**100%**

According to the EIA,[343] net demand for electricity in 2002 for transportation equipment (NAICS 336) was 27,700 million kW hours. Secondary data on the proportion of total energy use typically supported with backup power was not available.

MARKET TRENDS

The impact of unscheduled downtime from power outages in this sector can be significant, as was underscored by the August 2003 blackout. Power outages affected automotive manufacturers and suppliers throughout the United States and Canada and resulted in an estimated production loss of 35,000 vehicles, the temporary layoff of more than 100,000 workers, and more than $1 billion in lost wages and production.[344]

[339] U.S. Census, U.S. Department of Commerce. 2000. Annual Survey of Manufacturers, various years. Available at http://www.census.gov/econ/overview/ma0300.html [Accessed December 2006].
[340] Berkeley National Laboratory. 2003. Energy Efficiency Improvement and Cost Savings Opportunities for the Vehicle Assembly Industry: an ENERGY STAR® Guide for Energy and Plant Managers.
[341] U.S. Census, U.S. Department of Commerce. 2000. Annual Survey of Manufacturers, various years. Available at http://www.census.gov/econ/overview/ma0300.html [Accessed December 2006].
[342] Berkeley National Laboratory. 2003. Energy Efficiency Improvement and Cost Savings Opportunities for the Vehicle Assembly Industry: an ENERGY STAR® Guide for Energy and Plant Managers.
[343] Energy Information Administration. 2002. Manufacturing energy consumption survey. Available at http://www.eia.doe.gov/emeu/mecs/contents.html [Accessed December 2006].
[344] Portal Publishing Ltd. 2004. Automotive Industry Action Group's crisis management process could save millions. Available at http://www.continuitycentral.com/news0910.htm [Accessed September 2006].

According to The Electricity Consumers Resource Council,[345] at least 70 auto and parts plants and several offices were shut down by the August 14, 2003, blackout. General Motors Corporation reported that the blackout affected approximately 47,000 employees at 19 manufacturing facilities and three parts warehouses in Michigan, Ohio, and Ontario. The Ford Motor Company reported that 23 of Ford's 44 plants in North America were shut down, as were numerous office, engineering, and product development facilities in southeastern Michigan. Other facilities were affected by disruptions in parts supply lines. At Ford's casting plant in Brook Park, Ohio, the outage caused molten metal to cool and solidify inside one of the plant's furnaces. The company reported that a week would be required to clean and rebuild the furnace.

The North American operating units of DaimlerChrysler AG lost production at 14 of its 31 plants. Six of those were assembly plants with paint shops. All the vehicles that were moving through the paint shop at the time of the outage had to be scrapped. The company reported that, in total, 10,000 vehicles had to be scrapped. A number of other manufacturing and assembly plants were affected as a result of the blackout, including Honda Motor Company's assembly plant in Alliston, Ontario, Delphi's Flint East Manufacturing Complex, and several of Neff-Perkins Company's manufacturing plants. Specific operations affected by the blackouts include presses, air conditioning units, and painting machines.

As illustrated by the power outages experienced in August 2003, OEMs and suppliers typically do not maintain backup power for all manufacturing and assembly processes. Short interruptions in production can usually be made up by running overtime, and larger manufacturers keep approximately 2 months worth of inventory in dealer lots. However, longer unplanned plant shutdowns have a direct impact on earnings, since automakers book revenues when a vehicle is built.

The industry uses some backup power technologies. Diesel generators appear to be a common type of backup system. Honda, for example, has two diesel generators (a 200 kW and 500 kW) in one of its plants and uses diesel generators for backup power in all North American locations. Some motor vehicle manufacturers buy power from other facilities for backup; others maintain their own power plants, which generate electricity from coal or natural gas.

The industry has also investigated fuel cell technology, although not for backup power applications. Ford Motor Company completed testing in 2003 on a 5 kW solid oxide fuel cell at the Dearborn Assembly Plant in Michigan. The fuel cell system utilized hydrogen gas from the plant's vehicle paint shop (supplemented with natural gas) to provide electricity and heat for the facility. In 2001, Ford installed a 200 kW PAFC at its North American Premier Automotive Group headquarters in Irvine, California. The fuel cell, fueled by natural gas, provided 25 % of the building's electricity and hot water.

MARKET SEGMENT ANALYSIS

To identify the market opportunities for direct PEM fuel cells among OEMs and suppliers, 39 companies were contacted, and two responses were received. One respondent represented a

[345] The Electricity Consumers Resource Council. 2004. The Economic Impacts of the August 2003 Blackout. Available at http://www.elcon.org/Documents/EconomicImpactsOfAugust2003Blackout.pdf [Accessed May 2006].

large engine machining manufacturing plant, while the other was a small manufacturer of oxygen sensors.

Respondents reported that backup power was required for all machining operations and lighting, computer servers, and basic utilities. Of these operations, respondents typically indicated that machining operations and computer servers were the most critical functions. However, a number of manufacturers, including some who declined to take the survey, indicated that backup power systems are not feasible for their manufacturing processes due to the magnitude of power requirements.

The large engine machining manufacturer had experienced five power outages in the last 12 months; three of these outages were weather related, and two were related to problems with the power company. All five outages lasted less than 3 seconds, and all outages were considered very disruptive. The small oxygen sensor manufacturer experienced approximately four outages in the last 12 months, lasting 60 seconds on average. This respondent stated that outages lasting 1 second were minimally disruptive, 3-minute outages were moderately disruptive, and outages lasting 1 hour or more were very disruptive. Both respondents noted that power outages resulted in disruptions in production; one respondent also stated that power outages resulted in implementation of emergency management plans and disruptions in distribution.

Respondents indicated that backup power requirements are being met through UPS systems and generators. The large manufacturer has multiple backup power systems, including one 5 kW, two 50 kW, one 10 kW, one 15 kW, and one 50 kW. The small manufacturer indicated that it has two diesel generators, one of 200 kW and one of 500 kW.

Both respondents indicated that important characteristics to consider in selecting a backup power system were reliability and startup time. One respondent also stated that emissions, ease of use, fuel availability, and reliability were other critical decision factors.

When asked to rate the performance of their current backup power systems, respondents indicated that reliability, lifetime of the unit, and fuel availability were generally good. One respondent stated that ease of use, capital cost, and startup time were good, while annual operating costs and emissions of the current system were not very good. The other respondent indicated that capital cost, annual operating cost, startup time, and ease of use were not very good.

Neither survey respondent anticipated a growing need for backup power in this market; nor had they considered alternatives to current backup power systems. Neither respondent had heard of PEM fuel cells.

One respondent stated that purchase decisions for backup power systems are based on the payback period of the investment, but that government incentives are considered; the other respondent stated that decisions were made based on return on investment and that government incentives are not considered.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

Potential applications for backup power by OEMs and suppliers include computer servers, machining operations, emergency lighting, and basic utilities. These applications consume a small portion (< 30%) of the power required for automotive manufacture and supply. Based on limited data, users appear to have a high level of satisfaction with current backup power systems, which include UPS systems and generators ranging from 5 kW to 500 kW. While PEM fuel cell systems may be adequately sized to meet some of these backup power needs (e.g. emergency lighting), respondents lacked familiarity with PEM fuel cells and did not express interest in pursuing new or alternative technologies.

Power requirements for large, automated applications such as molten metal furnaces and continuous flow assembly lines are too large to be accommodated by current PEM fuel cell technology. Additionally, despite the negative impact of extended power outages on OEMs and suppliers, there is little indication that companies are vigorously pursuing strategies to provide more backup power.

There eventually may be opportunities PEM fuel cells to provide backup power in small, niche applications; companies who are actively pursuing PEM fuel cell technology for vehicle applications could potentially be willing adopters of stationary PEM fuel cells for demonstration purposes. However, there do not appear to be any strong drivers for the use of PEM fuel cells as a backup power source in near term.

RESEARCH SUMMARY:
PETROLEUM REFINERIES

MARKET SEGMENT DESCRIPTION

This market segment comprises establishments primarily engaged in refining crude petroleum into refined petroleum. This market segment was examined because the process of oil refining produces and utilizes hydrogen gas, and can potentially provide a more economical source of hydrogen. Other applications in the oil and gas market like backup power for offshore oil rigs (unmanned platforms) and protection of pipelines are not discussed here. This market segment includes firms engaged in producing gasoline, kerosene, distillate fuel oils, residual fuel oils, aliphatic and aromatic chemicals, and lubricants, through fractionation or straight distillation of crude oil, redistillation of unfinished petroleum derivatives, cracking, or other processes. Table p-1 identifies the SIC and NAICS classifications for petroleum refining.

Table p-1. SIC and NAICS Codes for Petroleum Refining.

2-Digit SIC Code	29 – Petroleum refining and related industries
4-Digit SIC Code	2911 – Petroleum refining
NAICS Code	324110 – Petroleum refineries

The major products of the petroleum refining sector are transportation fuels, but its products are also used in other energy applications and as feedstock for the chemical industries (e.g., solvents, xylene, styrene). Refinery operations fall into five major categories that involve separation, cracking, rearrangement, and blending of hydrocarbons. Table p-2 lists major petroleum refining processes.

Table p-2. Major Petroleum Refining Processes.[346]

Category	Major Technologies
Topping (Separation of Crude Oil)	Atmospheric distillation Vacuum distillation Solvent deasphalting
Thermal and Catalytic Cracking	Delayed coking Fluid coking/flexicoking Visbreaking Catalytic cracking Catalytic hydrocracking
Combination/Rearrangement of Hydrocarbons	Alkylation Catalytic reforming Polymerization Isomerization Ethers manufacture
Treating	Catalytic hydrotreating/hydroprocessing Sweetening/sulfur removal Gas treatment
Specialty Product Manufacture	Lube oil Grease Asphalt

[346] Energy Information Administration - EIA - Official Energy Statistics from the U.S. Government. 2006. Petroleum Analysis Industry Brief. Available at http://www.eia.doe.gov/emeu/mecs/iab98/petroleum/tech.html [Accessed June 2006].

Potential areas of application within the refinery are for supervisory control and data acquisition (SCADA) systems, mainframe computers controlling manufacturing and data center operations, emergency lighting, and alarm systems.

MARKET SIZE

The U.S. petroleum refining industry is the largest in the world and processes approximately one quarter of all crude oil globally. There were approximately 149 petroleum refineries around the U.S. as of January 2006,[347] employing over 65,000 employees.[348] The number of refineries has declined significantly from 205 in 1990.

The U.S. refining industry produces a mix of products with a total value exceeding $151 billion. According to the EIA,[349] total U.S. petroleum product consumption declined by 77,000 billion barrels per day (bbl/d), or 0.4%, in 2005. Higher prices and the impact of hurricanes on liquefied petroleum gases and petrochemical feedstocks drove this decline in consumption. In 2006 and 2007, petroleum consumption is projected to increase by 0.9% and 2.1%, respectively. However, several refineries are still shut down or are operating at reduced rates because of hurricane damage. Petroleum refineries are located in 33 states, but the largest number of refineries is found on the Gulf Coast, followed by California, New Jersey, and Alaska.[350] The size of the U.S. petroleum refining market based on the number of adopters is provided in Table p-3. Statistics are provided for specialty segments within the industry. A total of 1,536 establishments generate annual sales of $617,199 million.

Table p-3. Number of Businesses in Petroleum Refining Industry (2911).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)*
2911-0000	Petroleum refining	776	63,035	586,018.625
2911-0100	Gases and liquefied petroleum gases	72	1,163	3,151.5
2911-0101	Gas, refinery	86	5,721	24,126.6
2911-0102	Liquefied petroleum gases, LPG	11	161	17
2911-0200	Light distillates	2	415	295.3
2911-0201	Alkylates	2	4	7.3
2911-0202	Gasoline blending plants	23	359	582.2
2911-0203	Jet fuels	24	458	387.9
2911-0204	Kerosene	1	1	0.1
2911-0206	Solvents	24	195	349
2911-0300	Intermediate distillates	1	3	0.3
2911-0301	Acid oil	2	17	0.1
2911-0302	Diesel fuels	87	362	58
2911-0303	Oils, fuel	132	2,037	247.7
2911-0304	Oils, illuminating	4	24	2.7
2911-0305	Oils, partly refined: sold for rerunning	8	498	6.8

[347] As of January 2006, seven refineries had idle distillation units. The large increase in idle capacity as of 1/1/2006 compared to the prior year is due primarily to the continuing impact from Hurricanes Katrina and Rita that kept BP-Texas City (437,000 bbls/cd), ConocoPhillips-Alliance (247,000 bbls/cd), and Murphy-Meraux (120,000 bbls/cd) idle. [Energy Information Administration (EIA), Form EIA-820, Annual Refinery Report.]

[348] Worrell, E. and C. Galitsky. 2005. Energy Efficiency Improvement and Cost Saving Opportunities for Petroleum Refineries: An ENERGY STAR® Guide for Energy and Plant Managers. Ernest Orlando Lawrence Berkeley National Laboratory.

[349] Energy Information Administration - EIA - Official Energy Statistics from the U.S. Government. 2006. Short-Term Energy Outlook. Available at http://www.eia.doe.gov/emeu/steo/pub/ [Accessed December 2006].

[350] Worrell, E. and C. Galitsky. 2005. Energy Efficiency Improvement and Cost Saving Opportunities for Petroleum Refineries: An ENERGY STAR® Guide for Energy and Plant Managers. Ernest Orlando Lawrence Berkeley National Laboratory.

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)*
2911-0306	Still oil	2	12	1.6
2911-0400	Heavy distillates	1	9	0.9
2911-0401	Mineral jelly	2	4	0.4
2911-0402	Mineral oils, natural	14	95	6.5
2911-0403	Mineral waxes, natural	6	139	1.6
2911-0404	Oils, lubricating	41	1,008	555.3
2911-0405	Paraffin wax	8	87	2.6
2911-0500	Residues	2	4	3
2911-0501	Asphalt or asphaltic materials, made in refineries	35	576	615.9
2911-0502	Coke, petroleum	12	636	256.4
2911-0503	Greases, lubricating	7	52	14.4
2911-0504	Petrolatums, nonmedicinal	3	265	N/A
2911-0505	Road materials, bituminous	5	37	3.1
2911-0506	Road oils	6	43	8
2911-0600	Aromatic chemical products	59	1,557	57.1
2911-0601	Benzene, made in refineries	1	1	0.1
2911-0700	Nonaromatic chemical products	10	36	3.5
2911-0702	Fuel additives	55	1,225	400.7
2911-9901	Fractionation products of crude petroleum, hydrocarbons, nec	12	69	17.5
	Total	**1,536**	**80,308**	**617,199.375**

Note: Not all establishments have a specialty. Sales figures are in millions.
Source: Dun and Bradstreet. Industry Reports www.zapdata.com, accessed June 2006.

U.S. petroleum refineries are operated by 59 companies.[351] Although there are a relatively large number of independent companies in the U.S. refining industry, the majority of the refining capacity is operated by a small number of multi-national or national oil processing companies. The largest companies (as of January 2003) include: ConocoPhilips, ExxonMobil, BP, Valero, ChevronTexaco, Marathon Ashland, and Shell, which combined represent 59% of crude distillation unit (CDU) capacity. Table p-4 lists the top-producing facilities as of January 2005.

Table p-4. Top 10 U.S. Petroleum Refineries, by Operable Atmospheric Crude Oil Distillation Capacity (Barrels per Calendar Day) as of January 1, 2005.[352]

Rank	Company Name	State	Site	Barrels Per Day
1	ExxonMobil Refining & Supply Co	Texas	Baytown	557,000
2	ExxonMobil Refining & Supply Co	Louisiana	Baton Rouge	493,500
3	Bp Products North America Inc	Texas	Texas City	437,000
4	Bp Products North America Inc	Indiana	Whiting	410,000
5	ExxonMobil Refining & Supply Co	Texas	Beaumont	348,500
6	Sunoco Inc (R&M)	Pennsylvania	Philadelphia	335,000
7	Deer Park Refining Ltd Partnership	Texas	Deer Park	333,700
8	Chevron USA Inc	Mississippi	Pascagoula	325,000
9	Citgo Petroleum Corp	Louisiana	Lake Charles	324,300

[351] Worrell, E. and C. Galitsky. 2005. Energy Efficiency Improvement and Cost Saving Opportunities for Petroleum Refineries: An ENERGY STAR® Guide for Energy and Plant Managers. Ernest Orlando Lawrence Berkeley National Laboratory.
[352] Energy Information Administration - EIA - Official Energy Statistics from the U.S. Government. 2006. U.S. Refineries Operable Atmospheric Crude Oil Distillation Capacity (Barrels per Calendar Day). Available at http://www.eia.doe.gov/neic/rankings/refineries.htm [Accessed June 2006].

Rank	Company Name	State	Site	Barrels Per Day
10	Conoco Phillips	Illinois	Wood River	306,000

Petroleum refining is the most energy-intensive manufacturing industry in the U.S. and accounts for about 7.5% of total U.S. energy consumption.[353] The petroleum refining industry uses energy both to supply heat and power for plant operations and as a raw material for the production of petrochemicals and other non-fuel products.

Petroleum refineries are also one of the largest users of hydrogen. Refineries use hydrogen in processes such as hydrocracking (simultaneously breaking down large hydrocarbons and adding hydrogen), hydrotreating (adding hydrogen), catalyst regeneration, desulfurization, and heavy oil upgrading.

Refineries spend typically 50% of cash operating costs (i.e., excluding capital costs and depreciation) on energy, making energy a major cost factor and also an important opportunity for cost reduction.[354] Energy consumption increased from 5,762 trillion Btu in 1991 to 7,130 Btu in 1998.[355] Refinery gas, natural gas, and petroleum coke account for the largest shares of energy use. Energy use is also a major source of emissions in the refinery industry, making energy efficiency improvement an attractive opportunity to reduce emissions and operating costs. The petroleum industry produces about 32% of electricity onsite, primarily by means of cogeneration.[356] The refining industry is the third largest cogenerator in the manufacturing sector. The amount of electricity consumed as backup power is unknown.

MARKET TRENDS

Rotating power outages (i.e., rolling blackouts) in California have the potential to impact refinery operations and could potentially influence demand for backup or supplementary power. In 2001, EIA conducted a study of the impact of power outages on California petroleum refineries and natural gas supply in response to a 2001 California Public Utilities Commission ruling that utilities must include transmission level customers (like refineries) in rotating outages. [357] The survey study found that the potential impact of rotating electrical outages on individual California refineries ranged from minimal to severe. About one-fourth of the refining capacity in California is protected from electrical outages either because of sufficient cogeneration capacity within the refinery or because it is in an electric utility service area that is not expected to be subject to rotating electrical outages (e.g., in the Los Angeles Department of Water and Power service area). The rest of the refineries could be forced to either reduce operating rates or shut down completely during an electricity outage if it should affect their supply of electricity.[358] According to the EIA study, about 40 % of the California refining capacity has some

[353] Energy Information Administration - EIA - Official Energy Statistics from the U.S. Government. 2006. Petroleum Analysis Industry Brief. Available at http://www.eia.doe.gov/emeu/mecs/iab98/petroleum/tech.html [Accessed June 2006].
[354] Worrell, E. and C. Galitsky. 2005. Energy Efficiency Improvement and Cost Saving Opportunities For Petroleum Refineries: An ENERGY STAR® Guide for Energy and Plant Managers. Ernest Orlando Lawrence Berkeley National Laboratory.
[355] Energy Information Administration - EIA - Official Energy Statistics from the U.S. Government. 2006. Petroleum Analysis Industry Brief. Available at http://www.eia.doe.gov/emeu/mecs/iab98/petroleum/tech.html [Accessed June 2006].
[356] Worrell, E. and C. Galitsky. 2005. Energy Efficiency Improvement and Cost Saving Opportunities For Petroleum Refineries: An ENERGY STAR® Guide for Energy and Plant Managers. Ernest Orlando Lawrence Berkeley National Laboratory.
[357] Energy Information Administration. 2001. Electricity Shortage in California: Issues for Petroleum and Natural Gas Supply. Available at http://www.eia.doe.gov/emeu/steo/pub/special/california/june01article/carefinery.html [Accessed June 2006].
[358] Energy Information Administration. 2001. Electricity Shortage in California: Issues for Petroleum and Natural Gas Supply. Available at http://www.eia.doe.gov/emeu/steo/pub/special/california/june01article/carefinery.html [Accessed June 2006].

cogeneration capabilities, but not enough to keep operating at full rates. Processing rates at these refineries would need to be reduced by up to 30 % or selected units shut down in order to continue operating during an electrical outage. Returning to full production after a scheduled shutdown can take up to several days, so the period of reduced production would potentially be longer than the period of the electrical outage. Finally, up to 27 % of the California refining capacity is expected to be forced to shut down completely during a rotating electrical outage should it occur in their block. It takes a refinery 1 to 2 weeks to return to full operating rates following a forced emergency shutdown.

Regarding the susceptibility of a refineries' hydrogen supply, the EIA study also found that most refineries are self-sufficient in their hydrogen supply and produce it within the refinery by the reforming unit. However, several California refineries were found to produce additional hydrogen from natural gas, and several reported receiving hydrogen from outside the refinery. A temporary loss of outside hydrogen supply would require storing untreated product until hydrogen was restored. Longer disruptions would require cutbacks in refinery production rates. However, outside hydrogen supply is not expected to be a significant refinery risk issue in California because the major hydrogen producer is in the Los Angeles area and has a cogeneration plant that is likely to be protected from disruption.[359]

The EIA also recently conducted an analysis of the impact of Gulf Coast hurricanes on the petroleum industry. EIA estimates that at the height of the refinery outages (September 22 to 25, 2005), as much as 4.9 million barrels per day of refining capacity (nearly 29 % of U.S. refining capacity and over 60 % of refining capacity in the Gulf Coast region) were shut down. Some of the shutdowns were precautionary, ahead of the storms, but several refineries were damaged extensively, thus keeping them shut down for a relatively long time. For example, as of October 10, 2005, more than 2 million barrels per day of refining capacity were still shut down.[360]

One potential driver for increased backup power at petroleum refineries is the Gasoline for America's Security Act of 2005, passed in the wake of Hurricanes Katrina and Rita.[361,362] Section 203 of the bill requires an assessment of the adequacy of backup power capacity, and the need for any additional capacity, to provide for continued operation during emergencies. This requirement applies to crude oil or refined petroleum product pipeline facilities that are significant to the nation's supply needs and are located in areas that have historically been subject to higher incidents of natural disasters, such as the Gulf Coast, where the petroleum refining industry is concentrated.

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[359] Energy Information Administration - EIA - Official Energy Statistics from the U.S. Government. 2006. Petroleum Analysis Industry Brief. Available at http://www.eia.doe.gov/emeu/mecs/iab98/petroleum/onsite.html [Accessed June 2006].
[360] Energy Information Administration. 2006. The Impact of Tropical Cyclones on Gulf of Mexico Crude Oil and Natural Gas Production. Available at http://www.eia.doe.gov/emeu/steo/pub/pdf/hurricanes.pdf [Accessed June 2006].
[361] THOMAS (Library of Congress). 2006. Gasoline for America's Security Act of 2005. Available at http://thomas.loc.gov/cgi-bin/bdquery/z?d109:HR03893:@@@L&summ2=m& [Accessed December 2006].
[362] The Committee on Energy and Commerce. 2006. Gasoline for America's Security Act of 2005. Available at http://energycommerce.house.gov/108/news/Gas_Bill.pdf; http://energycommerce.house.gov/108/Markups/09282005markup1659.htm; and http://energycommerce.house.gov/108/News/09262005_1661.htm#Related [Accessed December 2006].

To date, no U.S. petroleum refineries have adopted fuel cell technologies. However, an oil refinery in Japan has installed a 1 kW PEM fuel cell.[363] Lawrence Livermore National Laboratory[364] has investigated the use of a direct carbon fuel cell and a SOFC that use by-products of petroleum refining. Advantages of this system are a significant decrease in carbon dioxide emissions and reduced power costs.

A few other industry trends could influence opportunities for fuel cells in the petroleum refining industry. Recently, facilities in this sector have announced plans to increase their on-site capacity for generating hydrogen. For example, in April 2006 Linde Gas LLC announced plans to build and operate an on-site hydrogen steam methane reformer at the Shell Chemical LP plant in Mobile, Alabama. From this facility, Linde will supply industrial-grade hydrogen facilitating gas oil hydrotreating by Shell at Mobile. The scheduled start-up for the Linde facility is November 2007. This latest contract represents Linde's fourth on-site hydrogen generation plant serving the North American marketplace.[365] Similarly, Chicago Bridge & Iron Company (CB&I) recently reported that they had been awarded a $40 million contract by a major U.S. refiner to supply a large-scale hydrogen plant for one of its refineries located in Texas. Delivery of the plant is scheduled for summer 2007.[366] Such developments could potentially result in a more economical fuel source for PEM fuel cell systems sited at refineries.

MARKET SEGMENT ANALYSIS

To identify the market opportunities for direct PEM fuel cells, 10 petroleum refining companies were contacted. Two responses were received. One respondent was a large company (> 3000 employees) and one respondent was a medium sized company (500 to 3000 employees). Typical operations that require backup power as identified by respondents include SCADA, mainframe computing hardware, emergency lighting and alarm systems. Neither respondent was able to report the exact number of outages experienced in the past 12 months. They indicated that grid reliability varied significantly by location. Both respondents indicated that without backup power any outage would be highly disruptive and could result in disruptions in production and distribution. Users used a combination of UPSs, batteries, and generators to provide backup power. One respondent also uses a 250 kW PAFC to support data center operations. The size of the backup systems ranged from < 5 kW to > 2000 kW. The most important user requirements when selecting a backup power system are reliability, start-up time, emissions, fuel availability, and good experience with system in the past. Respondents indicated that performance of their systems were good, and reported no specific concerns. Respondents did identify a growing need for backup power. Only one of two respondents had considered alternatives, including fuel cells. This user has a pre-existing PAFC installation and is familiar with fuel cells. The user indicated satisfaction with the performance of their system but was dissatisfied with operations and maintenance requirements and associated costs of the PAFC system. Neither user was

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363 Fuel Cells 2000. 2005. Worldwide Fuel Cell Installations. Available at http://www.fuelcells.org/info/charts/FCInstallationChart.pdf [Updated October 2005; accessed June 14, 2006].

364 Steinberg, M., J. F. Cooper, and N. Cherepy. 2002. High Efficiency Direct Carbon and Hydrogen Fuel Cells for Fossil Fuel Power Generation. DOE, Lawrence Livermore National Laboratory. Available at http://www.llnl.gov/tid/lof/documents/pdf/242935.pdf [Accessed June 2006].

365 Linde Gas. 2006. News. Available at http://www.us.lindegas.com/international/web/lg/us/likelgus.nsf/docbyalias/news_shell [Accessed June 2006].

366 Chicago Bridge & Iron (CB&I) Company N.V. 2006. CB&I to Supply Large Hydrogen Plant for Refinery in Texas. Available at http://www.cbi.com/ir/release.aspx?releaseid=192318 [Accessed December 2006].

particularly concerned about hydrogen as a fuel. Both respondents indicated that government incentives were considered when making purchasing decisions.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

This market was examined to determine opportunities for PEM fuel cells in backup power only. Like the chemical industry, petroleum refineries are large producers of hydrogen gas and have large energy requirements, making them potential candidates for application of PEM fuel cells in grid parallel and grid independent applications. However, one potential barrier to the application of fuel cells in the petroleum industry for these applications is the already high expenses associated with hydrogen production or purchase. Hydrogen is used in the refinery in large quantities for processes such as hydrocrackers and desulfurization using hydrotreaters. Adopting PEM fuel cells may require the additional purchase or production of sufficient quality hydrogen. In order to determine if PEM fuel cells show value for these applications, this added cost of purchasing hydrogen fuel would need to be compared to the energy cost savings resulting from fuel cells' improved efficiency over grid electricity or other power sources.

The industry is highly sensitive to power outages, and reliability requirements for backup power technologies are very high. While the impact of Hurricanes Katrina and Rita may increase demand for sustained backup power capacity in the event of natural disasters that strike petroleum refineries, the potential size of the petroleum refinery market is small relative to other industries (149 operating refineries in 2006). Due to the need for reliable power, refineries have built in redundancy to ensure a continuous power supply. Backup power at an operational level is provided through alternate grid lines, large generators, and turbines. At a control systems level, backup power is provided through batteries and UPS systems. Due to limited power size and durability, PEM fuel cells are not likely to be adopted in the near term for operational level backup. Early applications for PEM fuel cells for backup power may be limited to specific applications like communications support and emergency lighting.

Marketing research indicates that users are fairly satisfied with current technologies and alternatives have been considered only to a limited extent. It appears that there is only a limited understanding of PEM fuel cells for backup power in this market segment. As users emphasize reliability, start-up time, fuel availability, and good experience with the system as factors that would influence them when selecting a backup system, it is likely that PEM fuel cells will not be adopted in the near term.

RESEARCH SUMMARY:
PHARMACEUTICALS

MARKET SEGMENT DESCRIPTION

This market segment comprises establishments primarily engaged in the manufacture of in-vivo diagnostic substances and pharmaceutical preparations (except biological) intended for internal and external consumption in dose forms, such as ampoules, tablets, capsules, vials, ointments, powders, solutions, and suspensions.[367] Products of this industry include pharmaceutical preparations promoted primarily to the dental, medical, or veterinary professions, and pharmaceutical preparations promoted primarily to the public.

This analysis considers the potential for PEM fuel cells for backup power at pharmaceutical manufacturing facilities. Table q-1 identifies the SIC and NAICS codes associated with this market segment.

Table q-1. SIC and NAICS Codes for Pharmaceutical Manufacturing.

2-Digit SIC Code	28 – Chemicals and allied products
4-Digit SIC Code	2834 – Pharmaceutical preparations
NAICS Code	325412 – Pharmaceutical preparation manufacturing

There is a need for continuous power and reliable backup power for the production, storage, and testing of drug products. A constant, reliable supply of electricity – 99.999 reliability – is necessary for operations.

In manufacturing pharmaceutical products, strict adherence to quality assurance is critical to ensure that the product is manufactured correctly. Exact requirements for specifications and dosage must be met. To meet these requirements, reliable power is needed during the production process to ensure that precise quality control processes are followed and all production parameters are monitored and recorded.[368] Losses of power during critical production steps can result in failed batches that must be discarded. Revenue losses of $1 million per hour of downtime are reported for the pharmaceutical industry.[369]

For storage and testing facilities, backup power is needed for stability chambers in the event of power failures. Temperature and humidity within each chamber must be continually monitored and documented with an automatic chart recorder or electronic monitoring system. Extended exposure to significantly changed temperature or humidity can put significant stress on the samples, and can lead to inaccurate or failing results. Therefore, it is essential that the temperature and humidity within each stability storage unit be closely monitored and the chambers be re-validated routinely.[370]

[367] U.S. Census Bureau. 2006. North American Industry Classification System (NAICS) 2002. Available at http://www.census.gov/epcd/www/naics.html [Accessed December 2006].
[368] Pentadyne Power Corporation. 2006. Case Study: Multinational Pharmaceutical Company Depends on Pentadyne's DC Flywheel to Keep Data Center Operations Up and Running. Available at http://www.pentadyne.com/Power%20Protection%20for%20Pharmaceutical%20Applications.pdf [Accessed December 15, 2006].
[369] META Group, Inc. 2000. Quantifying Performance Loss: IT Performance Engineering and Measurement Strategies. Available at http://www.esolutionsgroup.ca/services/network_data.shtml [Accessed December 2006].
[370] Pharmatek Laboratories, Inc. 2004. Press Release: Pharmatek Expands Pharmaceutical Stability Storage and Testing Services. Available at http://www.pharmatek.com/pdf/021004_press.pdf [Accessed December 2006].

Traditional backup power sources for pharmaceutical companies include battery-based UPS systems and diesel generators. Another option that can be used in combination with backup generators is a DC flywheel power system. The flywheel power system can provide bridging power to the backup generators when a power outage occurs. While the flywheel system is compatible with the UPS system, the flywheel requires low maintenance, saves space, and provides high reliability as an alternative to UPS battery banks.[371]

A vaccine manufacturer experiencing frequent power interruptions elected to install a 2200 kVA PureWave UPS system combined with a backup generator. The combination provides 100% protection from power outages, a critical requirement for the vaccine production process. The PureWave UPS system provides 30 seconds of backup power at full load and 60 seconds at half-load. For longer outages, the UPS system transfers the load to the backup generator and then back to the utility feeder when power is restored. The PureWave UPS system allows room for expansion and does not require an air-conditioned room.[372]

MARKET SIZE

Hoover's, Incorporated reports approximately 700 pharmaceutical manufacturing companies in the U.S. (NAICS Code 325412). The top 10 companies, by sales, are listed in Table q-2.

Table q-2. Top 10 U.S. Pharmaceutical Manufacturing Companies, by Sales.[373]

Company Name	Location	Sales ($ mil)
Cardinal Health, Inc.	Dublin, OH	74,910.7
The Procter & Gamble Company	Cincinnati, OH	56,741.0
Pfizer Inc	New York, NY	51,298.0
Johnson & Johnson	New Brunswick, NJ	50,514.0
Tyco International Ltd.	Princeton, NJ	39,727.0
Abbott Laboratories	Abbott Park, IL	22,337.8
Merck & Co., Inc.	Whitehouse Station, NJ	22,011.9
3M Company	St. Paul, MN	21,167.0
Bristol- Myers Squibb Company	New York, NY	19,207.0
Wyeth	Madison, NJ	18,755.8

No secondary data were available on the total market for backup power in the pharmaceutical industry.

MARKET TRENDS

Secondary research identified one fuel cell demonstration project in the pharmaceutical industry in a grid parallel application; there are no known fuel cell demonstrations in backup power applications for this sector.

In 2002, Merck installed a fuel cell at its Rahway, New Jersey, facility, making it the first pharmaceutical company in the U.S. to adopt fuel cell technology.[374] The 200 kW PAFC,

[371] Pentadyne Power Corporation. 2006. Case Study: Multinational Pharmaceutical Company Depends on Pentadyne's DC Flywheel to Keep Data Center Operations Up and Running. Available at http://www.pentadyne.com/Power%20Protection%20for%20Pharmaceutical%20Applications.pdf [Accessed December 2006].
[372] S&C Electric Company. 2004. PureWave UPS System Provides a "Shot in the Arm" to Pharmaceutical Manufacturer. Case Study 653-1002, September 13, 2004.
[373] Hoovers, Inc. 2006. Industry fact sheets. Available at http://premium.hoovers.com/ [Accessed July 2006].

developed by United Technologies Corp., provides supplemental power for manufacturing and research operations at the 210 acre Merck complex in Rahway. The installation was initiated as a 4 year demonstration program. The project was made possible by funding incentives from the New Jersey Clean Energy Program and the DoD Climate Change Program.

A few pharmaceutical companies participate in U.S. EPA's Climate Leaders program, including Pfizer, Johnson & Johnson, and Baxter International, Inc. As partners in the Climate Leaders program, these companies have taken steps to reduce U.S. greenhouse gas emissions by reducing energy consumption. Pfizer is beginning to investigate renewable energy sources as an alternative to fossil fuel use. The company has installed a photovoltaic system at a facility in Germany and plans to continue to seek opportunities to implement clean energy technologies in the future.[375]

MARKET SEGMENT ANALYSIS

Approximately 15 pharmaceutical companies were contacted to further determine requirements for backup power and the potential for application of fuel cells. Obtaining responses from pharmaceutical companies proved difficult; no responses to surveys were received.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

Based on secondary data analysis, it is difficult to assess the potential for PEM fuel cells to meet backup power for pharmaceutical manufacturing companies. The industry does have promising characteristics, such as a strong demand for backup power due to the high cost of unscheduled downtime. Recent energy-related trends in this sector are also encouraging, including Merck's fuel cell demonstration project and industry involvement in the EPA's Climate Leaders program, which is exploring alternatives to fossil fuels.

However, additional data from end users is required to adequately assess the mid- to long-term potential for fuel cell technology in this sector. Specifically, information on the current backup power systems used, specific applications they support, and user satisfaction with these systems needs to be better understood.

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[374] Merck. 2002. Merck Installs Cutting Edge Fuel Cell Technology. Available at http://www.merck.com/about/feature_story/11112002_fuel_cell.html [Accessed December 2006].
[375] U.S. EPA. 2006. Climate Leaders. Available at http://www.epa.gov/climateleaders/ [Accessed December 2006].

RESEARCH SUMMARY:
RAILWAYS

MARKET SEGMENT DESCRIPTION

Railways are used by various industries for short- and long-range transportation of goods and materials; they are also used for short- and long-range passenger transportation. Line-haul rail provides freight transportation and passenger transportation over longer distances, while subway and transit rail provide local and suburban transit. Subway and transit rail furnish mass passenger transportation over regular routes and on regular schedules, with operations confined principally to a municipality, contiguous municipalities, or a municipality and its suburban areas. A sector that provides critical support to railways is the switching and terminal operations industry. This industry includes establishments primarily engaged in the furnishing of terminal facilities for rail passenger or freight traffic for line-haul service, and in the movement of railroad cars between terminal yards, industrial sidings, and other local sites. Terminal companies do not necessarily operate any vehicles but may operate the stations and terminals. Table r-1 lists the SIC and NAICS classifications associated with railways.

Table r-1. SIC and NAICS Codes for Railways.

2-Digit SIC Codes	40 – Railroad transportation 41 – Local, suburban transit & interurban highway passenger transport
4-Digit SIC Codes	4011 – Railroads, line-haul operating 4013 – Switching and terminal services 4111 – Local and suburban transit
NAICS Codes	482111 – Line-haul railroads 482112 – Short line railroads 485112 – Commuter rail systems 485119 – Other urban transit systems 488210 – Support activities for rail transportation

Railways use backup power for a variety of applications; secondary research indicated that the most important application was backup power for signal and crossing mechanisms, particularly for freight railroads. Primary research also revealed that subway and transit rail use backup power technologies to provide power for railway coaches and on-train applications such as doors and lighting. The primary technology used to provide backup power in the railways sector is batteries.

Typical applications of backup power in the railway sector include the following:

- Signals and Crossing Guard Mechanisms – This includes active warning devices, interlocking and control points, and crosses interconnected with traffic signals. Current backup used/required is a 12 to 16V battery system for the controls, lights, and gate at active warning intersections.
- Coach Backup Power – Emergency backup power for railway coaches (passenger quarters). Coach backup power typically uses NiCd batteries, which provide 3 to 5 hours of backup life.
- Mass Transit Backup – Emergency backup power for mass transit and electric locomotives (electromotive units, or EMUs). This includes metro systems (underground,

elevated, and ground-level), rapid suburban rail networks, tramways, automatic shuttles, and buses. Backup systems provide buffer power for on-board systems, such as door opening or braking, as well as backup power for other onboard systems such as air conditioning and lighting. Backup times typically required are between 20 and 90 minutes; NiCd batteries are currently the primary backup power source.

- On-site Communications – This includes railway station/terminal communications, computer equipment, and telephone switches and air conditioning in order to maintain safe and timely operations.

MARKET SIZE

Table r-2 presents market statistics on the railway sector. Only the eight-digit SIC Code specialties relevant to railways are shown. There are approximately 2,800 U.S. establishments involved in line-haul rail operations (SIC Code 4011), employing over 98,000 individuals in electric railroads, interurban railways, and steam railroads. The terminal and switching services industry (SIC Code 4013) includes nearly 700 establishments and employs almost 23,000 individuals. With total sales of over $3.4 billion, the local and suburban transit market (SIC Code 4111) comprises approximately 4 % of total sales in the railway sector.[376]

Table r-2. Number of Businesses Associated with Railroad Operation – Industries: Railroads, Line-haul Operating (4011), Switching and Terminal Services (4013), and Local and Suburban Transit (4111).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)*
4011-0000	Railroads, line-haul operating	2,644	93,322	83,517.797
4011-9901	Electric railroads	40	476	223.6
4011-9902	Interurban railways	96	4,384	2,933.9
4011-9903	Steam railroads	14	169	15
4013-0000	Switching and terminal services	445	12,033	751.3
4013-9901	Belt line railroads	8	170	55
4013-9902	Logging railroads	12	50	3.5
4013-9903	Railroad switching	100	2,692	373.4
4013-9904	Railroad terminals	129	8,010	71.8
4111-0400	Passenger rail transportation	77	1,760	139.4
4111-0401	Commuter rail passenger operation	29	11,165	1,410.9
4111-0402	Local railway passenger operation	49	2,115	266.3
4111-0403	Subway operation	38	5,555	1,573.4
4111-9902	Elevated railway operation	8	131	19
	Total	**3,689**	**142,032**	**91,354**

Sales figures are in millions. Source: www.zapdata.com, accessed September 2006.

The key players in line-haul rail operations are the large railroad companies, which include the main passenger railway, Amtrak, as well as freight railways, such as CSX, Union Pacific, and Burlington Northern Santa Fe (BNSF). Other key players in the railway market include active warning device/signal manufacturers, such as Digicon, Safetran, Union Switch and Signal, and Western-Cullen-Hays; the Association of American Railroads; AREMA (American Railway Engineering and Maintenance-of-Way Association); Departments of Transportation; and the Federal Railroad Administration.

[376] Dun and Bradstreet. 2006. Zapdata industry report. Available at http://www.zapdata.com [Accessed September 2006].

Freight Rail: Backup Power for Signal and Crossing Guard Mechanisms
The market size for backup power for signal and crossing guard mechanisms in the U.S. freight and passenger line-haul rail market can be characterized by the following statistics:[377]

- Total railroad crossings – 253,000
- Active crossings (crossings with warning devices) – 65,000
- Crossings interconnected with traffic signals – 9,000
- Interlocking/control points – 5,000
- On-site backup – 2,800 (number of sites)
- Units less than 15 kW – 1,375 (annual sales volume in units)
- For units < 15 kW – priced $4,000 to $6,000 per unit, $4 to 8 million in sales.

Railroads invest a substantial amount of time and resources into improving rail safety, including ensuring safe crossings. For instance, Union Pacific averages about 400 diagnostic (signal crossing improvement) projects annually on its 23-state system.[378] BNSF spent approximately $36 million in 2005 on grade-crossing signal maintenance and repair, which includes inspection of gates, lights, and backup power sources.[379]

Subway and Transit Rail: Backup Power for Rail Coaches, On-board Lights, etc.
Local and suburban transit rail is primarily comprised of public transit systems. Large metropolitan areas often have significant investments in rail systems such as subways. Cities with railways of significant size include:

- New York City – Metropolitan Transportation Authority (MTA)
- Chicago – Chicago Transit Authority (CTA)
- Washington, DC – Washington Metropolitan Area Transit Authority (WMATA)
- San Francisco – Bay Area Rapid Transit (BART)
- Boston – Massachusetts Bay Transportation Authority (MBTA)
- Atlanta – Metropolitan Atlanta Rapid Transit Authority (MARTA)
- Philadelphia – Southeastern Pennsylvania Transportation Authority (SEPTA)
- Miami – Miami-Dade Transit Service
- Cleveland – Greater Cleveland Regional Transit Authority
- Los Angeles – Los Angeles County Metropolitan Transportation Authority (MTA)
- Baltimore – Maryland Mass Transit Administration (MTA)

The New York City Department of Transportation (NYCDOT) has been considering adding battery backup to signals at critical intersections. Substations convert as many as 27,000 V of power-plant electricity for use in the subway.[380] Alternating current (AC) operates signals, station and tunnel lighting, ventilation, and miscellaneous line equipment. Direct current (DC) operates trains and auxiliary equipment, such as water pumps and emergency lighting. As a

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[377] Ducker Worldwide, Inc. 2002. Market Opportunity Assessment for Long Term Standby Gensets in the United States. Market assessment provided for Battelle Memorial Institute by Ducker Worldwide Inc.
[378] Union Pacific Railroad. 2003. Who Decides Where Railroad Crossings Are Located? Available at http://www.uprr.com/newsinfo/railroad/2003/1216_install.shtml [Accessed September 2006].
[379] Burlington Northern Santa Fe Railway. 2006. Grade Crossing Safety. Available at http://www.santaferailway.com/communities/pdf/4_GradeCrossingSafety.pdf [Accessed September 2006].
[380] Metropolitan Transportation Authority. 2006. Subways. Available at http://mta.info/nyct/facts/ffsubway.htm [Accessed September 2006].

point of reference, the NYC Transit subway system uses enough power annually to light the City of Buffalo for a year. In the subway system, backup power is required for functions such as lighting and ventilation, as well as signals. Not all intersections require backup power. The following statistics indicate the size of the NYC subway system:[381]

- NYC has 11,600 signalized intersections
- NYC Transit Department of Signals operates 6,700 trains
- 11,646 track circuits and 11,000 automatic train stops
- 12,080 wayside signals (which are being converting to LCD displays)
- 361 storage batteries
- NYC Transit track and infrastructure (annual) budget
    - Operating (maintenance): $116 million
    - Capital: $150 million.

MARKET TRENDS

Overall industry growth in the railway sector is flat. Additionally, railways are attempting to close unnecessary crossings (e.g., Union Pacific has closed more than 1,000 in the last four years; BNSF has closed 3,000 in the last six years[382]). Railways are also developing systems in addition to signals to help prevent accidents due to broken or faulty crossing and grade signals. Alaska Railroad is developing a Collision Avoidance System (CAS), which is a computer-based network designed to prevent train-to-train collisions, among other functions.[383] The DOT is incorporating sensors, computers, and digital communications into "Intelligent Railroad Systems" for train control (including braking, grade-crossing warnings, and planning). The impact of these systems on the need for backup power is unclear; however, they may signify some reduction in the need for signals. Still, some growth projections for backup power applications, particularly in signals and crossings applications, are healthy, given that certain measures are taken to educate and promote backup power in the railroad segment.[384]

A number of factors are driving the need for backup power in the railways industry. One driver for backup power in locomotives is to maintain low-cost operations and high customer satisfaction. Storms and heavy weather can cause commercial power outages, producing extensive signal damage and disrupting rail operations. Some railroads are using geographic information systems (GIS) and weather forecasting to prepare for outages; however, backup power is still considered critical. A power outage in the northeast U.S. recently interrupted Amtrak transit service, stranding thousands of rush-hour commuters in hot tunnels.[385]

[381] No author. 2004. 100 years of subway signals. Railway Age 205(6). Available at http://www.findarticles.com/p/articles/mi_m1215/is_6_205/ai_n6134827/pg_1 [Accessed September 2006].
[382] Burlington Northern Santa Fe Railway. 2006. Grade Crossing Safety. Available at http://www.santaferailway.com/communities/pdf/4_GradeCrossingSafety.pdf [Accessed September 2006].
[383] No author. 2004. CBTC under way in Alaska. Railway Age 205(1). Available at http://www.findarticles.com/p/articles/mi_m1215/is_1_205/ai_112985914 [Accessed September 2006].
[384] Ducker Worldwide, Inc. 2002. Market Opportunity Assessment for Long Term Standby Gensets in the United States. Market assessment provided for Battelle Memorial Institute by Ducker Worldwide Inc.
[385] King, L. 2006. Amtrak presses its probe of massive rail power outage. The Philadelphia Inquirer (May 27, 2006). Available at http://www.railserve.com/railnews/newsjump.cgi?http://www.philly.com/mld/inquirer/news/local/states/pennsylvania/counties/bucks_county/14679078.htm [Accessed September 2006].

Power interruptions to Canadian National's communications equipment and intermodal operations have caused major disruptions in shipping schedules.[386] Any delays at the yard can quickly ripple throughout the entire rail network, costing the railroad thousands of dollars in penalties for late deliveries. However, when Canadian Pacific recently experienced a power outage, emergency backup power allowed it to continue railway operations uninterrupted.[387]

More important than inconveniences and disruptions to services, backup power for signals and crossings is required for safety. CSX has received two fines of over $225,000 in the last several years related to signal failure as a cause of crossing accidents.[388,389] Although railroads have standards and long-standing legislation for backup power at signal crossings, highway traffic signals do not currently utilize any backup power device.[390] Due to train/car accidents, there is recent legislation regarding the need for backup power at rail crossings where traffic signals are interconnected; such legislation may increase the market for backup power in rail and associated segments.[391]

Future legislation/regulations could help promote the use of backup power for traffic signal/railroad interconnections. The Federal Transit Authority and the Federal Railroad Administration, as well as railroad companies, are key decision-makers in establishing new railway crossings.[392] Regulators and stakeholders, such as the Federal Transit Authority and the Federal Railroad Administration, will have an impact on the need and standards for backup power.

In addition to backup power for locomotives, signals, and crossings, backup power for communication equipment and computers used in railway operations is important. During the 2003 blackout that affected the northeastern U.S. and Canada, transportation agencies learned to keep low-tech phones on hand in case of a power outage. Other agencies realized, during an extended outage in August, that computer equipment supported by backup generators would require air conditioning to maintain a safe operating temperature.[393]

There have been a limited number of fuel cell demonstration projects in this sector, and some interest in developing a fuel cell-powered train. In February 2005, New York Power Authority installed two 200 kW PAFCs in the Grand Central train station terminal. The fuel cell uses natural gas to produce hot water used in restaurants and hotels. In 2006, New York Power Authority is slated to install a 200 kW PAFC in a subway maintenance facility in Corona. The PAFC will generate electricity for railway maintenance and cleaning equipment, and will be able

[386] Judge, T. 2004. Weathering the Storms. Railway Age 205 (10): 20.
[387] Judge, T. 2004. Weathering the Storms. Railway Age 205 (10): 20.
[388] No author. 2006. Cracking down on crossing safety: FRA fines CSXT $227,000 for fatal warning system failure at New York grade crossing. Progressive Railroading.Com. Available at http://www.progressiverailroading.com/freightnews/article.asp?id=8354 [Accessed October 2006].
[389] No author. 2005. CSX agrees to improve railroad crossing safety. The Business Review (March 7, 2005). Available at http://www.bizjournals.com/albany/stories/2005/03/07/daily7.html [Accessed October 2006].
[390] Ducker Worldwide, Inc. 2002. Market Opportunity Assessment for Long Term Standby Gensets in the United States. Market assessment provided for Battelle Memorial Institute by Ducker Worldwide Inc.
[391] Ducker Worldwide, Inc. 2002. Market Opportunity Assessment for Long Term Standby Gensets in the United States. Market assessment provided for Battelle Memorial Institute by Ducker Worldwide Inc.
[392] Union Pacific Railroad. 2003. Who Decides Where Railroad Crossings Are Located? Available at http://www.uprr.com/newsinfo/railroad/2003/1216_install.shtml [Accessed September 2006].
[393] Judge, T. 2004. Weathering the Storms. Railway Age 205 (10): 20.

to operate as a standalone generator during a grid power outage.[394] An international consortium, led by Vehicle Projects LLC of Denver, is developing a 1 MW fuel cell-powered locomotive. The five-year project began in May 2003 to develop and demonstrate the first fuel cell-powered locomotive for military and commercial railway applications.[395] However, there have been no fuel cell demonstrations in backup power applications in the railroad sector.

MARKET SEGMENT ANALYSIS

To identify the market opportunities for direct PEM fuel cells in the railroad industry, 26 individuals were contacted, and six responses were received. Of the six respondents, three were large freight railways (two from the same company), one was a medium-sized freight railway, and one was a small freight railway. One respondent was a large consulting firm that supports suburban and local transit. Respondents indicated that applications for backup power include signals and crossings, bridges, emergency communication, and emergency lighting. All respondents indicated that signals and crossings were critical. The local transit railway indicated that emergency communication and lighting were also critical.

Participants indicated difficulty in determining the frequency and duration of blackouts. One indicated that the severity of a blackout depended on circumstances (e.g., if a train is approaching a crossing). Three companies indicated that outages of longer durations (i.e., > 1 hour) would have a more severe impact than those of shorter durations (i.e., < 1 hour). One company indicated that power outages of all durations were extremely disruptive. On average, companies experienced anywhere from one to ten disruptive power outages per year. Companies indicated that the most significant impact of power outages is on distribution and production, but that safety (in terms of the potential for lost lives) is also a key consideration.

Respondents used a wide variety of technologies from sizes of < 5 kW to > 250 kW to provide backup power. All respondents indicated that they use batteries. The following technologies were also used by two or more organizations: backup generators, solar cells, UPS units, and wind power. Respondents had one-to-two backup units per signal, crossing, or station. The overall number of backup units depended on the size of the company and the number of signals and crossings it maintains. All respondents indicated that reliability was a critical factor in backup power systems. Other critical factors noted to be important were: start-up time (identified by four respondents), lifetime of the unit (identified by three respondents), and ease of use (identified by two respondents). Five of the six respondents indicated that the performance of their current backup systems was very good; one did not address the issue of performance. Concerns regarding current backup systems included high capital cost and lack of reliability.

When asked to rate current backup systems compared to alternatives, five respondents rated reliability as good; one rated reliability as very good. Start-up time was rated good by two respondents and very good by four. Respondents rated the lifetime of their backup units as fair to good; they rated ease of use as good to very good.

All respondents anticipated a growing need for backup power in the railroad industry. Three of the six respondents had considered alternatives to their current backup power systems; among

[394] No author. 2004. Rail experts press for cash to fund research into fuel-cell locomotives. Professional Engineering 17(8): 6.
[395] No author. 2004. Rail experts press for cash to fund research into fuel-cell locomotives. Professional Engineering 17(8): 6.

the alternatives considered were diesel and propane generators and flywheel systems. Two of the six had heard of PEM fuel cells as a means of supplying backup power. While neither of these two thought that PEM fuel cells would be able to successfully compete against alternatives, they indicated that the factors driving adoption would be: energy efficiency, environmental benefits, positive demonstration projects, price, and availability of government incentives.

One respondent indicated that the decision to purchase backup systems is based on initial capital cost; three indicated that it is based on payback period, and one indicated that it is based on return on investment. Incentives are usually considered when they are offered. Purchase decisions for backup signal power are made by the signals departments or other individuals with engineering expertise. Standards departments are often consulted as well.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

Within the railroad industry, backup power for signals and crossings represents the most critical application area. While the industry as a whole may not be large, the number of signals and crossings distributed across U.S. railroad and suburban transit systems is significant. PEM fuel cell products are considered as a good fit with user requirements for this application and in this industry. They are expected to meet user requirements for high reliability, quick start-up time, and ease-of-use. Additionally, the small power size requirements for signal and crossing applications fit will with commercially available PEM fuel cells.

Significant market growth is not projected for either line-haul or transit rail; it is expected that the market size, particularly for transit rail, will remain steady. However, regulatory requirements may drive increased interest in backup power for both line-haul and transit rail. PEM fuel cells may offer advantages in reliability and durability in harsh climates over current backup sources (primarily batteries), but cost is expected to be a barrier to market adoption in this segment. Additionally, the railway industry has been characterized as having a "high willingness to work with new products"[396] and may offer a potential market for PEM fuel cells.

[396] Ducker Worldwide, Inc. 2002. Market Opportunity Assessment for Long Term Standby Gensets in the United States. Market assessment provided for Battelle Memorial Institute by Ducker Worldwide Inc.

RESEARCH SUMMARY:
SKI RESORTS

MARKET SEGMENT DESCRIPTION

The ski resort industry comprises establishments primarily engaged in providing short-term lodging as well as alpine recreational activities, including downhill skiing, cross-country skiing, Telemark skiing, snowboarding, etc. In addition, the establishments in this industry may offer services such as food and beverage services, recreational services, conference rooms and convention services, spa facilities, ski and snowboard lessons, snow-making and grooming operations, shopping and other retail services, ski-lift and tramway transportation, laundry services, and parking. Table s-1 identifies the primary SIC and NAICS codes associated with this market segment.

Table s-1. SIC and NAICS Codes Associated with Ski Resorts.

2-Digit SIC Codes	79 – Amusement and recreation services
4-Digit SIC Codes	7999 – Amusement and recreation, not elsewhere classified
NAICS Code	713920 – Skiing facilities

A report prepared by Spirae Inc. and The Brendle Group provides a summary of energy use for ski area operations.[397] The report notes that while the bulk of the energy use at ski areas is associated with driving the motors that operate chair lifts and the air compressors and water pumps used in snow making, various other ski resort facilities also require electricity, including lodges, restaurants, shops, ticket sales offices, maintenance facilities, and others. These facilities use electricity not only for lighting, cooking, and operating HVAC fans, pumps, and other equipment, but also for space and water heating during much of the operating season.

Ski resort operations require constant power. Hospitality and lodging provide services on a constant basis; recreational facilities typically operate during daytime hours; while maintenance activities, such as snow-making, occur primarily at night. Operating chair lifts (daytime) and making snow (nighttime), consume the bulk of the energy at ski areas, which in some months can be on the order of 80 % or more.

The halting of the ski lift operations from power loss can result in the need to rescue passengers from lifts.[398,399] In those cases when power went out, backup generators were used to power the ski lifts so passengers could safely depart in a timely manner. Chair lift operations are required to have a backup source of power in order to evacuate passengers in case of an emergency. One New York ski resort uses a Prime Energy 1,500 kW generator system as a backup power source

[397] Spirae Inc. and The Brendle Group. 2004. The Role of Distributed Energy Resources in Optimizing Energy Use for Ski Area Operations. Final report, submitted to the Colorado Governor's Office of Energy Management and Conservation and the U.S. Department of Energy Denver Regional Office. Available at http://www.eere.energy.gov/de/pdfs/der_ski_areas.pdf [Accessed September 2006].
[398] No author. 1995. Power outage strands skiers. Milwaukee Sentinel (February 4, 1995). Available at http://www.findarticles.com/p/articles/mi_qn4208/is_19950204/ai_n10183939 [Accessed September 2006].
[399] Ski Press Media, Inc. 2004. Powder causes power outage in Telluride. Ski Press (March 3, 2004). Available at http://www.skipressworld.com/us/en/daily_news/2004/03/powder_causes_power_outage_in_telluride.html?cat=Resorts [Accessed September 2006].

for ski lift operations.[400] Numerous other resorts report the use of generators to use off-grid power sources and for load-shedding in order to reduce demand during peak periods.[401]

The predominant backup system used for ski lifts is a diesel engine connected via V-belts, chain, gear drive, or driveshaft to the speed-reducing gearbox.[402] Additionally, a few gasoline engines are used, typically on smaller lifts. Engine capacities, which tend to vary depending on the vertical gain and length of the lift as well as the chair spacing, range from relatively small (less than 50 HP or 37 kW) to well over 1,000 HP (746 kW), in one case exceeding 2,500 HP (1,864 kW). Well over one-third of the total lifts had backup systems rated at 100 HP (75 kW) or less, providing less than 5% of the total HP of all lifts. The large number of smaller chair lifts skews this value lower than might be expected; the average power rating is just over 250 HP (186 kW).

MARKET SIZE

Current data on the ski resort market are provided below. SIC Codes 7011 and 7999 covering ski resorts and ski resort activities, respectively, are represented in Table s-2. Only the eight digit SIC Code specialties relevant to ski resorts are shown.

Table s-2. Number of Companies Associated with Ski Resorts and Ski Resort Activities – Industry: Amusement and Recreation, nec (7999).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)
7999-1119	Ski instruction	171	1,714	69.8
7999-1501	Aerial tramway or ski lift, amusement or scenic	84	4,172	245.9
7999-1510	Ski rental concession	227	2,061	109.8
	Total	**482**	**7,947**	**425.5**

Sales figures are in millions. Source: www.zapdata.com, accessed September 2006.

The National Ski Areas Association (NSAA) reports that 492 ski areas operated in the United States during the 2004/2005 ski season, according to its 2004/2005 Kottke National End of Season Survey.[403]

The breakdown of the 492 ski resorts by location is shown in Table s-3. With 50 ski areas in operation during the 2004/2005 season, Colorado leads the ski industry, followed by Michigan (44), Wisconsin (36), and Pennsylvania (35).

[400] Hull, P. 2004. Leasing power. Distributed Energy, the Journal for Onsite Power Solutions (May/June). Available at http://www.distributedenergy.com/de_0405_leasing.html [Accessed September 2006].
[401] National Ski Areas Association. 2006. Energy use for lifts. Available at http://www.nsaa.org/nsaa/environment/the_greenroom/index.asp?mode=greenroom&topic=T09 [Accessed September 2006].
[402] Spirae Inc. and The Brendle Group. 2004. The Role of Distributed Energy Resources in Optimizing Energy Use for Ski Area Operations. Final report, submitted to the Colorado Governor's Office of Energy Management and Conservation and the U.S. Department of Energy Denver Regional Office. Available at http://www.eere.energy.gov/de/pdfs/der_ski_areas.pdf [Accessed September 2006].
[403] National Ski Areas Association. 2005. 492 U.S. ski resorts in operation during 2004-2005 season. Available at http://www.nsaa.org/nsaa/press/2005/04-05-sa-number-history.pdf [Accessed September 2006].

Table s-3. Ski Areas Operating Per State.[404]

Alabama (1)	Massachusetts (15)	Ohio (6)
Alaska (9)	Michigan (44)	Oregon (13)
Arizona (4)	Minnesota (22)	Pennsylvania (35)
California (31)	Missouri (2)	Rhode Island (1)
Colorado (27)	Montana (16)	South Dakota (3)
Connecticut (6)	Nebraska (1)	Tennessee (1)
Georgia (1)	Nevada (4)	Utah (15)
Idaho (16)	New Hampshire (22)	Vermont (20)
Iowa (6)	New Jersey (3)	Virginia (3)
Illinois (5)	New Mexico (10)	Washington (13)
Indiana (4)	New York (50)	West Virginia (4)
Maine (20)	North Carolina (6)	Wisconsin (36)
Maryland (1)	North Dakota (6)	Wyoming (10)

Although the number of ski resorts has declined, the popularity of skiing and other winter sports seems to be increasing. The NSAA reports that five of the six best seasons on record have all occurred in the past six years, and that ski visits are up in all regions. Preliminary estimates for the NSAA's Kottke End of the Season Report show that national skier visits for the 2005/2006 season set an all-time record of 58.8 million visits, an increase of 3.3% from 2004/2005, and 2% higher than the previous record set in 2002/03.[405] Visits to the Pacific West, which contributed an increase of nearly 1.3 million visits, contributed to the record-setting season. Specifically, the Pacific Northwest rebounded from one of its worst seasons on record last season and shows an estimated 125% increase. The Rocky Mountain region, the largest of the five NSAA regions, registered a gain of 5.8%, or over 1.1 million additional visits over the previous record set in 2004/2005. Both the Southeast and Midwest regions also reported solid visitation in 2005/2006, contributing estimated increases of 6.1% and 3.4%, respectively, in comparison to 2004/2005.

MARKET TRENDS

As noted above, the ski industry is heavily dependent on electricity for its primary business operations.[406] This analysis provides evidence that the ski industry is moving toward a more environmentally conscious business model. A key driver is the fact that many people visit ski areas to experience the natural beauty of resort surroundings (i.e., they desire an environment free of noise and noxious emissions). Such visitors also tend to place a high priority on environmental concerns.

One example of industry's shift in environmental awareness is the development and adoption of an Environmental Charter, commonly referred to as "Sustainable Slopes," which provides guidance to resorts on the "greening" of all aspects of operations.[407] This Charter consists of 21 best practices for ski area owners and operators and focuses on various topics, including water conservation, fish and wildlife habitat protection, energy conservation, waste reduction, and air

[404] National Ski Areas Association. 2005. Ski areas operating per state. Available at http://www.nsaa.org/nsaa/press/0506/04-05-sa-per-state.pdf [Accessed September 2006].
[405] National Ski Areas Association. 2006. Preliminary Kottke Report indicates 2005/06 skier visits hit all-time record. Available at http://www.nsaa.org/nsaa/press/2006/PreliminaryReportKottke06.asp [Accessed September 2006].
[406] Spirae Inc. and The Brendle Group. 2004. The Role of Distributed Energy Resources in Optimizing Energy Use for Ski Area Operations. Final report, submitted to the Colorado Governor's Office of Energy Management and Conservation and the U.S. Department of Energy Denver Regional Office. Available at http://www.eere.energy.gov/de/pdfs/der_ski_areas.pdf [Accessed September 2006].
[407] National Ski Areas Association. 2006. Sustainable Slopes: The environmental charter for ski areas. Available at http://www.nsaa.org/nsaa/environment/sustainable_slopes/Charter.pdf [Accessed September 2006].

quality. According to the 2006 Sustainable Slopes Annual Report, 180 resorts have endorsed the Environmental Charter since its adoption in June 2000, representing over 75 % of the ski resorts nationally (based on skier/snowboarder visits).[408]

An example of the industry's efforts to mitigate impacts of climate change is the Keep Winter Cool campaign.[409] Recognizing the potentially disastrous effects of climate change upon the earth's systems and its bottom line, the ski resort industry has adopted a climate change policy. Keep Winter Cool is a partnership between the Natural Resources Defense Council and NSAA, and its goals are to raise visibility and public understanding of global warming and to spotlight existing opportunities to start addressing the issue.

The ski industry's focus on environmental concerns could be a compelling driver for fuel cell use in this market segment. However, no evidence was found to suggest that fuel cells are currently being used in any U.S. ski resorts. The Spirae Inc./Brendle Group report indicates that while fuel cells in the ski industry are a promising concept they are still cost-prohibitive. The analysis cites several challenging cost barriers associated with fuel cells, including: membrane technology development; platinum loading; and the sheer number of cells, and thus separate component layers of precision-fabricated materials, that must be stacked up to provide adequate power for most applications.[410] The report also explores limitations associated with other energy alternatives, such as diesel generators, batteries, and wind turbines.

MARKET SEGMENT ANALYSIS

Twenty ski resorts, associations, and resort operators were contacted to try to gather information on requirements for backup power and the potential for fuel cell use in ski resorts. One complete survey response was received.

According to the one survey response, backup power is provided for lift operations. It was indicated that power outages do not pose a significant problem; however, longer interruptions of power to ski lifts are of greater concern than shorter outages. Diesel and propane generators serve as the sole source of backup power; each lift in operation at the resort has its own generator for backup power.

Reliability, start up time, and emissions were cited by the respondent as the most important factors guiding the choice of backup power. The respondent indicated that resort personnel are highly satisfied with the use of generators for backup power. The resort representative indicated they had not considered alternatives to their current backup power sources and, while they were aware of PEM fuel cells as backup power sources, they did not think PEM fuel cells were currently a viable alternative due to high costs.

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[408] National Ski Areas Association. 2006. Ski industry releases annual environmental report. Available at http://www.nsaa.org/nsaa/press/2006/SkiIndustryReleasesAnnualEnvironmentalReport.asp [Accessed September 2006].
[409] National Ski Areas Association. 2006. Keep Winter Cool campaign. Available at http://www.nsaa.org/nsaa/environment/climate_change/keep_winter_cool.asp [Accessed September 2006].
[410] Spirae Inc. and The Brendle Group. 2004. The Role of Distributed Energy Resources in Optimizing Energy Use for Ski Area Operations. Final report, submitted to the Colorado Governor's Office of Energy Management and Conservation and the U.S. Department of Energy Denver Regional Office. Available at http://www.eere.energy.gov/de/pdfs/der_ski_areas.pdf [Accessed September 2006].

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

Regulatory requirements directing the use of backup power for chair lift operations is a key driver of the demand for backup power in the ski industry. PEM fuel cells appear to be a good size fit with industry requirements for backup power. It is also expected that the industry would welcome the opportunity to eliminate diesel emissions from its operations in light of the industry's efforts to manage its environmental impacts and appeal to its environmentally conscious customers. However, the market size is small. Approximately one-third of chair lifts require backup systems of 75 kW or smaller. Assuming the roughly 500 ski areas in the U.S. have at least a two small chair lifts, the potential market would be over 1000 units.

In addition, other barriers exist to the adoption of PEM fuel cells. Ski resort owners and operators have indicated that cost would be a significant barrier. The lack of understanding about PEM fuel cell performance in cold climates could also present a potential barrier. Furthermore, ski resorts appear to be generally satisfied with generators as their primary backup power source and are thought to be unlikely to switch without significant incentives. While encouraging, the real impact of recent industry "greening" efforts, such as the adoption of the Sustainable Slopes charter, is yet to be seen in terms of influencing capital investment decisions for power technologies.

RESEARCH SUMMARY: WATER AND WASTEWATER TREATMENT

MARKET SEGMENT DESCRIPTION

Water treatment plants include establishments primarily engaged in distributing water for sale for domestic, commercial, and industrial use. Wastewater or sanitary sewage treatment plants include establishments primarily engaged in the collection and disposal of wastes released into a sewer system by residences, businesses, and industries in a community. This analysis considers the potential for PEM fuel cells for backup power in these market segments. The handling of storm water and other runoff is not included in this analysis. Table t-1 identifies the SIC and NAICS codes associated with water and sewage treatment plants.

Table t-1. SIC and NAICS Codes for Water and Wastewater Treatment Plants.

2-Digit SIC Code	49 – Electric, gas, and sanitary services
4-Digit SIC Codes	4952 – Sewerage systems
	4941 – Water supply
NAICS Codes	221320 – Sewage treatment facilities
	221310 – Water supply and irrigation systems

Secondary research indicates that there is a need for continuous power and reliable backup power at wastewater treatment plants and pumping stations, due to the problem of sewage overflow during a power outage.[411] Public water systems also have a need for backup power, in case of loss of electrical power, at the treatment plant to continue treating water and at pumping stations that distribute drinking water to customers. Backup power maintains operation of the SCADA or computer system that monitors and controls plant processes. At some plants, backup power is also required for emergency lights and communications.

Diesel-fueled generators (either leased or permanently installed) are typically used for backup power. In New York City, nearly all treatment plants are provided with backup generators to prevent sewage overflows in case of a power failure. However, the lag time before generators begin operating, in addition to the possibility of faulty or inoperable generators, can result in spilled sewage. Due to their size, diesel-fueled generators also require additional real estate at the pump station.[412]

UPS systems may also be used in combination with generators to provide backup power at water and wastewater treatment plants. Sometimes batteries and multiple power feeds from the local power company are utilized. Primary research gathered from water/wastewater treatment plants indicates that generators used for backup power range in size from approximately 15 kW to 1,000 kW.

[411] No author. 2006. Power Outage Unleashes Raw Sewage. Washington Post (May 20, 2006). Available at http://www.washingtonpost.com/wp-dyn/content/article/2006/05/19/AR2006051901595.html [Accessed June 2006].
[412] WaterTechONLINE. 2003. NYC officials: Wastewater a problem following blackout. Available at http://watertechonline.com/News.asp?mode=4&N_ID=42621 [Accessed March 2006].

MARKET SIZE

Hoover's, Incorporated reports approximately 50 wastewater treatment companies in the U.S. (SIC Code 4952). The top ten companies, by sales, are listed in Table t-2. The number of facilities, or sewage treatment plants (STPs) operated by these companies vary. No specific information on the exact number operated by each company could be located. U.S. EPA reports 16,255 wastewater treatment facilities in the U.S. in the year 2000.[413]

Table t-2. U.S. Wastewater Treatment Companies, by Sales.

Company Name	Location	Sales ($ mil)
Gold Kist Inc.	Atlanta, GA	2,304.30
South Carolina Public Service Authority	Moncks Corner, SC	1,151.00
Covanta Energy Corporation	Fairfield, NJ	700.4
Lower Colorado River Authority	Austin, TX	694.4
Orlando Utilities Commission	Orlando, FL	673.1
Knoxville Utilities Board	Knoxville, TN	525.6
Aqua America, Inc.	Bryn Mawr, PA	496.8
Washington Suburban Sanitary Commission	Laurel, MD	442.7
Public Utility District No. 1 of Clark County	Vancouver, WA	423.6
California Water Service Group	San Jose, CA	320.7

Source: Hoover's, Inc. 2006. Available at www.Hoovers.com. Accessed 6-27-06.

Hoover's, Incorporated reports 82 water distribution companies in the U.S. (SIC Code 4941). The top ten companies, by sales, are listed in Table t-3. The U.S. public water system consists of approximately 53,000 community water systems and 21,400 not-for-profit non-community water systems (e.g., schools, churches). Approximately 85% of the 53,000 community water systems are small systems serving 3,300 or fewer consumers. The remainder are large water systems (1,041 systems) serving greater than 50,000 people, and medium systems (7,638 systems) serving 3,301 to 50,000 people.[414]

Table t-3. Top Ten U.S. Water Treatment Companies, by Sales.

Company Name	Location	Sales ($ mil)
Wisconsin Energy Corporation	Milwaukee, WI	3,815.50
Salt River Project	Tempe, AZ	2,251.70
We Energies	Milwaukee, WI	2,147.50
Wisconsin Power and Light Company	Madison, WI	1,409.60
South Carolina Public Service Authority	Moncks Corner, SC	1,151.00
USFilter Water & Wastewater Systems	Warrendale, PA	720.7
Covanta Energy Corporation	Fairfield, NJ	700.4
Lower Colorado River Authority	Austin, TX	694.4
Orlando Utilities Commission	Orlando, FL	673.1
Knoxville Utilities Board	Knoxville, TN	525.6

Source: Hoover's, Inc. 2006. Available at www.Hoovers.com. Accessed June 2006.

[413] EPA. 2003. Clean Watersheds Needs Survey 2000: Report to Congress. EPA-832-R-03-001. Available at http://www.epa.gov/owm/mtb/cwns/2000rtc/toc.htm [Accessed December 2006].
[414] EPA. 2005. Drinking Water Needs Infrastructure Survey and Assessment: Third Report to Congress. EPA 916-R-05-001. Available at http://www.epa.gov/safewater/needssurvey/pdfs/2003/report_needssurvey_2003.pdf [Accessed December 2006].

MARKET TRENDS

A Drinking Water Infrastructure Needs Survey and Assessment, conducted by U.S. EPA in 2003, indicates that the nation's public water systems need to invest $276.8 billion over the next 20 years to ensure continued safe drinking water for consumers. Needs identified in the U.S. EPA survey include new infrastructure, as well as repair or replacement of deteriorating or inadequate water distribution infrastructure. Of the total needs identified in the survey, $2.3 billion is estimated for upgrades categorized as "Other," which includes emergency power generators among other projects.[415]

Medium and large community water systems represent the greatest need for improvement in EPA's Drinking Water Infrastructure Needs Survey and Assessment, with the total cost of improvements estimated at $103 billion and $123 billion, respectively. Capital investment costs, on a per-household basis, are expected to be significantly higher for smaller systems than for larger systems, which can spread the costs over a larger customer base; larger systems can also take advantage of economies of scale. The total estimated cost for improvements to smaller community water systems is $34 billion.[416]

EPA has also documented needed improvements for U.S. wastewater treatment facilities. EPA's 2000 Clean Water Needs Survey reports that much of the nation's wastewater treatment infrastructure has reached or is nearing the end of its design life. The report predicted, based on year 2000 data, that an estimated 1,687 new wastewater treatment facilities were needed, in addition to repair, replacement, or expansion of existing infrastructure.[417] The need for backup power was not specifically noted in EPA's survey.

No reports of PEM fuel cells being demonstrated for backup power at U.S. public water systems were found. Other fuel cells have been demonstrated at a number of facilities in the wastewater treatment market both in the U.S. and overseas. Ability to use anaerobic digester gas (ADG) generated on-site appears to offer a promising solution for meeting a facility's energy needs. Brief descriptions of fuel cell installations at wastewater treatment facilities are presented below. These installations predominantly provide primary electricity to the treatment plant, rather than backup power. Projects initiated in the 2003 to 2004 timeframe include:

- Two 250 kW direct fuel cell units providing electricity and heat for the El Estero Wastewater Treatment Facility in Santa Barbara, California
- A 250 kW direct fuel cell at Palmdale Water Reclamation Plant in Los Angeles, California
- Four 250 kW direct fuel cell modules (forming one 1 MW unit) at South Treatment Plant in Renton, Washington (two-year demonstration project)
- A 250 kW direct fuel cell at the Los Angeles Department of Water and Power (LADWP) Terminal Island wastewater treatment facility in San Pedro, California.[418]

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[415] EPA. 2005. Drinking Water Needs Infrastructure Survey and Assessment: Third Report to Congress. EPA 916-R-05-001. Available at http://www.epa.gov/safewater/needssurvey/pdfs/2003/report_needssurvey_2003.pdf [Accessed December 2006].
[416] EPA. 2005. Drinking Water Needs Infrastructure Survey and Assessment: Third Report to Congress. EPA 916-R-05-001. Available at http://www.epa.gov/safewater/needssurvey/pdfs/2003/report_needssurvey_2003.pdf [Accessed December 2006].
[417] EPA. 2003. Clean Watersheds Needs Survey 2000: Report to Congress. EPA-832-R-03-001. Available at http://www.epa.gov/owm/mtb/cwns/2000rtc/toc.htm [Accessed December 2006].
[418] Fuel Cells 2000. 2005. Worldwide Fuel Cell Installations. Available at http://www.fuelcells.org/info/charts/FCInstallationChart.pdf [Last updated October 2005; accessed June 2006].

In 1997, the New York Power Authority (NYPA) installed a UTC Power 200 kW PAFC at the Westchester County Wastewater Treatment Plant in Yonkers, New York. This became the world's first commercial fuel cell to use ADG to produce electricity. Ultra-low emissions (carbon monoxide and sulfur oxide emissions less than 1 ppm, and nitrous oxides less than 0.37 ppm), combined with high efficiency and reliability, prompted the NYPA to purchase eight additional fuel cells, which have been installed at four New York City Department of Environmental Protection wastewater treatment facilities in Brooklyn, Staten Island, the Bronx, and Queens.[419] For example, two 200 kW PAFCs that utilize ADG have operated at Bowery Bay Wastewater Treatment Plant since 2002.[420]

From 1997 to 2002, the Deer Island Sewage Treatment Plant in Boston, Massachusetts, operated a 200 kW PAFC from UTC Power that utilized digester gas.[421]

The City of Portland, Oregon, tested a 200 kW PAFC in 1999 at Columbia Boulevard Waste Water Treatment Plant. The fuel cell provided heat and electricity to the facility, generating as much as 1.6 million kW hours per year. Also in 1999, two 200 kW PAFCs were tested at Las Virgenes Wastewater Treatment Plant in Calabasas, California. The fuel cells provided 99% of on-site electricity.[422]

MARKET SEGMENT ANALYSIS

Approximately 30 wastewater treatment plants were contacted to further determine requirements for backup power and the potential for application of fuel cells. Responses were received from three wastewater treatment facilities, three water distribution centers, and one engineering consulting firm that had experience with water and wastewater systems. All respondents surveyed were small and had less than 500 people on site. The respondent from the engineering consulting firm identified his facility as small, but it should be noted that the respondent is part of a large engineering consulting firm.

Responses from the water treatment facilities are presented separately from the wastewater treatment facilities. Responses from the engineering consulting firm are also summarized separately.

Water Treatment and Distribution Response Analysis

Respondents indicated that backup power was typically required for plant emergency lights, SCADA and communications systems, computer operations, water pump operations including low and high service pumps, chemical feed system, mixers, and filters. All three respondents indicated that SCADA and communications systems were critical to their operations. One respondent indicated that pumps, chemical feed systems, mixers, and filters were also critical to their operations.

[419] Gangi, J. 2004. Fuel Cells: Providing Customer Value Today. Distributed Energy, the Journal for Onsite Power Solutions (November/December). Available at http://www.distributedenergy.com/de_0411_fuel.html [Accessed June 2006].
[420] Fuel Cells 2000. 2005. Worldwide Fuel Cell Installations. Available at http://www.fuelcells.org/info/charts/FCInstallationChart.pdf [Last updated October 2005; accessed June 2006].
[421] Fuel Cells 2000. 2005. Worldwide Fuel Cell Installations. Available at http://www.fuelcells.org/info/charts/FCInstallationChart.pdf [Last updated October 2005; accessed June 2006].
[422] Fuel Cells 2000. 2005. Worldwide Fuel Cell Installations. Available at http://www.fuelcells.org/info/charts/FCInstallationChart.pdf [Last updated October 2005; accessed June 2006].

Two respondents indicated that they had experienced outages over the past year. One respondent reported that ten outages lasted longer than one hour, while the other respondent had experienced three outages, two of which lasting less than 60 seconds and the other one lasting 3 to 5 minutes. Respondents indicated that power outages greater than 1 hour were very disruptive. They indicated that outages could result in loss of safe drinking water, disruptions in production and distribution, and in extreme cases where water is not available for fire protection, outages could result in lives lost.

Two respondents indicated that, to protect themselves from power outages, they relied on additional feeds from the electric utility. All three respondents indicated that they relied on UPS systems to backup their SCADA and computer systems, while they used generators for pumps and other critical applications. The size of systems used varies significantly among users, from 5 to 15 kW to over 750 kW. Respondents were asked to rate various factors that were most important to them in selecting backup power systems. Respondents indicated that reliability, start-up time, good experience, and fuel availability were the most important factors in selecting a backup power system. Respondents also identified lifetime of the unit and ease of use, and capital cost as other important decision factors. For backup power, respondents indicated that capital cost was less important than the aforementioned decision factors.

All three respondents were very satisfied with the current performance of their systems. One respondent was concerned about emissions from their diesel generators and also indicated that they were difficult to use. One respondent reported difficulty in transporting their backup power unit. Respondents rated their current backup systems on a variety of characteristics and identified reliability, operation and maintenance costs, lifetime of unit, annual operating costs, ease of use, and startup time as very good. Satisfaction with emissions ranked lower than all other characteristics.

Respondents were split on the growing need for backup power in their market segment. Only one respondent had considered alternatives and was investigating solar, wind, and fuel cell technologies. None of the respondents had heard of PEM fuel cells for backup power applications. Two respondents indicated that decisions to purchase were made on initial capital cost. One respondent indicated that they also considered return on investment. One respondent indicated that they made decisions based on environmental concerns. Two respondents indicated that they took government incentives into consideration when making purchasing decisions.

Wastewater Treatment Response Analysis

Respondents indicated that backup power was mainly required for operation of pumps, aeration blowers and mixers, clarifier drivers, digester blowers, wastewater processing equipment, and traveling bridges. All respondents experienced power outages. The number of outages varied from two to ten. Respondents indicated that longer outages were more disruptive. The length of outages typically varied from 3 to 5 minutes or 1 to 4 hours. Respondents indicated that outages could result in disruptions in distribution, loss of safe drinking water, and implementation of emergency management plans.

Backup power is typically supplied through UPS and generators. Size varies based on the application supported and ranges from 5 to 30 kW to over 250 kW. Respondents indicated that reliability, capital cost, start-up time, ease of use, fuel availability, and good experience with the system were very important factors in selecting backup power products. Respondents were very satisfied with their current backup power systems and had no concerns about their operation. Respondents rated performance characteristics of their backup power systems, including reliability, annual operating costs, startup time, and fuel availability, as very good.

All three respondents indicated that there would be a growing need for backup power in their market segment. One respondent indicated that they had considered alternatives to their backup power systems and had explored the use of reclaimed landfill gas. None of the respondents had heard of PEM fuel cells for backup power.

Decision drivers for respondents to purchase PEM fuel cells include the availability of incentives, track record of others using the PEM fuel cell system, and the cost of not having electricity. Respondents indicated that purchase decisions were made based on initial capital cost, return on investment, and payback period.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

Potential applications of PEM fuel cells in water and wastewater treatment facilities include backup power for pump stations, aeration blowers, SCADA systems, digester blowers, and other water/wastewater processes. Users appear to be fairly satisfied with their current mode of operation. There is limited interest in alternatives for backup power in the waste water and water treatment market segments. Users in the wastewater market segment are primarily interested in utilizing waste gas to provide additional power to support operations. Initial capital cost and track record of others using new technologies are important considerations for users in this market segment when adopting new technologies.

Despite limited user interest in backup power, several factors suggest that wastewater treatment plants may represent a favorable market for adopting PEM fuel cell technology. These include large market size (16,255 wastewater treatment facilities in the U.S.), industry's willingness to explore possibilities for fuel cell technologies, and industry's experience gained through fuel cell demonstrations at wastewater treatment plants. Furthermore, fuel cells offer a distinct advantage in areas with space limitations, such as New York City, where adequate property to house diesel-fueled generators is limited.[423] Noise and emissions from diesel generators at pump stations in predominantly residential areas also present problems. Aging wastewater treatment systems may be in need of a makeover that includes updating backup power. Such facilities may consider adopting fuel cells provided the technology is cost-competitive (over its useful lifetime) with traditional backup power sources.

Due to price sensitivity and limited user interest, water and wastewater utilities appear to represent a favorable mid-term market for PEM fuel cells. In the near-term field demonstrations in backup applications (e.g. for SCADA systems) will be a key factor in increasing user familiarity with the technology and building user confidence.

[423] WaterTechONLINE. 2003. NYC officials: Wastewater a problem following blackout. Available at http://watertechonline.com/News.asp?mode=4&N_ID=42621 [Accessed March 2006].

RESEARCH SUMMARY:
SPECIALTY VEHICLES – ELECTRIC BICYCLES AND SCOOTERS

MARKET SEGMENT DESCRIPTION

Electric bicycles are defined in the Consumer Product Safety Act (15 U.S.C. 2085(b)) as "a two- or three-wheeled vehicle with fully operable pedals and an electric motor of less than 750 W (1 HP), whose maximum speed on a paved level surface, when powered solely by such a motor while ridden by an operator who weighs 170 lbs, is less than 20 miles per hour (mph)."[424] Physically, electric bicycles resemble a standard bicycle to which an electric motor has been added to make pedaling easier for the rider. Electric bicycles are used as a convenient means of local transportation by people who wish to ride a bicycle but do not wish to do all the pedaling themselves.

The word "scooter" conjures different images to different people. The State of California defines a motorized scooter as "any two-wheeled device that has handlebars, is designed to be stood upon or sat upon by the operator, and is powered by an electric motor that is capable of propelling the device with or without human propulsion."[425] Vehicles powered by a source other than electrical power (e.g., a gasoline-powered two-stroke engine) are also classified as motorized scooters. This definition encompasses vehicles of various shapes and sizes. Some consider powered scooters to be motorized versions of the two-wheeled, stand-on scooters often ridden by children, which resemble a narrow skateboard with handlebars. Others use the term to describe the sit-down motorbikes (e.g., the "Vespa") popular in heavily congested cities outside the U.S. Still others consider three- or four-wheeled personal mobility devices used by elderly and handicapped individuals to be a type of scooter. Scooters used for personal mobility by elderly or handicapped people are covered briefly in the "Wheelchair" section of this report. All other types of scooters will be covered here. Table u-1 identifies the SIC and NAICS classifications that cover manufacturing of electric bicycles and scooters.

Table u-1. SIC and NAICS Codes for Bicycle and Scooter Manufacturing.

2-Digit SIC Code	37 – Transportation equipment
4-Digit SIC Code	3751 – Motorcycles, bicycles, and parts
NAICS Code	336991 – Motorcycle, bicycle, and parts manufacturing

In general, powered stand-on scooters are similar in design to the manual stand-on variety but may have larger wheels. Powered ride-on scooters (hereafter termed "motorscooters") resemble motorcycles but have a step-through frame on which the rider sits without straddling the engine. Motorscooters typically have smaller wheels (between 8 and 14 inches in diameter) than motorcycles, along with a small displacement (between 30 cc and 250 cc).[426] Gas-powered motorscooters are capable of traveling between 25 and 60 mph.[427] Most motorscooters have automatic transmissions and, until recently, air-cooled or water-cooled two-stroke engines.

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[424] U.S. Department of Transportation. 2005. Two- and Three-Wheeled Vehicles. Federal Register 70 (114): 34810-34814.
[425] Los Alamitos Police Force. 2006. The LAW – Los Al Watch: Special Bulletin – Motorized Scooters & Mini-Motorcycles (Pocket Rockets). Available at http://www.losalamitospolice.org/040810_mini-bikes.pdf [Accessed June 2006].
[426] Wikimedia Foundation, Inc. 2006. Scooter (motorcycle). Available at http://en.wikipedia.org/wiki/Motorscooter [Accessed June 2006].
[427] GS MotorWorks. 2006. About Gas Scooters. Available at http://www.gsmotorworks.com/about_gas_scooters/c8/Riding_Life.html [Accessed June 2006].

However, more stringent emissions controls have resulted in a growing number of four-stroke motorscooter engines. Another recent trend is the development of larger motorscooters, otherwise known as Mega Scooters or maxi-scooters, with engines ranging in size from 250 cc to 650 cc.[428]

Motorized bicycles and scooters can be powered by battery-driven electric motors or gasoline engines. Various types of rechargeable batteries are used to power electric bicycles and scooters. By far, the most common battery type for vehicles sold in the U.S. is sealed lead-acid (SLA), followed by NiCd and NiMH. In Europe and Asia, NiCd and NiMH are used more commonly than lead batteries.[429]

As indicated above, electric bicycles are defined as having motors of less than 750 W (1 HP). Among the products offered by U.S. manufacturers, electric bicycles typically use 24V or 36V electric motors powered by various battery configurations (two or three 12V SLA or twenty 1.2V NiMH batteries); several 12V models are also available. The power range for bicycle motors generally runs from 200 W to 450 W, with 450 W motors being the most common among the products identified. Electric bicycles vary in weight from 40 to 120 lbs, with most in the 65 to 85 lb range. These bicycles typically range in price from $300 to $3,300, [430] though more costly high-performance models are available.

Battery-powered stand-on scooters tend to be slower, have smaller wheels, and cost less than gasoline-powered models.[431] Electric scooters offer a broader range of motors than bicycles, from 90 W, 12V systems to 1 kW, 36V motors. Typically, electric stand-on scooters are driven by 100 to 750 W DC motors, have an operating range of 8 to 20 miles, and weigh 20 to 100 lbs.[432] Scooters with motors of 500 W or greater are typically powered by 36V battery systems (three 12V SLAs), while motors sized at < 500 W tend to be powered by 24V systems (two 12V SLAs). The self-balancing Segway scooter, which runs on two 1.88 kW motors (one per wheel), can be powered by lithium-ion (Li-ion) or NiMH battery packs; specific battery sizes were not available on the manufacturer's website. Most powered stand-on scooters are imported from China and retail for $150 to $900.[433] However, some uniquely designed scooter products such as the Segway can cost in the neighborhood of $5,000. In 2003, sales of electric and gas-powered stand-on scooters were approximately equal.[434]

Most gasoline-powered scooters (both stand-on and motorscooters) are manufactured abroad. These vehicles are available with engines in the 22 to 50 cc range, capable of generating 1.2 to 4.2 HP (0.9 kW to 3.1 kW). Competition or "sport" models typically have the largest engines (> 3 HP/2.2 kW). Some gas stand-on scooters run on four-stroke engines, while others run on two-

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[428] Wikimedia Foundation, Inc. 2006. Scooter (motorcycle). Available at http://en.wikipedia.org/wiki/Motorscooter [Accessed June 2006].
[429] CycleElectric. 2002. Market Size for Two Wheelers. Available at http://www.cycleelectric.com/rsc/worldsales2003.pdf [Accessed June 2006].
[430] Benjamin, E. 2005. Light Electric Vehicle Propulsion. Available at http://www.cycleelectric.com/rsc/LEVPropulsion.ppt [Accessed June 2006].
[431] U.S. Consumer Product Safety Commission. 2005. Powered Scooters. Consumer Product Safety Review 10(2).
[432] Benjamin, E. 2005. Light Electric Vehicle Propulsion. Available at http://www.cycleelectric.com/rsc/LEVPropulsion.ppt [Accessed June 2006].
[433] Benjamin, E. 2005. Light Electric Vehicle Propulsion. Available at http://www.cycleelectric.com/rsc/LEVPropulsion.ppt [Accessed June 2006].
[434] U.S. Consumer Product Safety Commission. 2005. Powered Scooters. Consumer Product Safety Review 10(2).

stroke engines that are fueled by a mixture of oil and gasoline. Standard motorscooters are available with two-stroke or four-stroke engines ranging in size from 30 cc to 250 cc, though more powerful "maxi-scooters" have 250 cc to 650 cc engines.[435]

Electric bicycles, powered scooters, and motorscooters are used by individuals for recreational and commuting purposes. Manufacturers of electric bicycles and scooters are primarily headquartered outside the United States, with several notable exceptions (ZAP, Currie Technologies, Razor USA, and Segway Inc.). Electric bicycles are distributed through various channels, including bicycle shops, the internet, catalog retailers, electric vehicle specialists, mass merchants, sporting goods stores, power sports retailers, and direct purchases from the manufacturer. Scooters are distributed through some of the same channels (mass merchants, the internet, bicycle shops, sporting goods stores) but can also be purchased at flea markets, independent retailers, recreational vehicle (RV) dealers, golf cart retailers, and truck vendors.[436]

MARKET SIZE

Current data on the electric bicycle and powered scooter manufacturing market are provided below. SIC Code 3751, covering manufacturing of motorcycles, bicycles, and parts, is represented by Table u-2. Only the eight-digit SIC Code specialties relevant to electric bicycles and powered scooters are shown. Note that the category of "Bicycles and related parts" includes manufacturers of standard (i.e., non-motorized) bicycles.

Table u-2. Number of Electric Bicycle and Scooter Manufacturers – Industry: Motorcycles, Bicycles, and Parts (3751).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)*
3751-0102	Motor scooters and parts	58	684	72.3
3751-0200	Bicycles and related parts	207	3,286	251.4
	Total	**265**	**3,970**	**323.7**

Sales figures are in millions. Source: www.zapdata.com, accessed 6/20/06.

The markets for electric bicycles and scooters are seeing modest growth in the U.S., though the domestic market still pales in comparison to the foreign market for these vehicles. Approximately 65,000 electric bicycles were expected to be sold in the U.S. in 2004, up from 45,000 in 2003. In contrast, in China 7,000,000 electric bikes were sold in 2004, up from 4,000,000 the previous year.[437]

CycleElectric is an international consulting group that tracks market trends for electric bicycles and electric scooters. This group predicts that the market for electric bicycles in the U.S. will eventually reach approximately 1.5 million vehicles per year and that the market for light electric scooters will eventually reach about 15 million vehicles per year.[438] However, no timeline is provided for these forecasts.

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[435] Wikimedia Foundation, Inc. 2006. Scooter (motorcycle). Available at http://en.wikipedia.org/wiki/Motorscooter [Accessed June 2006].
[436] Benjamin, E. 2004. Market Trend and Regulation of E-Scooter and E-Bike in North America. Presentation for ITRI, Taiwan. Available at http://www.cycleelectricusa.com/rsc/USA.ppt [Accessed June 2006].
[437] Alvord, K. 2004. Plugged in: E-Bikes and Segways are slow to catch on—but rebates help. E: The Environmental Magazine (September/October). Available at http://www.findarticles.com/p/articles/mi_m1594/is_5_15/ai_n6335040/pg_2 [Accessed June 2006].
[438] Benjamin, E. 2004. Market Trend and Regulation of E-Scooter and E-Bike in North America. Presentation for ITRI, Taiwan. Available at http://www.cycleelectricusa.com/rsc/USA.ppt [Accessed June 2006].

Leading manufacturers of electric bicycles include Currie Technologies, Inc., and ZAP. Leading manufacturers of powered stand-on scooters include Razor USA LLC, The Apache Motor Company, and Segway LLC. Leading manufacturers of motorscooters include Vectrix Corporation; Piaggio & C., S.p.A.; Yamaha Motor Corporation; and American Honda Motor Co., Inc.

MARKET TRENDS

Some companies have begun integrating fuel cells into electric bicycles. As early as 2000, a bicycle powered by a PEM fuel cell was successfully tested by Manhattan Scientifics, Inc. The PEM fuel cell used in this bicycle had an energy density of 205 W per kg, nearly seven times the energy density of lead-acid batteries (30 W per kg) and over three times the energy density of NiMH batteries (60 W per kg). More recently, Masterflex AG recently supplied the German city of Herten with the world's first fleet of bicycles propelled by fuel cell systems.[439] These bicycles will be targeted to executive commuters, delivery services, and area tourists. The fuel cell system allows the bicycles to travel distances of 120 to 250 kilometers (75 to 155 miles), which greatly exceeds the distance achievable by electric bicycles on a single charge.[440]

There has also been fuel cell activity in the scooter market. Palcan Fuel Cells demonstrated a scooter powered by a 2 kW PEM fuel cell in 2003 (based on metal hydride hydrogen storage technology). This fuel cell was developed specifically for use in two- and three-wheeled vehicles used in European and Asian markets, including scooters and rickshaws.[441] Vectrix, a European scooter manufacturer with offices in Rhode Island and Massachusetts, has developed a maxi-scooter powered by a fuel cell-battery hybrid system. Protonex's 500 W fuel cell system continuously charges the vehicle's NiMH batteries and is supplemented by a regenerative braking system. Vectrix plans to launch the vehicle in European markets before making it available in the U.S.[442]

MARKET SEGMENT ANALYSIS

To help identify the market opportunities for direct PEM fuel cells in electric bicycles and scooters, three U.S. manufacturers of these vehicles were contacted. Because this is a highly distributed market, individual users were not contacted. It was deemed that responses from manufacturers would provide insight into user requirements. None of these manufacturers responded. Therefore, the following analysis of opportunities for PEM fuel cells is based solely on secondary research.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

The market for scooters and electric bicycles is still an emerging one in the U.S.; however, several issues have been identified as being particularly important to consumers. These issues

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[439] No author. 2005. Masterflex receives first order for fuel cell bicycles. Fuel Cell Today. Available at http://www.fuelcelltoday.com/FuelCellToday/IndustryInformation/IndustryInformationExternal/NewsDisplayArticle/0,1602,6836,00.html [Accessed June 2006].
[440] Bangkok Post. 2006. German develops fuel-cell bicycles. Fuel Cell Works. Available at http://www.fuelcellsworks.com/Supppage4340.html [Accessed June 2006].
[441] Shen, J. 2003. Palcan showcases the future with fuel cell powered scooter for global masses. Available at http://www.palcan.com/s/NewsReleases.asp?ReportID=63580 [Accessed June 2006].
[442] Green Car Congress. 2005. Vectrix readies its electric and fuel cell hybrid scooters for market. Available at http://www.greencarcongress.com/2005/03/vectrix_readies.html [Accessed June 2006].

are as follows: cost, noise, torque, reliability, weight, and efficiency.[443] It remains to be seen whether fuel cell-powered vehicles will be able to compete with relatively inexpensive electric and gas-powered vehicles from a cost perspective. Fuel cell-powered or fuel cell-electric hybrid vehicles may be more likely to compete based on other benefits. For example, PEM fuel cells are: 1) much quieter than ICE vehicles, 2) capable of exceptional performance over battery-powered vehicles in terms of power density, 3) lighter than purely battery-driven models, 4) more efficient, and 5) easier to maintain.[444] Furthermore, PEM fuel cells and other electric vehicles eliminate the significant environmental concerns associated with ICE emissions, particularly from the much more widely used two-stroke engines.[445]

While the market for scooters and electric bicycles is growing in the U.S., it is significantly smaller that in other parts of the world. Manufacturers of PEM fuel cell-powered systems are targeting the European and Asian markets in the near term. Also, because of the distributed nature of users of these vehicles, a highly distributed refueling architecture will be required to support widespread adoption in the U.S. For these reasons, the market for electric bicycles and scooters is not considered a likely near-term market for PEM fuel cells in the U.S.

[443] Benjamin, E. 2005. Light Electric Vehicle Propulsion. Available at http://www.cycleelectric.com/rsc/LEVPropulsion.ppt [Accessed June 2006].
[444] Parker Hannifin Corporation/Vectrix USA. 2004. The World's First Fuel Cell/Electric Hybrid Scooter. Available at http://www.parker.com/chomerics/Scooter-Brochure-10-04.pdf [Accessed June 2006].
[445] Shen, J. 2003. Palcan showcases the future with fuel cell powered scooter for global masses. Available at http://www.palcan.com/s/NewsReleases.asp?ReportID=63580 [Accessed June 2006].

RESEARCH SUMMARY:
SPECIALTY VEHICLES – COMMERCIAL SWEEPERS/SCRUBBERS

MARKET SEGMENT DESCRIPTION

Commercial sweepers and scrubbers are vehicles equipped with one or more broom, mop, or brush attachments for heavy-duty cleaning of industrial floors or pavement. These vehicles can be used indoors or outdoors. Walk-behind and ride-on sweepers and scrubbers are available in a wide variety of shapes and sizes. Smaller walk-behind models may resemble lawnmowers and weigh as little as ~100 lbs. The largest ride-on models, which may include a combination of sweeping and scrubbing functions, can weigh in excess of 7,000 lbs. Some models are equipped with wet/dry vacuums and/or squeegees for more aggressive cleaning and water extraction. Table v-1 identifies the SIC and NAICS classifications that cover manufacturing of commercial sweepers and scrubbers.

Table v-1. SIC and NAICS Codes for Commercial Sweeper/Scrubber Manufacturing.

2-Digit SIC Code	35 – Industrial and commercial machinery and computer equipment
4-Digit SIC Code	3589 – Service industry machinery, not elsewhere classified
NAICS Code	333319 – Other commercial and service industry machinery manufacturing

Commercial sweepers and scrubbers can be powered by gasoline, propane, CNG, or diesel ICEs, as well as electric batteries. Corded electric models are also available. Electric models typically have smaller engines with motors ranging in capacity from 0.5 HP (375 W) to 4.6 HP (3.5 kW). Variously sized (12V, 24V, and 36V) battery systems, comprised of sealed flooded, gel cell, or absorption glass mat (AGM) deep-cycle batteries are used. Both walk-behind and riding sweepers/scrubbers may have electric motors. ICEs are used primarily in riding sweepers and scrubbers, though one 2.5 to 4 HP (1.9 to 3 kW) gas-powered walk-behind sweeper was found. Among the commercially available riding products reviewed for this analysis, gasoline and propane engines ranged between 55 HP (41 kW) and 97 HP (72 kW). Diesel engines ranged between 37 HP (28 kW) and 65 HP (48.5 kW). Specifications for CNG engines were unavailable.

Pricing for commercial sweepers and scrubbers is extremely variable. Walk-behind machines typically are available for $4,000 to $11,000. Riding machines range between $11,000 and $93,000; however, many models (including combination sweepers/scrubbers) are available for under $25,000.[446]

MARKET SIZE

Current data on the size of the commercial sweeper/scrubber manufacturing market are provided below. SIC Code 3589, which covers manufacturing of these vehicles, is represented in Table v-2. Only those eight-digit SIC Code specialties relevant to sweeper and scrubber manufacturing are shown.

[446] Prices obtained from online retailer of commercial sweepers and scrubbers: Caliber Equipment, Inc. Available at http://www.caliberequipment.com/ [Accessed June 2006].

Table v-2. Number of Commercial Sweeper/Scrubber Manufacturers - Industry: Service Industry Machinery, Not Elsewhere Classified (3589).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)*
3589-0200	Commercial cleaning equipment	175	3,991	1,042.9
3589-0202	Carpet sweepers, except household electric vacuum sweepers	11	437	49.1
3589-0203	Dirt sweeping units, industrial	32	520	57.1
3589-0205	Floor washing and polishing machines, commercial	47	1,015	205.1
3589-0207	Vacuum cleaners and sweepers, electric: industrial	83	2,962	604.8
	Total	**348**	**8,925**	**1,959**

Source: www.zapdata.com, accessed June 2006.

The user market for commercial sweepers and scrubbers encompasses any facility with a hard floor, as well as outdoor areas where clean surfaces are desired (e.g., amusement parks, sidewalks). A few common industrial applications for compact riding models include retail home centers, warehouses, manufacturing plants, airports, and distribution centers. Walk-behind models are best suited for use in office buildings, educational facilities, hotels, convention centers, convenience stores, and shopping malls, though they can also be used in airports and manufacturing plants.

Detailed information on commercial sweepers and scrubbers was provided in a 2005 EPA report on nonroad engines (see Table v-3). This report, which documented the source of nonroad engine population values in EPA's NONROAD emissions inventory model, provided the most recent population data available (termed "base year" data) for non-road engines in a wide range of vehicles and equipment. All data were obtained from Power Systems Research, an independent market research firm that surveyed engine manufacturers and users to derive its estimates. For commercial sweepers and scrubbers, the year 1998 was designated as the base year. [447]

Major sweeper/scrubber manufacturers include American-Lincoln; Nilfisk Advance, Inc.; Tennant Company; Tornado® Industries, Inc.; TYMCO; Elgin Sweeper Co.; and Factory Cat/RPS Corporation.

[447] EPA. 2005. Nonroad Engine Population Estimates. EPA420-R-05-022. Washington, DC, EPA Office of Transportation and Air Quality.

Table v-3. Total Population of Commercial Sweepers/Scrubbers in the United States in 1998.

Year	Equipment Description	Min HP	Max HP	Avg HP	U.S. Population
1998	2-Str Sweepers/Scrubbers	1	3	1.276	3,298
1998	4-Str Sweepers/Scrubbers	3	6	4.735	3,777
1998	4-Str Sweepers/Scrubbers	6	11	9,855	5,779
1998	4-Str Sweepers/Scrubbers	11	16	14.85	1,563
1998	4-Str Sweepers/Scrubbers	16	25	18.23	3,348
1998	4-Str Sweepers/Scrubbers	25	40	31.91	2,011
1998	4-Str Sweepers/Scrubbers	40	50	46	2,273
1998	4-Str Sweepers/Scrubbers	50	75	63.35	2,306
1998	4-Str Sweepers/Scrubbers	75	100	90	23
1998	4-Str Sweepers/Scrubbers	100	175	150.0	47
1998	4-Str Sweepers/Scrubbers	300	600	411.0	3
1998	LPG – Sweepers/Scrubbers	25	40	31	2,011
1998	LPG – Sweepers/Scrubbers	40	50	47	2,273
1998	LPG – Sweepers/Scrubbers	50	75	63.35	2,306
1998	LPG – Sweepers/Scrubbers	75	100	90	23
1998	LPG – Sweepers/Scrubbers	100	175	150	47
1998	LPG – Sweepers/Scrubbers	300	600	411	3
1998	CNG – Sweepers/Scrubbers	175	300	190	20
1998	Diesel – Sweepers/Scrubbers	3	6	5	302
1998	Diesel – Sweepers/Scrubbers	6	11	11	14
1998	Diesel – Sweepers/Scrubbers	11	16	13.65	1
1998	Diesel – Sweepers/Scrubbers	16	25	21.69	1,845
1998	Diesel – Sweepers/Scrubbers	25	40	34.83	4,436
1998	Diesel – Sweepers/Scrubbers	40	50	43.64	2,993
1998	Diesel – Sweepers/Scrubbers	50	75	60.81	2,898
1998	Diesel – Sweepers/Scrubbers	75	100	81.86	10,672
1998	Diesel – Sweepers/Scrubbers	100	175	134.3	11,984
1998	Diesel – Sweepers/Scrubbers	175	300	216.7	3,222
1998	Diesel – Sweepers/Scrubbers	300	600	363.8	55
Total Population					**69,533**

Source: Adapted from EPA, 2005. Nonroad Engine Population Estimates. Washington, DC: EPA Office of Transportation and Air Quality. EPA420-R-05-022.

MARKET TRENDS

Emissions from ICE-powered commercial sweepers and scrubbers are regulated by EPA and state agencies within the category of nonroad engines. As such, they would be subject to the new emissions standards recently proposed by EPA for nonroad diesel engines. These standards, to be implemented in phases between 2008 and 2014, will require diesel engine manufacturers to outfit new engines with advanced emission control technologies.[448] Also, the California Air Resources Board (CARB) has proposed to adopt more stringent emission standards and test procedures for large (> 25 HP or 19 kW), spark-ignited engines in various types of equipment, including forklifts, sweepers/scrubbers, industrial tow tractors, and ground support equipment.[449]

[448] U.S. Department of Transportation, Federal Aviation Administration. 2005. Aviation and Emissions - A Primer. Washington, DC, FAA Office of Environment and Energy.
[449] California Air Resources Board. 2006. Staff report: New emission standards, fleet requirements, and test procedures for forklifts and other industrial equipment. Available at http://www.arb.ca.gov/regact/lore2006/isor.pdf [Accessed June 2006].

As early as 1999, analysts predicted that cleaner electric sweepers and scrubbers would eventually capture much of the market from their ICE-powered counterparts.[450] All major scrubber/sweeper manufacturers offer electric models, and numerous manufacturers offer alternatively fueled (CNG or propane) vehicles, as well.

MARKET SEGMENT ANALYSIS

To help identify the market opportunities for direct PEM fuel cells in commercial sweepers and scrubbers, manufacturers of these vehicles were contacted. Because this is such a highly distributed market with varied applications, manufacturers were thought to be best-positioned to provide a comprehensive view of user applications and requirements. Five manufacturers were contacted, and three responses were received. All respondents were manufacturers of industrial sweepers and scrubbers; two noted that their companies offered additional products and services. One small, one medium, and one large company responded.

Product offerings varied among the manufacturers who responded. One offered only electric sweepers and scrubbers, while the other two offered both electric and ICE-powered models. One manufacturer offered ICE products fueled by diesel or gasoline, and the other offered diesel, gasoline, propane, and combination-fuel ICEs.

Regarding which user markets are most affected by product downtime, one manufacturer indicated that the impact is somewhat dependent on the size of the vehicle being used and its application. However, several markets were deemed particularly sensitive to downtime, including building service contractors; large manufacturing facilities with multiple shifts and complex operations; and heavy industrial applications (e.g., foundries and mining), which have concerns about the cleanliness of the environment and product contamination.

Two manufacturers addressed the O&M requirements associated with their products. According to one respondent, O&M requirements vary according to the products offered and the applications in which they are used. Battery-based vehicles require frequent charging (and swapping with charged batteries), as well as water level monitoring, watering, and venting. ICE-based products primarily need to be refueled, but maintenance and monitoring of engine hydraulics are also required.

There are safety concerns with both electric and ICE models, as noted by two of the manufacturers contacted. The use of batteries raises concerns over leaking and splattering of acid, as well as toxic emissions that are released when a battery is vented. To avoid these emissions and the risk of a battery leak, one large manufacturer is shifting to sealed gel cell batteries, even though they do not last as long as flooded lead-acid systems. According to one large manufacturer, ICE-powered sweepers and scrubbers raise concerns over emissions. A medium-sized manufacturer pointed out that material safety data sheets must be maintained for the fuels and other substances associated with ICEs.

[450] Moore, B. 1999. Follow the money – non-road electric vehicles. EV World. Available at http://www.evworld.com/archives/interviews2/krein.html [Accessed June 2006].

Of the three manufacturers contacted, only one (the largest) was aware of PEM fuel cells as a potential substitute for existing power sources. This manufacturer examines all new and emerging technologies and has just begun to consider the potential for fuel cells in its products. When evaluating new technologies, the manufacturer indicated that maximizing run-time is a critical issue, but other factors are important as well. For example, ICEs provide more power than batteries, but batteries offer lower emissions and noise levels. Regarding fuel cells, the manufacturer was not prepared to call them a viable alternative but noted that they may have potential. The respondent doubted that fuel cells would ever fully replace ICE products because ICEs offer much-needed power; however, fuel cells may compete with batteries or some ICE applications.

Sweeper/scrubber manufacturers were asked about potential drivers for and barriers to the successful adoption of fuel cells. Two manufacturers addressed potential barriers. The largest manufacturer identified customer acceptance as a potential barrier but added that customers are likely to accept a change when they can see that it works. The same manufacturer noted that significant research and development may be necessary to meet the engineering requirements of sweepers and scrubbers (e.g., the power source must drive the engine as well as the brushes, vacuum attachments, water tank, and other functions). A medium-sized manufacturer noted that fuel cell use would depend on cost and competitiveness with current products. Only one manufacturer (the largest) suggested potential drivers for fuel cell use. This manufacturer noted that key drivers would be environmental concerns (citing tremendous potential benefits) and extended run-time.

Only two manufacturers responded to a question inquiring whether their customers would be concerned over the use of hydrogen as a fuel. A medium-sized manufacturer indicated that its customers would not be concerned as long as hydrogen were widely available and appropriate demonstration projects were conducted. A large manufacturer indicated that its customers might have some concerns.

There was limited interest among those contacted in working with DOE to demonstrate PEM fuel cells. The small manufacturer was not interested and did not wish to be contacted again. The medium and large manufacturers indicated that they might be interested but would have to ask around within their organizations before providing a more definitive response. Both agreed to be contacted again.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

With the exception of one major manufacturer who is considering the potential for PEM fuel cells in its sweeper and scrubber vehicles, no evidence was found through secondary or primary research to suggest that commercial sweeper/scrubber manufacturers are actively pursuing fuel cells as alternative power sources for their vehicles. The need to comply with EPA's stricter emission standards for nonroad diesel engines and the need to minimize hazardous emissions, particularly in indoor environments, are thought to be prompting the move from ICE to electric vehicles. While this may provide an opportunity for PEM fuel cells to enter this market, it is important to note that batteries also meet these requirements and battery-powered sweepers/scrubbers are already available. PEM fuel cells would need to demonstrate a competitive advantage (cost or performance) with these existing battery products in order to be viable within this market. In light of current lack of development activity with PEM fuel cells and the status of incumbent technologies, the sweepers and scrubbers are not considered a likely near-term market for PEM fuel cell-powered specialty vehicles.

RESEARCH SUMMARY:
SPECIALTY VEHICLES – ICE RESURFACERS

MARKET SEGMENT DESCRIPTION

An ice resurfacer is a motorized vehicle, shaped like an industrial truck or tractor, which is used to smooth the surface of an ice rink after activities such as figure skating or hockey. The machine was invented in 1949 by Frank J. Zamboni and is still manufactured by Frank J. Zamboni & Co., Inc.; as a result, ice resurfacers, regardless of their origin, are often referred to as "Zambonis." Prior to Zamboni's invention, resurfacing was conducted manually using hoses and scrapers.[451] Table w-1 identifies the SIC and NAICS classifications that cover manufacturing of ice resurfacers.

Table w-1. SIC and NAICS Codes for Ice Resurfacer Manufacturing.

2-Digit SIC Code	35 – Industrial and commercial machinery and computer equipment
4-Digit SIC Code	3559 – Special industry machinery, not elsewhere classified (nec)
NAICS Code	333298 – All other industrial machinery manufacturing

Many different sizes and shapes of ice resurfacers are available to accommodate differently sized ice rinks, though all perform similar functions. All resurfacers use a conditioner, or a large and very sharp metal blade, to shave the surface of the ice. Ice shavings are swept and picked up by augers attached to the machine. At this stage of the process, wash water may be sprayed onto the ice to remove foreign material that has fallen onto the ice surface. Behind the conditioner, a sprinkler pipe and mop spread clean water onto the ice to fill in residual grooves and form a smooth new surface. Generally, resurfacers are equipped with tanks to hold the clean water and wash water; an engine or motor to provide propulsion to the vehicle and hydraulic power to the conditioner, tanks, and augers; and a reservoir to collect shaved ice.[452]

Currently, there are only two manufacturers of ice resurfacers: Frank J. Zamboni & Co., headquartered in California, and Resurfice Corp., located in Ontario. Both Resurfice Corp. and Frank J. Zamboni & Co. offer battery-powered and ICE-powered ice resurfacers. Zamboni offers an electric resurfacer driven by a 17.5 HP (13 kW) electric motor, which is powered by a 510 amp-hour lead acid battery pack. Resurfice Corp.'s Olympia Cellect™ resurfacer is powered by 180 amp-hour, 144V NiCd batteries. The drive system for the Cellect™ is capable of 15 kW nominal power and 30 kW peak power. Resurfice Corp.'s ICE resurfacers are available with emission-controlled propane or natural gas engines. Frank J. Zamboni & Co.'s ICE products can be operated on unleaded gasoline, propane, diesel, or CNG.[453] Engine capacity information was not publicly available for Resurfice Corp.'s products; however, Zamboni's ICE-powered vehicles are driven by 4-cylinder, 63 HP (47 kW) engines.

ICE-powered resurfacers range in weight from 5,660 lbs to 9,420 lbs (empty) and from 7,040 lbs to 13,700 lbs (full of water). The average empty weight among the ICE products identified was 6,858 lbs, and the average filled weight was 9,175 lbs. Electric resurfacers weigh between 6,330

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[451] Wikimedia Foundation, Inc. 2006. Ice resurfacer. Available at http://en.wikipedia.org/wiki/Ice_resurfacer [Accessed June 2006].
[452] Wikimedia Foundation, Inc. 2006. Ice resurfacer. Available at http://en.wikipedia.org/wiki/Ice_resurfacer [Accessed June 2006].
[453] Kolpack, D. 2005. Ice-resurfacing vehicle runs on hydrogen. The Bismarck Tribune (November 8, 2005). Available at http://www.bismarcktribune.com/articles/2005/11/08/news/state/105186.txt [Accessed June 2006].

lbs and 9,750 lbs (empty) and between 7,905 lbs and 11,350 lbs (full of water). The average empty weight among the electric products was 7,687 lbs, and the average filled weight was 9,165 lbs.

Both Resurfice Corp. and Zamboni offer more ICE models than electric vehicles. Of the estimated 8,000 Zamboni machines sold in the past 50 years, only about 1,000 have been electric.[454] However, there are significant health and safety concerns associated with the use of ICE-powered vehicles indoors. Unless the ice rink is adequately ventilated, air quality within the rink can become quite poor due to carbon monoxide and nitrogen dioxide emissions from ice resurfacing vehicles, posing a health hazard to those inside the rink.[455]

Conventional ICE-powered ice resurfacers range in cost from roughly $55,000 to $80,000.[456] It has been estimated that electric resurfacers cost approximately 60% more than ICE-powered models.[457] Within the electric product line, NiCd units are about $18,000 more expensive than models powered by lead-acid batteries.[458] Although electric resurfacers are more expensive initially, they have lower maintenance and fuel costs than ICE models; furthermore, electric models do not require the installation and maintenance of expensive ventilation systems capable of handling ICE exhaust.[459]

MARKET SIZE

Users of ice resurfacers, as illustrated in Table v-3, are mainly captured within three SIC codes: 7941 (Professional Sports Clubs and Promoters), 7997 (Membership Sports and Recreation Clubs), and 7999 (Amusement and Recreation Services, Not Elsewhere Classified). Colleges, universities, and other schools that maintain ice rinks would also be considered part of the user market for ice resurfacers; these institutions are captured within SIC Codes 8221 (Colleges, Universities, and Professional Schools) and 8211 (Elementary and Secondary Schools). Only a small percentage of these academic institutions are expected to have ice rinks; however, data were not available to determine the exact number. In Tables w-2 and w-3, only the eight-digit SIC specialty categories deemed most relevant to ice resurfacer manufacturing and use are shown.

Table w-2. Number of Ice Resurfacer Manufacturers - Industry: Special Industry Machinery, Nec (3559).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)*
3559-9941	Ice resurfacing machinery	2	46	4
	Total	**2**	**46**	**4**

Sales figures are in millions. Source: www.zapdata.com, accessed June 2006.

[454] Kolpack, D. 2005. Ice-resurfacing vehicle runs on hydrogen. The Bismarck Tribune, (November 8, 2005). Available at http://www.bismarcktribune.com/articles/2005/11/08/news/state/105186.txt [Accessed June 2006].
[455] Pelham, T., L.E. Holt, and M.A. Moss. 2002. Exposure to carbon monoxide and nitrogen dioxide in enclosed ice arenas. Occupational and Environmental Medicine 59: 224-233.
[456] Kolpack, D. 2005. Ice-resurfacing vehicle runs on hydrogen. The Bismarck Tribune, (November 8, 2005). Available at http://www.bismarcktribune.com/articles/2005/11/08/news/state/105186.txt [Accessed June 2006].
[457] Pelham, T., L.E. Holt, and M.A. Moss. 2002. Exposure to carbon monoxide and nitrogen dioxide in enclosed ice arenas. Occupational and Environmental Medicine 59: 224-233.
[458] Sharke, P. 2000. With built-in ice maker. Mechanical Engineering. Available at http://www.memagazine.org/backissues/dec00/features/withice/withice.html [Accessed June 2006].
[459] Pelham, T., L.E. Holt, and M.A. Moss. 2002. Exposure to carbon monoxide and nitrogen dioxide in enclosed ice arenas. Occupational and Environmental Medicine 59: 224-233.

Table w-3. Number of Potential Ice Resurfacer Users - Industries: Sports Clubs, Managers, and Promoters (7941); Membership Sports and Recreation Clubs (7997); Amusement and Recreation, Nec (7999); Colleges and Universities (8221); Elementary and Secondary Schools (8211).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)*
7941-0000	Sports clubs, managers, and promoters	1,256	11,512	1,214.8
7941-0100	Professional and semi-professional sports clubs	138	1,622	225.6
7941-0104	Ice hockey club	137	2,839	452.3
7997-0000	Membership sports and recreation clubs	15,874	120,903	5,421.4
7997-0100	Ice sports	55	494	20
7997-0101	Curling club, membership	34	150	4.7
7997-0102	Hockey club, except professional and semi-professional	119	850	37.1
7999-0600	Skating rink operation services	1,226	9,404	269.8
7999-0601	Curling rinks	99	367	9.2
7999-0602	Ice skating rink operation	420	7,553	235.9
7999-1110	Hockey instruction school	188	1,017	33.8
7999-1118	Skating instruction, ice or roller	123	775	18.6
7999-1120	Sports instruction, schools and camps	638	3,920	191.9
7999-9910	Recreation center	3,972	40,022	923.5
8221-0000	Colleges and universities	7,175	548,984	22,464.801
8221-0100	Colleges and universities	1,226	94,625	6,431.7
8221-0101	College, except junior	1,327	236,245	26,440.4
8221-0102	University	7,730	1,231,983	154,037.094
8211-0000	Elementary and secondary schools	57,045	2,605,595	60,601.102
8211-0100	Catholic elementary and secondary schools	430	14,141	325.4
8211-0101	Catholic combined elementary and secondary school	242	9,335	241.7
8211-0103	Catholic junior high school	97	4,677	165.9
8211-0104	Catholic senior high school	477	29,091	820.8
8211-0200	Private elementary and secondary schools	2,398	62,836	2,933
8211-0205	Private combined elementary and secondary school	833	46,337	2,887.9
8211-0207	Private junior high school	195	9,587	514.3
8211-0208	Private senior high school	421	18,483	731.4
8211-0300	Public elementary and secondary schools	4,438	258,506	78,165.5
8211-0302	Public combined elementary and secondary school	2,026	92,468	17,098.1
8211-0304	Public junior high school	3,691	254,001	2,291
8211-0305	Public senior high school	5,477	449,520	11,471.6
8211-9903	High school, junior or senior, nec	2,427	163,936	5,388.7
8211-9906	Secondary school, nec	963	62,816	1,220.9
	Total	**122,897**	**6,394,594**	**403,290**

Sales figures are in millions. Source: www.zapdata.com, accessed June 2006.

MARKET TRENDS

There is significant concern over exhaust from ICE-powered ice resurfacers. Many arena officials are prohibiting the use of ICEs indoors.[460] As a result, both manufacturers of ice resurfacing vehicles offer electric models.

Resurfice Corp. partnered with ePower Synergies Inc. and the University of North Dakota's Energy and Environmental Research Center to create the "Ice Bear," a hydrogen fuel cell-powered ice resurfacer. The Ice Bear was touted as having the performance and convenience of a propane-powered unit, but without the associated pollution. The Ice Bear's developers are seeking supporters to fund production of additional models.[461] They are also working on the development of a portable hydrogen refueling station to accompany the Ice Bear.[462]

MARKET SEGMENT ANALYSIS

To identify the market opportunities for direct PEM fuel cells in ice resurfacers, both manufacturers and users of these vehicles were contacted. Neither of the two manufacturers responded. Similarly, three potential users were contacted, but no responses were received. Due to the lack of data from primary sources, the following analysis of potential opportunities for PEM fuel cells was based solely on secondary research.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

The electric ice resurfacers on the market currently address the growing concern about vehicle emissions in indoor environments. Furthermore, battery power may be sufficient to generate the required level of performance, since ice resurfacers typically only have to work for shifts of 20 minutes or less (e.g., between hockey periods) to cover the entire ice rink surface. They are not subjected to repeated start-stop cycles; nor do they operate for 8-hour shifts like some other specialty vehicles.

The greatest obstacle to using hydrogen fuel cells in ice resurfacers may be cost. A prototype hydrogen-powered ice resurfacer recently developed through the collaboration between Resurfice Corp. and ePower Synergies Inc. costs $150,000, whereas a conventional Zamboni product costs only $80,000. In fact, the Frank J. Zamboni Co. evaluated the use of fuel cells in its products and concluded that the idea was cost prohibitive for its customers.[463] While the cost would come down as production scaled up, it seems unlikely that the cost reductions from economies of scale would close this gap in the next few years. Considering the cost disadvantage and the ability of battery-powered vehicles to effectively address user requirements, ice resurfacers are not considered a promising near-term market for PEM fuel cells.

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460 Kolpack, D. 2005. Ice-resurfacing vehicle runs on hydrogen. The Bismarck Tribune, (November 8, 2005). Available at http://www.bismarcktribune.com/articles/2005/11/08/news/state/105186.txt [Accessed June 2006].

461 Kolpack, D. 2005. Ice-resurfacing vehicle runs on hydrogen. The Bismarck Tribune, (November 8, 2005). Available at http://www.bismarcktribune.com/articles/2005/11/08/news/state/105186.txt [Accessed June 2006].

462 Fuel Cell Today. 2005. Fuel Cell-Powered Ice Refinisher Arrives at the Home of 2010 Winter Olympics. Available at http://www.fuelcelltoday.com/FuelCellToday/IndustryInformation/IndustryInformationExternal/NewsDisplayArticle/0,1602,6915,00.html [Accessed June 2006].

463 Kolpack, D. 2005. Ice-resurfacing vehicle runs on hydrogen. The Bismarck Tribune, (November 8, 2005). Available at http://www.bismarcktribune.com/articles/2005/11/08/news/state/105186.txt [Accessed June 2006].

RESEARCH SUMMARY:
SPECIALTY VEHICLES – GOLF CARTS

MARKET SEGMENT DESCRIPTION

Golf carts are motorized, four-wheeled vehicles that were originally designed to transport golfers and their equipment on a golf course. Today, golf carts are used in a wide variety of applications (both on and off the golf course) to transport small numbers of people over short distances at relatively slow speeds (typically 12 to 15 mph maximum range).[464] Golf carts are typically configured to carry two or four passengers. They may be covered (e.g., with a canopy and windshield) or uncovered. Approximately half of the golf carts manufactured come with small gasoline engines, and the other half are electrically powered. Electric golf carts were the first mass-produced electric vehicles for private consumer use; they are used in many communities where pollution control, noise control, and safety for pedestrians and other carts (due to slow speeds) are prized attributes.[465] Table x-1 identifies the SIC and NAICS classifications that cover manufacturing of golf carts.

Table x-1. SIC and NAICS Codes for Golf Cart Manufacturing.

2-Digit SIC Code	37 – Transportation equipment (manufacturing)
4-Digit SIC Code	3799 – Transportation equipment, not elsewhere classified (nec)
NAICS Code	336999 – All other transportation equipment manufacturing

This analysis will focus on golf carts used on golf courses and in residential environments. When golf cart-like vehicles are modified for use in specialty applications (e.g., to transport personnel and/or equipment in commercial, industrial, and institutional environments), they are referred to as utility vehicles or personnel carriers, which are covered in separate sections of this report.

All major golf cart manufacturers offer two types of vehicles: carts powered by gasoline ICEs and carts powered by electric batteries. Among the products offered by all golf cart manufacturers identified for this analysis, gasoline engines ranged in capacity from 9 HP (6.7 kW) to 13 HP (9.7 kW), with 9 HP (6.7 kW) and 11.5 HP (8.6 kW) being the most common engine sizes available. Electric golf carts operate on either SLA deep-cycle batteries or sealed gel batteries. Variously sized electric motors and battery configurations are available. Motor capacities among the manufacturers identified ranged from 2.5 HP (1.9 kW) to 5 HP (3.7 kW); multiple products were available in the 3.2 to 3.5 HP (2.4 to 2.6 kW) range. Several golf carts operate using 48V battery systems (configured as four 12V, six 8V, or eight 6V batteries); others operate on 36V systems (six 6V batteries) or 42V systems (seven 6V batteries).

There are drawbacks to both ICE and battery power sources. ICE golf carts are louder than electric models and require routine maintenance (e.g., fluid changes, tune-ups) like any other ICE-powered vehicle. Also, ICE exhaust is associated with air pollution, which is particularly undesirable in air quality nonattainment areas. Batteries also have drawbacks and limitations. Among these are low energy density and cycle-life, compared to ICE vehicles, maintenance

[464] Wikimedia Foundation, Inc. 2006. Golf cart. Available at http://en.wikipedia.org/wiki/Golf_cart [Accessed June 2006].
[465] Wikimedia Foundation, Inc. 2006. Golf cart. Available at http://en.wikipedia.org/wiki/Golf_cart [Accessed June 2006].

(charging) requirements, and weight.[466] Also, the performance of batteries may be reduced on uphill climbs, and they must be recycled at the end of their functional life.

Golf carts generally cost under $10,000. Pricing for a new golf cart begins at approximately $4,000 for the most basic model. More typically, golf carts cost between $6,000 and $9,000. Luxury models with extras such as upgraded upholstery, lights, and special wheels can cost upwards of $10,000. Because purchase prices are so high, leasing of golf carts is common; 75% to 90% of all new golf carts are leased instead of sold. Most commonly, leasing occurs through fleet rentals to golf courses. Golf carts are typically purchased, rather than leased, when they are for personal use.[467]

MARKET SIZE

Current data on the number of adopters in the golf cart market are provided below. Golf cart manufacturers (covered by SIC Code 3799) are represented in Table x-2. Table x-3 characterizes the recreational (i.e., golf-related, non-residential) user market for golf carts in the U.S.; this table includes public golf courses (SIC Code 7992); members-only golf, country, and other recreational clubs (SIC Code 7997); and small golf courses (pitch-and-putt) and driving ranges, as well as other recreational facilities (SIC Code 7999). Note that Table x-3 does not represent all recreational uses for golf carts, just those related directly to the sport of golf. In Tables x-2 and x-3, only those eight-digit SIC specialties related to the manufacturing or use of golf carts are shown.

Table x-2. Number of Golf Cart Manufacturers - Industry: Transportation Equipment, Nec (3799).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)*
3799-0204	Golf carts, powered	52	438	39.5
	Total	**52**	**438**	**39.5**

Sales figures are in millions. Source: www.zapdata.com, accessed June 2006.

[466] Cook, B. 1999. The Low-Speed EV Marketplace: Synopsis of Presentation Delivered at 1999 Non-Road Electric Vehicle Conference, Orlando, FL. Available at http://www.evworld.com/archives/conferences/epri99/bcook.html [Accessed June 2006].
[467] BuyerZone.com, Inc. 2006. Golf Carts Buyer's Guide: Utility vehicle and golf car pricing. Available at http://www.buyerzone.com/industrial/golf_carts/buyers_guide6.html [Accessed June 2006].

Table x-3. Number of Potential Golf Cart Users - Industries: Public Golf Courses (7992); Membership Sports and Recreation Clubs (7997); Amusement and Recreation, Nec (7999).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)*
7992-0000	Public golf courses	8,487	150,167	7,865.9
7997-9904	Country club, membership	3,543	143,905	10,270.1
7997-9906	Golf club, membership	3,080	83,928	3,935.7
7999-0200	Golf services and professionals	1,248	8,630	351.2
7999-0201	Golf cart, power, rental	89	676	37.1
7999-0202	Golf driving range	1,112	7,124	339.4
7999-0203	Golf professionals	270	1,838	73.2
7999-0204	Golf, pitch-n-putt	49	386	8.2
	Total	**17,878**	**396,654**	**22,881**

Note: Not all establishments have a specialty. Sales figures are in millions. Source: www.zapdata.com, accessed June 2006.

Sales of golf carts, which represented a large share of the market for personal mobility vehicles in 2002 (see Table x-4), are expected to increase through 2012. Demand for golf carts from 1992 to 2012 (projected) is presented in Table x-5. As Table x-5 also indicates, the number of golf courses in the U.S. is expected to grow through 2012.

Table x-4. Demand for Personal Mobility Devices by Type, 2002 (Total of $780 million).

Item	%
Golf Carts	55
Utility Vehicles	15
In-Plant Personnel Carriers	13
Commercial Vehicles	8
Other Products	9

Source: Adapted from The Freedonia Group, Inc. 2005. Power Lawn & Garden Equipment to 2009. Report #1903.

Table x-5. Demand for Golf Carts and Other Personal Mobility Devices, 1992-2012.[468]

Item	1992	1997	2002	2007	2012
Number of Golf Courses (000's)	14.4	16.1	17.5	19.5	21.5
Sales of Golf Carts Per Course ($000's)	14	21	25	29	35
Golf Cart Sales ($millions)	202	333	430	575	750
% of Golf Cart Sales (of total below)	56.0	56.3	55.1	53.5	52.6
Sales of Other Personal Mobility Devices ($millions)	361	592	780	1075	1425

Source: Adapted from The Freedonia Group, Inc. 2005. Power Lawn & Garden Equipment to 2009. Report #1903.

In order to assess the market size, it is necessary to consider how many golf courses are operational in the United States. According to the National Golf Foundation (NGF) there were 16,057 facilities containing at least one golf course as of December 31, 2004. The states with the most golf facilities include: Florida (1,073), California (925), Texas (857), Michigan (852), and New York (822). It is estimated that a total of 150.5 new 18-hole equivalents came online across the U.S. in 2004, suggesting a growth rate of approximately 1% per year. However, in that same year there were 990.5 18-hole equivalent golf courses in the construction pipeline.[469] No data

[468] The Freedonia Group, Inc. 2005. Power Lawn & Garden Equipment to 2009. Report #1903. Cleveland, OH, The Freedonia Group, Inc.

[469] National Golf Foundation. 2006. Questions/FAQ's. Available at http://www.ngf.org/cgi/whofaqa.asp? [Accessed May 2006].

were available on the average number of golf carts per course, but it is estimated that golf carts number in the tens at smaller golf courses, and can be in the hundreds for larger courses.

Limited data were found on the current market for residential golf cart users. However, at least one major golf cart manufacturer has noted recent growth in its market for private golf carts.[470]

The leading golf cart manufacturers are Club Car, Inc.; E-Z-Go (a Textron Company); Yamaha Golf Car Company; and Columbia ParCar Corp.

MARKET TRENDS

Although golf cart manufacturers still offer both gas and electric models, secondary research suggests that electric golf carts are gaining ground over gasoline-powered models, both in golf and residential applications. This may be attributable to the high costs of gasoline and the fact that electric models are quieter and less polluting than ICE models. New clean air standards have forced some localities to plan replacement of gas-powered golf cart fleets with electric models.[471] Residential subdivisions are seeking permission for their residents to operate electric golf carts on city streets,[472] and even some larger cities have reported increased neighborhood use of electric golf carts by their residents.[473]

In recent years, manufacturers have predicted a shift in the golf cart market away from gas vehicles and toward electric vehicles for various reasons, including increasingly stringent environmental standards (e.g., air emissions and hazardous material permitting requirements).[474]

There also appears to be a growing interest in developing alternative energy sources to supplement and work in conjunction with the batteries in electric carts. For example, companies have developed photovoltaic roof panels for golf carts, which keep the batteries charged and significantly extend battery life. PowerLight Corporation's SunCaddy solar electric systems were used on a fleet of 60 golf carts at the Francis H. I'i Brown golf course in Hawaii.[475]

Several companies have investigated the potential for fuel cells to be used in golf carts and other golf applications. Most notably, Astris Energi Inc., a Canadian R&D firm that focuses on alkaline fuel cells, recently developed its second fuel cell-powered golf cart prototype. This vehicle, known as the FII, has been converted to run on an alkaline fuel cell generator instead of batteries, making it lighter (by 170 lbs.) than the standard, battery-powered golf cart and allowing it to run for 3 days between hydrogen refills (compared to 8 to 10 hours between battery charges).[476] Humboldt State University's Schatz Energy Research Center (SERC)

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[470] Milicia, J. 2005. Golf carts traveling onto city streets. Las Vegas Sun (June 20, 2005). Available at http://www.lasvegassun.com/sunbin/stories/nat-gen/2005/jun/20/062005781.html [Accessed June 2006].
[471] Lee Enterprises. 2006. City approves budget for golf, bocce projects. The Napa Valley Register (January 2006). Available at http://www.napavalleyregister.com/articles/2006/01/19/news/briefing/iq_3260327.txt [Accessed June 2006].
[472] Piotraschke, J. 2005. Town board might allow golf carts on subdivision's streets. Greeley Tribune (November 4, 2005). Available at http://www.greeleytrib.com/article/20051104/NEWS/111040087 [Accessed June 2006].
[473] Milicia, J. 2005. Golf carts traveling onto city streets. Las Vegas Sun (June 20, 2005). Available at http://www.lasvegassun.com/sunbin/stories/nat-gen/2005/jun/20/062005781.html [Accessed June 2006].
[474] Golf Car Catalog. 2002. Todd Sauey, President & CEO of Par Car. Available at http://www.golfcarcatalog.com/index.cfm?fuseaction=archive&step=3&archive_id=19 [Accessed June 2006].
[475] Golf Press Association. 2002. Fleet of Solar-Powered Golf Cars Shine in Hawaii. The Wire. Available at http://www.golftransactions.com/equipment/suncaddy011702.html [Accessed June 2006].
[476] Astris Energi Inc. 2006. FII – Alkaline Fuel Cell (AFC) Powered Golf Car. Fact Sheet. Available at http://www.astris.ca/PR/pdf/Astris-FIIGolfCar.pdf [Accessed June 2006].

developed three golf carts powered by 4kW PEM fuel cells. These golf carts have been used in Palm Desert, California, since 1996.[477] Other golf-related fuel cell activities include a cooperative effort between residential developer WCI Communities and Florida Power & Light Company. These organizations collaborated on a project to install a stationary hydrogen fuel cell manufactured by Plug Power at a golf club in Venice, Florida. This fuel cell was used to help charge the club's golf carts.[478]

MARKET SEGMENT ANALYSIS

To identify the market opportunities for direct PEM fuel cells in golf carts, both manufacturers and users of these vehicles were contacted. Various contacts within four companies that manufacture golf carts were contacted, and two responses were received. Similarly, four golf courses and two industry groups also were contacted, and one response was received from an industry group representative. No golf courses responded.

The two golf cart manufacturers – one a small company and one medium-sized with a large parent company – offer electric and gasoline ICE-powered golf carts. The small manufacturer also produces ICE vehicles for industrial and commercial use.

The manufacturers indicated that all of their markets, particularly golf courses and industrial fabrication plants (for the manufacturer that produces industrial vehicles) are sensitive to downtime. The industry representative did not address downtime, as he was unaware of any such issues regarding golf carts.

Sparse information was obtained regarding O&M requirements. The small manufacturer indicated that maintenance was required every 2 weeks for batteries and every 4 weeks for other electric vehicle components, compared to a minimum of every 4 weeks for ICE-based products. The medium-sized manufacturer indicated that charging was the only O&M requirement for electric vehicles and did not address O&M requirements for ICE vehicles.

No real safety concerns were noted by respondents. The small manufacturer noted that batteries have the potential to explode but that such an event is extremely rare. No safety concerns related to ICE vehicles were reported.

In general, the manufacturers who responded appeared to be satisfied with the performance of batteries. One manufacturer praised their energy efficiency. Another manufacturer expressed concerns over ICE vehicles, noting that their performance and reliability lagged behind those of battery vehicles.

One manufacturer and an industry association representative were aware of the potential for fuel cells to be used as alternatives to existing power sources. The manufacturer was unable to comment on whether or not fuel cells were being evaluated by the company; however, the respondent noted that price and fuel availability were key issues when considering any energy

[477] Fuel Cells 2000. 2006. Fuel Cell Specialty Vehicles. Available at http://www.fuelcells.org/basics/fct/specialty.html [Accessed June 2006].

[478] WCI Communities, Inc. 2004. Golfers to drive the hydrogen highway. Available at http://wci.wcicommunities.com/?pageID=press_releases_detail&siteID=1000&vid=1000&CID=1081348271828 [Accessed June 2006].

source. The manufacturer also pointed out that golf courses buy anywhere from 50 to 350 golf carts at a time, so there is the potential for widespread use if the technology were to be made available. The industry association representative noted that a Canadian company had already developed a fuel cell-powered golf cart and that other alternative energy sources (e.g., solar power) were being investigated.

Regarding whether their customers would be concerned over the use of hydrogen as a fuel, neither manufacturer believed this would be a problem from a safety perspective. One manufacturer stressed the need for hydrogen to be accessible and inexpensive in order for customers to use it.

Both manufacturers expressed some interest in working with DOE to demonstrate PEM fuel cells; one was more interested in providing a vehicle to DOE for R&D than in forming an ongoing partnership. Both manufacturers also agreed to be contacted again.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

ICE-powered golf carts appear to be losing ground to electric golf carts in both recreational and residential environments, particularly in areas where air pollution and noise are a concern. Battery-powered models are currently widely used, and batteries are generally considered to be inexpensive, readily available, and reliable.

However, environmental and practical drivers lend support to the adoption of PEM fuel cells by golf cart manufacturers, which offer some of the same advantages of both battery-powered and ICE-powered golf carts. These drivers include:

- Need for exhaust-free vehicles, particularly in areas with strict emission laws (note that California is home to more golf courses than any other state but Florida)
- Need for quiet equipment, since many golf courses are built near residential communities with noise ordinances
- Customer desire for fuel source that is not as vulnerable to fluctuating oil prices as gasoline
- Superior acceleration and hill climbing abilities, compared to battery-powered golf carts[479]
- Refueling speed would equal that of gas-powered engines and be significantly faster than battery recharging
- Extended operation time over battery-powered vehicles.[480]

While longer runtimes between refueling/recharging are a potential advantage, it is not clear that this will be a strong selling point for fuel cells. As long as a battery charge holds throughout the day, recharging at night is not likely viewed as an inconvenience. Other potential barriers to fuel

[479] Astris Energi Inc. 2006. Astris Energi is Looking to Form Partnership to Integrate our MODEL E7 Battery Replacement Fuel Cell Generator into Utility Vehicle Applications. Available at http://www.fuelcellmarkets.com/article_default_view.fcm?articleid=12786&subsite=912 [Accessed June 2006].

[480] Astris Energi Inc. 2006. Astris Energi is Looking to Form Partnership to Integrate our MODEL E7 Battery Replacement Fuel Cell Generator into Utility Vehicle Applications. Available at http://www.fuelcellmarkets.com/article_default_view.fcm?articleid=12786&subsite=912 [Accessed June 2006].

cell use in golf carts include the high cost and difficulties associated with storage of hydrogen, as well as the lack of existing infrastructure for hydrogen refueling.

PEM fuel cells do not appear to be ready for near-term deployment in this market, but the market size, initial interest in hydrogen fuel cells and other power alternatives (e.g. solar cells), and performance advantages suggest that this may hold promise as a mid-term market if a cost-effective hydrogen refueling solution can be developed for golf course environments and if PEM fuel cells can be competitive with battery-powered electric vehicles.

RESEARCH SUMMARY:
SPECIALTY VEHICLES - LAWNMOWERS

MARKET SEGMENT DESCRIPTION

Lawnmowers are vehicles equipped with rotating blades designed to cut grass. This analysis focuses on powered lawnmowers, which include both walk-behind and riding models. Lawnmowers can be used in residential, commercial, and institutional environments. Typical locations in which lawnmowers are used include areas serviced by professional landscapers, such as golf courses, educational facilities, parks, athletic fields, country clubs, farms, ranches, and cemeteries, as well as private yards.

Mower designs vary greatly depending on application, though there are two basic classes of power mowers: walk-behind and ride-on models. Lawnmowers designed for commercial use on golf courses, athletic fields, or other large properties are typically ride-on units with multiple blade attachments that cover a wide expanse of grass and are dragged behind or pushed in front of the vehicle. Front-engine and rear-engine riding mowers (referring to the position of the engine in relation to the driver) are available. Lawnmowers designed to be used in small yards and residential environments are typically walk-behind push mowers with a 21”-wide cutting area. Self-propelled push mowers can be either front-wheel or rear-wheel driven. Table y-1 identifies the SIC and NAICS classifications that cover manufacturing of lawnmowers.

Table y-1. SIC and NAICS Codes for Lawnmower Manufacturing.

2-Digit SIC Code	35 – Industrial and commercial machinery and computer equipment
4-Digit SIC Codes	3523 – Farm machinery and equipment 3524 – Lawn and garden tractors and home lawn and garden equipment
NAICS Codes	333111 – Farm machinery and equipment manufacturing 333112 – Lawn and garden tractor and home lawn and garden equipment manufacturing

Lawnmowers are available with several different power sources, including ICEs and batteries. ICE-powered models are fueled by gasoline, diesel, or propane. Propane is a recent addition to the lawnmower market; the clean-burning fuel is being marketed as an environmentally friendly alternative to diesel and gasoline. Some operators report that propane-powered mowers are more powerful than identical gasoline units. Dixie Chopper, which manufactures 30 to 54 HP (22.4 to 40.3 kW) propane models for commercial use, expects to sell between 500 and 1,000 units in 2006.[481]

Some manufacturers are producing both corded and cordless electric models in an effort to avoid the noise and emissions associated with fossil fuel-powered mowers. The cordless mowers, which are usually walk-behind push models suited for use in small areas, typically run on 24V of electric power (configured as one 24V or two 12V batteries). Corded electric mowers are driven by electric motors ranging in power from 6 to 12 amps. Jacobsen Golf and Turf has developed

[481] Guyette, J.E. 2006. Grounds pros claim that alternative-fuel commercial mowers have power and big potential. Landscape Management. Available at http://www.landscapemanagement.net/landscape/article/articleDetail.jsp?id=317568&pageID=1&sk=&date= [Accessed May 2006].

an electric riding mower for use on golf courses. The E-Plex™ II runs on a 3.5 HP (2.6 kW), 48V electric motor powered by six 8V batteries.[482]

In general, walk-behind mowers (both commercial and residential) are powered by smaller engines (typically < 20 HP/14.9 kW) than riding mowers. Residential walk-behind mowers with 21" mowing decks tend to have the smallest engines (< 10 HP/7.5 kW). Commercial walk-behind mowers often have wider mowing decks than residential mowers; these decks range from 21" to 60" or wider. The engines of commercial walk-behind mowers tend to be greater than 10 HP (7.5 kW) but still less than 20 HP (14.9 kW). As indicated above, electric walk-behind mowers, such as those manufactured by Sunlawn, Black and Decker, and Neuton, are typically powered by 24V, rechargeable batteries. However, a 48V, 3.5 HP (2.6 kW) electric riding mower is also on the market.

Riding mowers vary greatly in size and shape and are powered by a wide range of engines. The mowing decks on riding mowers are significantly larger than the 21" decks used in walk-behind models; large commercial riders can use multiple decks capable of covering an expansive surface. Residential riding mowers are typically powered by engines smaller than 25 HP/18.6 kW (most often < 15 HP/11.2 kW). Commercial riding mowers can be powered by smaller (< 25 HP/18.6 kW) engines, but typically they have medium-sized (25 to 50 HP/18.6 to 37.3 kW) engines. Wide-area, multi-deck mowers used on athletic fields and golf courses can have engines that exceed 50 HP (37.3 kW).

Residential mowers are available in a wide range of prices, as evidenced by a review of models available for sale online. The most basic 21" walk-behind mowers can be purchased for approximately $170, while high-end models cost over $800. Residential zero turning radius mowers range from about $2,000 to more than $5,000. Residential lawn and garden tractors range from $1,500 to over $7,000.

Commercial mowers can be significantly more expensive than residential units. A review of commercial-grade 21" walk-behind mowers available for sale online identified models ranging from $700 to nearly $1,200. A report on zero turning radius mowers indicated that small (48") commercial models start at $4,000 to $5,000. The bulk of the commercial market is sized between 52" and 61"; these models typically have 20 to 30 HP gasoline engines and sell for $7,000 to $9,000. Heavier duty, water-cooled diesel greens mowers with 72" decks typically cost between $10,000 and $12,000, though even more expensive models are available.[483]

MARKET SIZE

Current data on the size of the lawnmower manufacturing market are provided below. Table y-2 includes SIC Code 3524, which covers manufacturing of residential mowers, and SIC Code 3523, which covers manufacturing of commercial mowers. Note that the categories of "Lawn and garden tractors and equipment," "Turf and grounds equipment," and "Turf equipment, commercial" may include other types of equipment in addition to mowers. Only those eight-

[482] Jacobsen Golf & Turf. 2006. E-Plex™ II. Available at http://www.jacobsengolf.com/products/riding_greens_mowers/e-plex_ii/ [Accessed June 2006].
[483] Parish, D. 2005. Zero Turning Radius Mowers: Selection, Use, Maintenance & Safety. Louisiana State University Agricultural Center, Pub. 2911. Available at http://www.agctr.lsu.edu/NR/rdonlyres/67A1DFB8-8597-467C-AD55-5D66F71B0861/12414/pub2911ZeroTurnMowers2.pdf [Accessed June 2006].

digit SIC Code specialties relevant to residential and commercial lawnmower manufacturing are shown.

Table y-3 characterizes the expansive user market for lawnmowers (based on the number of adopters), which is comprised of golf courses and other recreational fields that might require turf or grass maintenance; amusement parks, zoos, and other tourist attractions that may include grassy areas; cemeteries; and commercial landscapers or lawn-care professionals. Note that residential users of lawnmowers, who constitute a significant segment of the market, are not included in this table. Included in Table y-3 are public golf courses (SIC Code 7992); members-only golf, country, and other recreational clubs (SIC Code 7997); small golf courses (pitch-and-putt) and driving ranges, as well as other recreational facilities (SIC Code 7999); amusement parks (SIC Code 7996); cemeteries (SIC Code 6553); athletic fields (SIC Code 7941); zoos and botanical gardens (SIC Code 8422); and lawn and garden services (SIC Code 0782). Within this table, only those eight-code SIC specialties deemed likely to require grounds or greens maintenance are shown.

Table y-2. Number of Lawnmower Manufacturers - Industries: Lawn and Garden Equipment (3524); Farm Machinery and Equipment (3523).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)*
3524-0100	Lawn and garden tractors and equipment	43	1,256	1,131.5
3524-0200	Lawn and garden mowers and accessories	93	2,065	242.8
3524-0201	Grass catchers, lawn mower	28	230	12.4
3524-0202	Lawnmowers, residential: hand or power	58	4,993	131.8
3523-0500	Turf and grounds equipment	53	1,216	152.8
3523-0501	Greens mowing equipment	7	121	9.9
3523-0502	Grounds mowing equipment	30	1,720	412.1
3523-0503	Turf equipment, commercial	29	405	35.9
	Total	**341**	**12,006**	**2,129**

Sales figures are in millions. Source: www.zapdata.com, accessed May 2006.

Table y-3. Potential Users of Lawnmowers - Industries: Public Golf Courses (7992); Membership Sports and Recreation Clubs (7997); Amusement and Recreation, Nec (7999); Amusement Parks (7996); Cemetery Subdividers and Developers (6553); Sports Clubs, Managers, and Promoters (7941); Botanical and Zoological Gardens (8422); Lawn and Garden Services (0782).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)*
7992-0000	Public golf courses	8,487	150,167	7,865.9
7997-0400	Outdoor field clubs	874	3,797	124.4
7997-0401	Baseball club, except professional and semi-professional	969	5,496	185.9
7997-0402	Football club, except professional and semi-professional	67	475	14.7
7997-0403	Polo club, membership	25	160	4.5
7997-0404	Soccer club, except professional and semi-professional	417	1,933	86.7
7997-9904	Country club, membership	3,543	143,905	10,270.1
7997-9905	Flying field, maintained by aviation clubs	44	226	8.8
7997-9906	Golf club, membership	3,080	83,928	3,935.7
7997-9907	Lawn bowling club, membership	13	194	5.6
7997-9908	Riding club, membership	114	857	28.1
7999-0200	Golf services and professionals	1,248	8,630	351.2
7999-0202	Golf driving range	1,112	7,124	339.4
7999-0203	Golf professionals	270	1,838	73.2
7999-0204	Golf, pitch-n-putt	49	386	8.2
7999-0704	Skeet shooting facility	26	159	4.9
7999-0705	Trapshooting facility, non-membership	11	54	2
7999-1100	Instruction schools, camps, and services	1,405	5,869	210
7999-1102	Baseball instruction school	290	1,742	45.9
7999-1106	Day camp	391	4,814	157.4
7999-1515	Zoological garden, commercial	156	3,664	179
7999-9909	Picnic ground operation	142	1,794	58.7
7999-9910	Recreation center	3,972	40,022	923.5
7996-0000	Amusement parks	1,186	22,069	1,690.1
7996-9901	Kiddie park	160	2,476	86.9
7996-9903	Theme park, amusement	271	85,767	10,962.2
6553-0000	Cemetery subdividers and developers	4,620	24,173	605
6553-9901	Animal cemetery operation	130	648	22.8
6553-9902	Cemeteries, real estate operation	1,559	15,762	777
6553-9903	Cemetery association	684	6,140	339.4
6553-9905	Real property subdividers and developers, cemetery lots only	312	2,842	387.1
7941-0000	Sports clubs, managers, and promoters	1,256	11,512	1,214.8
7941-0100	Professional and semi-professional sports clubs	138	1,622	225.6
7941-0101	Baseball club, professional and semi-professional	385	11,494	1,719.8
7941-0102	Basketball club	235	3,784	876.4
7941-0103	Football club	641	8,005	1,837.8
7941-0105	Soccer club	805	4,483	476.7
7941-0200	Stadium event operator services	180	4,386	434.5
7941-0202	Sports field or stadium operator, promoting sports events	391	8,696	661.5
8422-0000	Botanical and zoological gardens	157	3,864	243.6
8422-0100	Aquariums and zoological gardens	41	1,520	90.7
8422-0103	Zoological garden, noncommercial	81	6,695	559.9
8422-0200	Arboreta and botanical gardens	16	322	12.3
8422-0201	Arboretum	56	1,010	116.3
8422-0202	Botanical garden	233	4,630	436.8

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)*
0782-0000	Lawn and garden services	18,989	69,694	2,513.7
0782-0200	Lawn services	8,433	36,115	1,397.2
0782-0201	Cemetery upkeep services	152	799	27.7
0782-0203	Lawn care services	23,722	70,428	6,091
0782-0204	Mowing services, lawn	1,911	4,275	154.7
0782-0210	Turf installation services, except artificial	639	1,719	66.1
0782-9902	Highway lawn and garden maintenance services	348	2,988	165
0782-9903	Landscape contractors	27,715	182,335	8,777
	Total	**122,151**	**1,067,487**	**67,853**

Note: Not all establishments have a specialty. Sales figures are in millions. Source: www.zapdata.com, accessed June 2006.

A recent market report estimated that the U.S. demand for power lawn and garden equipment, including lawnmowers, will increase by 3.1% each year from 2005 through 2009, when the market size will reach $10.7 billion.[484] Lawnmowers are expected to remain the dominant product group within this industry, due to their widespread use in both residential and commercial applications. Analysts attribute this growth to an expansion of the 55 to 64-year-old age group, which tends to replace older lawn and garden equipment with more expensive products and to hire professional lawn care services. Product innovations and upgrades, driven by consumer demand for lighter and more powerful equipment, are also expected to encourage growth.

Residential equipment dominates the lawn and garden industry, accounting for two-thirds of total sales in 2004.[485] However, commercial sales have outpaced residential sales in recent years, in part due to extensive growth in sales of zero-degree turning radius turf mowers to both commercial and residential consumers. The commercial market is expected to continue growing, stimulated by a sustained rise in the number of landscaping professionals.

Each year, the Outdoor Power Equipment Institute (OPEI) forecasts industry trends based on an econometric model. For the 2006 model year (running from September 2005 to August 2006), OPEI predicts that sales of consumer walk-behind mowers will fall 3.0% to 6.2 million units, while consumer riding mowers are predicted to decline by 2.0% to just under 1.9 million units. OPEI also predicts that commercial turf care walk-behinds will decline slightly and that commercial riders will grow by only 1.1%. According to OPEI, "commercial products combined will close the year at a level slightly above 242,000 units."[486] Table y-4 illustrates OPEI's forecast for the 2006 model year.

[484] The Freedonia Group, Inc. 2005. Power Lawn & Garden Equipment to 2009. Report #1903. Cleveland, OH, The Freedonia Group, Inc.
[485] The Freedonia Group, Inc. 2005. Power Lawn & Garden Equipment to 2009. Report #1903. Cleveland, OH, The Freedonia Group, Inc.
[486] Outdoor Power Equipment Institute. 2006. OPEI May 2006 Forecast Press Release for Consumer and Commercial Products. Available at http://www.opei.org/newsroom/docs/56_May%202006%20Consumer%20%20Commercial%20Forecast.pdf [Accessed May 2006].

Table y-4. OPEI Predictions for Model Year 2006 – Outdoor Power Equipment Forecast.

Annual Unit Shipment Growth					
	FY2002	FY2003	FY2004	FY2005	FORECAST FY2006
Consumer Products					
Walk-Behind Powered Mowers	5.2%	3.6%	6.3%	-1.8%	-3.0%
All Riding Units	6.1%	11.1%	10.6%	-4.4%	-2.0%
Commercial Turf Care Products					
Intermediate Walkers	-9.7%	-9.2%	12.0%	-15.3%	-0.8%
Riding Mowers	1.6%	25.3%	38.9%	0.1%	1.1%

Source: Adapted from OPEI, 2006.

Also relevant to the lawnmower industry are forecasts associated with lawnmower user markets. For example, the Freedonia Group estimated that the number of golf courses in the U.S. would increase from 14,400 in 1992 to 21,500 in 2012 (See Table y-5).[487]

Table y-5. Number of Golf Courses in the United States through 2012.

	1992	1997	2002	2007	2012
Golf Courses (000's)	14.4	16.1	17.5	19.5	21.5

Source: Adapted from Freedonia Group Inc. 2003. Wheelchairs & Other Personal Mobility Devices to 2007. Report Number #1745.

Major lawnmower manufacturers include Electrolux North America, Inc.; The Toro Company; John Deere; MTD Products; Black and Decker; American Honda Power Equipment; Snapper Pro; and Murray Outdoor Power Equipment.

MARKET TRENDS

Evidence indicates that turf maintenance professionals are seeking alternatives to ICE-powered mowers in an attempt to address customers' concerns: namely, noise and hydraulic oil leaks. For example, the superintendent of a golf resort in Florida began using an electric greens mower after receiving complaints on a nearly daily basis from guests at the resort about the noise generated by early-morning mowing.[488] Also, the tendency of large greens mowers and tractors to leak hydraulic fluid and damage turf is a well-recognized problem within the industry.[489]

The Toro Company has developed two working prototypes powered by PEM fuel cells.[490] Toro has worked with at least three fuel cell developers (Nuvera, Hydrogenics, and Metallic Power) in evaluating the performance of fuel cell modules in mowing equipment. Nuvera supplied Toro with a hydrogen power module from its H2e (hydrogen to electricity) line of small-scale fuel cell stacks, which are capable of providing between 1 and 6 kW of electric power.[491] In 2004, Toro awarded a contract to Hydrogenics to supply a PEM fuel cell module for integration into a

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[487] The Freedonia Group Inc. 2003. Wheelchairs & Other Personal Mobility Devices to 2007. Report #1745. Cleveland, OH, The Freedonia Group, Inc.
[488] Jacobsen Golf & Turf. 2006. Case Studies: Quiet Please: Jacobsen E-Plex Works Peacefully. Available at http://www.jacobsengolf.com/resources/case_studies/eplex_peacefully.html [Accessed June 2006].
[489] Bevard, D.S. 2002. After the Spill. Grounds Maintenance. Available at http://grounds-mag.com/mag/grounds_maintenance_spill/index.html [Accessed June 2006].
[490] Personal Communication between Jennifer Zewatsky (Battelle) and Jack Gust (The Toro Company), May 17, 2006.
[491] BioAge Group, LLC. 2004. Toro Evaluating Nuvera Fuel Cell. Available at http://www.greencarcongress.com/2004/11/toro_evaluating.html [Accessed June 2006].

prototype greens mower.[492] Hydrogenics' PEM fuel cell modules are capable of output ranging from 8 kW to 65 kW.[493] Metallic Power demonstrated a Toro greens mower powered by a 2 kW regenerative zinc/air fuel cell system at a South Coast Air Quality Management District meeting in October of 2001.[494] Toro's mowers are still in development and will not be commercially available for some time. At the earliest, they may be ready for commercial production by 2009 or 2010, depending on the availability and costs of hydrogen fuel, as well as the ability of engineers to protect fuel cells from the effects of outdoor storage.[495]

Mower manufacturers are not the only organizations that have investigated the use of hydrogen fuel and PEM fuel cells in mowing equipment. Hocking College in Nelsonville, Ohio, recently unveiled a project to develop a hydrogen-powered lawn tractor through its International Fuel Cell and Alternative Energy Training Center.[496] Energy Conversion Devices, Inc., a materials research and product development company, developed a prototype hydrogen-powered, walk-behind lawnmower with a 3 kW power output.[497] The Danish Technological Institute developed a lawnmower that runs on a PEM fuel cell.[498]

MARKET SEGMENT ANALYSIS

To identify the market opportunities for direct PEM fuel cells, both manufacturers and users of lawnmowers were contacted. Eight manufacturers were contacted, and three responses were received. Four golf courses (identified as key users of lawnmowers) and two golf industry groups were contacted, and one response was received from an industry group representative. No user responses were received.

Manufacturer respondents included one small and one medium commercial mower manufacturer, as well as one large provider of outdoor landscaping products and equipment. All of the manufacturers offer both riding and walk-behind mowers. Two focus on commercial equipment, while the third sells both residential and commercial-grade mowers. All three manufacturers offer diesel and gasoline-fueled ICE lawnmowers. One small company is developing a propane-fueled ICE mower, and a medium-sized manufacturer is developing an electric mower.

Unscheduled downtime was identified by two manufacturers as a major problem for professional landscapers. One small manufacturer offers a loaner program to alleviate the potential impact of downtime for its professional customers.

Manufacturers commented on the O&M requirements for ICE-based equipment only. All three indicated that regular oil and filter (both oil and air) changes were necessary. One manufacturer

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[492] Fuel Cell Works. 2004. Hydrogenics Awarded Contract by the Toro Company to Provide HyPM Technology for Fuel Cell Program. Available at http://www.fuelcellsworks.com/Supppage1092.html [Accessed June 2006].
[493] Hydrogenics Corporation. 2006. HyPM® Family – Fuel Cell Power Products. Available at http://www.hydrogenics.com/power/products.asp [Accessed June 2006].
[494] Metallic Power. 2001. Metallic Power Delivers Zinc/Air Fuel Cell Prototypes for Air Quality Management District Contract. Available at http://www.ewire.com/display.cfm/Wire_ID/775 [Accessed June 2006].
[495] Personal Communication between Jennifer Zewatsky (Battelle) and Jack Gust (The Toro Company), May 2006.
[496] Ohio Fuel Cell Coalition. 2006. Events. Available at http://www.fuelcellsohio.org/events.html [Accessed June 2, 2006].
[497] Sapru, K. 2003. Keeping it Clean: Congressional Briefing on Renewably Derived Hydrogen Capitol Bldg, June 3, 2003. Available at http://www.eesi.org/briefings/2003/EnergyandClimate/6.3.03%20Renewable%20Hydrogen/RH2.Sapru.pdf [Accessed June 2006].
[498] Danish Technological Institute. 2006. Hydrogen-powered Lawnmower. Available at http://www.danishtechnology.dk/energy/16319 [Accessed June 2006].

noted that oil changes are required approximately every 50 hours, and air filter changes are required frequently in dusty environments. Another respondent noted that liquid-cooled ICEs require filling the radiator with water in the summer and anti-freeze in the winter.

Several safety concerns were associated with ICE-based lawnmowers. Two manufacturers noted the potential for burns from the vehicle's exhaust system, which gets extremely hot. One respondent indicated that running a lawnmower indoors (e.g., in a maintenance shop) can result in carbon monoxide buildup. Another noted the potential for maintenance workers to injure their hands in the machines' rotating belts and pulleys.

All three manufacturers indicated that they are happy with ICEs in their lawnmower products. However, one medium-sized manufacturer noted that battery-powered electric vehicles may represent the future of the industry, as fossil fuels become more scarce and expensive. Therefore, his company is trying to lead the industry by investigating battery-powered lawnmowers. A small manufacturer predicted that the market for alternatively fueled lawnmowers will grow, since many cities restrict the use of diesel or gasoline-powered equipment on "ozone alert" days. Such restrictions can result in a tremendous loss of income for landscapers. This has prompted the manufacturer to investigate propane ICEs.

Two of the three manufacturers were aware of PEM fuel cells as alternatives to existing power sources. Of those two, one has already begun developing a PEM fuel cell-powered prototype mower; the other does not consider fuel cells to be economically feasible in the near-term. Two of the three manufacturers evaluate new power sources based on their ability to perform as well as their compatibility with existing systems in various environments. The third manufacturer noted the importance of identifying a quiet, leak-free power source that accommodates the weight restrictions associated with turf vehicles. This manufacturer compared the performance of alternative energy sources (batteries and fuel cells) and determined PEM fuel cells to be the most attractive mobile option. Echoing their responses to an earlier question, two manufacturers identified performance equal to ICE-powered equipment as the most important factor in selecting a new power source. The third manufacturer again stressed the importance of quiet, leak-free vehicles, noting that the hydraulic oil used in ICE vehicles can leak and kill grass and that mowers must often be used in or near communities with noise ordinances. One respondent indicated that PEM fuel cells will be a viable replacement for his company's products, while another suggested that it was possible.

Several barriers to fuel cell use in lawnmowers were identified. One manufacturer cited the cost of fuel cells and lack of refueling infrastructure. Another reiterated the fact that turf maintenance products are weight-limited. He noted that even though hydrogen is light, the tanks used to store it are heavy and bulky. The issue of securing enough on-board hydrogen without adding excess weight is a problem. A large manufacturer predicted that a fuel cell-powered mower could be introduced commercially by 2009 or 2010, at the earliest; however, this would almost entirely depend on the availability and cost of hydrogen fuel, as well as the ability of fuel cell vehicles to withstand outdoor storage in extremely low temperatures. No respondents felt that their customers would have concerns with using hydrogen from a safety perspective.

One large manufacturer addressed drivers for fuel cell use. This respondent cited a need to eliminate noise and the potential for hydraulic oil leaks from ICE-powered mowers. He added that the potential for greater reliability, ease of troubleshooting, and reduced maintenance could drive the adoption of fuel cell-based products.

One small manufacturer expressed interest in working with the DOE to develop fuel cell-based products; the other two manufacturers were open to the possibility but could not respond unequivocally at this time.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

Environmental and practical drivers support transition away from standard gasoline-powered ICE engines in the lawnmower market. These drivers include:

- Need for alternative fuels in regions concerned with ozone emissions (gas or diesel-powered equipment cannot be used on days when the ozone level is high)
- Need for quiet equipment, since many golf courses are built near residential communities with noise ordinances
- Need to eliminate the potential for hydraulic oil leaks from ICE-powered motors (oil kills grass)
- Need for greater reliability and reduced maintenance compared to ICE-powered machines.

Propane fuel addresses some of the emissions concerns, and electric mowers can effectively address most of these needs in small power applications; however, batteries are not yet widely employed in larger riding mower applications. These larger applications may present an opportunity for PEM fuel cell use in lawn mowers.

While PEM fuel cells could potentially meet these needs, several potential barriers to market entry would need to be addressed, including:

- Cost of hydrogen
- Lack of existing infrastructure for refueling, although for niche markets (e.g. golf courses, lawn service companies, and others that may have centralized refueling facilities) this may be less of an issue
- Bulkiness and weight of hydrogen tanks, particularly for turf vehicles which are weight limited
- Tendency of water produced by fuel cells to freeze if equipment is stored outdoors in low temperatures, which is a particular concern for commercial fleets
- Lack of confidence on the part of consumers in alternatives to ICE-powered mowers.

Considering these barriers to market entry and the expected timeframe for deployment of fuel cell technology in lawnmowers, this is not considered a likely near-term market for PEM fuel cells. However, the fact that battery-powered electric vehicles are not currently meeting the larger, commercial-scale applications, may open the door for fuel cells in the mid to longer term.

RESEARCH SUMMARY:
SPECIALTY VEHICLES – MINING

MARKET SEGMENT DESCRIPTION

Companies in this market segment use specialty vehicles to perform various functions in underground mines, such as loading and moving materials or transporting personnel. While specialty vehicles are also used for surface mining functions, the target market for this analysis is subsurface applications where emissions from ICEs pose health and safety risks. Mining segments that engage in subsurface extraction of minerals include:

- Coal Mining & Processing
- Copper Mining & Processing
- Diamond & Other Precious Stone Mining
- Precious Metals Mining & Processing (e.g., gold and silver ores)
- Industrial Metals & Minerals (e.g., iron, lead, zinc, and miscellaneous metal ores such as platinum ore).

Table z-1 identifies the SIC and NAICS classifications that represent mining segments involved in the subsurface extraction of minerals.

Table z-1. SIC and NAICS Codes for Coal and Metal Mining.

2-Digit SIC Code	12 – Coal mining
4-Digit SIC Codes	1222 – Bituminous coal underground mining
	1231 – Anthracite mining (hard coal)
	1241 – Coal mining services
NAICS Codes	21211 – Coal mining
	212112 – Bituminous coal underground mining
2-Digit SIC Code	10 – Metal mining
4-Digit SIC Codes	1011 – Iron ores
	1021 – Copper ores
	1031 – Lead and zinc ores
	1041 – Gold ores
	1044 – Silver ores
	1061 – Ferroalloy ores, except vanadium
	1081 – Metal mining services
	1094 – Uranium-radium-vanadium ores
	1099 – Miscellaneous metal ores, nec (includes platinum)
NAICS Codes	212210 – Iron ore mining
	212234 – Copper ore and nickel ore mining
	212231 – Lead ore and zinc ore mining
	212221 – Gold ore mining
	212222 – Silver ore mining
	213114 – Support activities for metal mining
	212291 – Uranium-radium-vanadium ore mining
	212299 – All other metal ore mining

Table z-2 identifies the SIC and NAICS Codes that cover manufacturing of underground mining vehicles.

Table z-2. SIC and NAICS Codes for Manufacturing of Underground Mining Vehicles.

2-Digit SIC Code	35 – Industrial and commercial machinery and computer equipment
4-Digit SIC Code	3532 – Mining machinery & equipment, except oil and gas field machinery & equipment
NAICS Code	333131 – Mining machinery and equipment manufacturing

Underground mining vehicles are used for loading and moving materials and transporting personnel. Many of the vehicles used to move materials are classified as underground load-haul-dump (LHD) vehicles. The major equipment categories that could be compatible with a fuel cell power plant are described below:

- **Shuttle cars** – A shuttle car is either a conveyer or mine car that uses rubber tires or continuous treads to transfer coal, ore, or other materials from loading machines in trackless areas of a mine to the main transportation system. Shuttle cars are estimated to require 50 to 80 HP. Underground mines typically have 2 to 3 shuttle cars.
- **Utility vehicles, personnel carriers, or mantrip** – These vehicles carry mine personnel, by rail or rubber tire, to and from the work area. They vary widely by size, structure (e.g., 3 or 4 wheels), and capacity. A case study of a moderate-sized mine had two 6-passenger carriers at 57 HP each, with an average operation of 1,500 hours per year each.[499]
- **Underground loaders** – An underground loader is a mechanical shovel or other machine that is used for loading coal, ore, mineral, or rock. A case study showed that a moderate-sized mine had three 277 HP LHD vehicles, and five 231 HP LHD vehicles, each of which operated an average of 3,500 hours per year.[500]
    - **Shaker-shovel loader** – A machine for loading coal, ore, or rock usually in headings or tunnels. It consists of a wide flat shovel that is forced into the loose material along the floor by the forward motion of the conveyor. The shaking motion of the conveyor brings the material backwards, and it is loaded into cars or a conveyor.
    - **Scraper loader** – A machine used for loading coal, rock, or ore by pulling an open-bottomed scoop back and forth between the face and the loading point and loading it into mine cars or onto a conveyor in an underground mine.
    - **Cutter loader** – A longwall machine that cuts and loads coal onto a conveyor as it travels across the face.
    - **Gathering arm loader** – A machine for loading loose rock or coal. It has a tractor-mounted chassis, carrying a chain conveyor, the front end of which is built into a wedge-shaped blade. Mounted on this blade are two arms, one on either side of the chain conveyor, which gather the material from the muck pile and feed it onto the loader conveyor. The tail or back end of the conveyor is designed to swivel and elevate hydraulically so that the coal or stone can be loaded into a car or onto another conveyor.

[499] Bickel, K., J. McDonald, J. Fruin, and D. Tiffany. 1997. Economic Comparison of Biodiesel Blends to Commercially Available Exhaust Emission Reduction Technologies for Underground Mines. Final Report to the National Biodiesel Board.
[500] Bickel, K., J. McDonald, J. Fruin, and D. Tiffany. 1997. Economic Comparison of Biodiesel Blends to Commercially Available Exhaust Emission Reduction Technologies for Underground Mines. Final Report to the National Biodiesel Board.

- **Locomotives** – An electric engine, operating either from current supplied by trolley and track or from storage batteries carried on the locomotive. The locomotive may be powered by battery, diesel, compressed air, trolley, or some combination thereof, such as battery-trolley or trolley-cable reel. Locomotives are used to move empty and loaded mine cars in and out of a mine, and to move personnel in specially designed "mantrip" cars. A leading locomotive manufacturer offers 6-ton (15 kW, 84V 42 cell battery), 10-ton (42 kW, 120V 60 cell battery), and 15-ton (90 kW with overhead line 250V DC) systems.
- **Roof bolter** – Used to install roof support bolts, primarily in underground coal mines. A model produced by DBT (LRB-15AR) has a single 40 HP (30 kW) primary drive motor, but others as big as 82 HP were identified for this analysis. A University of Minnesota case study indicates that these operate approximately 3,000 hours year.[501]
- **Forklifts** – Some mines use forklifts for surface and underground applications. The mine cited in the University of Minnesota case study above utilized one 82 HP forklift that operated 1,600 hours per year.

Power sources currently used in mining vehicles include the following:

- **Battery-powered electric vehicles** – Batteries are used primarily in underground applications where emissions from diesel-powered vehicles pose a problem. One limitation of battery power is that energy capacity is insufficient for hard rock mining.
- **Diesel-powered vehicles** – These vehicles have power density for high productivity, but emissions regulations and health and safety issues are limiting factors. Ventilation costs for underground mines are significant, representing an estimated 40% of power costs at a mine.[502] Diesel power also generates noise and heat.
- **Cable-tethered vehicles** – Tethered cables that supply electric power to vehicles (e.g., shuttle cars) from a power source outside of the mine are also frequently used in underground mining. In some cases they are remotely controlled. They are power-dense and emissions free, but the tether causes some safety concerns and can limit the operation range of the equipment.

Table z-3 presents estimated costs for underground mining utility vehicles and personnel carriers. Diesel vehicles cost more than battery-powered vehicles by as much as 45%. For instance, a 14-person diesel carrier costs $40,000 while the price of a 14-person battery-powered vehicle is $22,000. However, this does not consider the costs of operation and maintenance or accessories.

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[501] Bickel, K., J. McDonald, J. Fruin, and D. Tiffany. 1997. Economic Comparison of Biodiesel Blends to Commercially Available Exhaust Emission Reduction Technologies for Underground Mines. Final Report to the National Biodiesel Board.
[502] Betournay, M.C and M. Laflamme. 2006. Current Development and Future Opportunities of the Fuel Cell Mining Initiative. Presented at the 2005 CIM Annual General Meeting, Toronto, Canada, April 25, 2006. Available at http://www.mining.ca/www/media_lib/TSM_Presentations/cimcanmet.pdf [Accessed December 2006].

Table z-3. Cost Estimates for Underground Mining Utility Vehicle/Personnel Carriers.

Model	Payload	Power Source	Price
Industrial Lil'Mac	2-person	Battery	$9,000
Lil Mac 3-4 Wheeler	2-person	Battery	$7-8,000
Mac 8	14 person	Battery	$22,000
Mac XP	3 person	Battery	$28,000
Mac 2D	4-5 person	Diesel	$35,000
Mac 3D	4-5 person	Diesel	$35,000
Mac 8D	12 person	Diesel	$38,000
Mac 10D	14 person	Diesel	$40,000

Source: Damascus Corporation, http://www.damascuscorp.com/vehicles.html. Prices provided by personal communication between Heidi Mahy (Battelle) and sales representative at Damascus on June 30, 2006.

MARKET SIZE

For this analysis, no comprehensive source of information was found that describes the market size for specific types of underground mining vehicles in the U.S. Information was available for: 1) overall mining industry size for each mineral involved in underground mining, 2) total underground mining equipment sales, and 3) the number of diesel vehicles currently used in the coal mining industry.

Mining Industry Size

Table z-4 characterizes the underground coal mining market in terms of number of businesses, number of employees, and sales volume. Of the various coal types mined in the U.S., bituminous coal dominates the underground coal mining market. Table z-5 presents the number of businesses, by state, engaged in underground coal mining. Geographically, the greatest amount of underground coal mining activity occurs in the states of Kentucky, West Virginia, Pennsylvania, and Virginia.

Table z-4. Number of Businesses in Underground Coal Mining Industry (1222).[503]

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)
1222-0000	Bituminous coal-underground mining	268	17,320	15,878
1222-9901	Underground mining, semianthracite	1	100	12.8
1222-9902	Underground mining, semibituminous	6	113	165.5
1222-9903	Underground mining, subbituminous	12	1,489	233.6
	Total	**287**	**19,022**	**16,289.9**

Sales figures are in millions.

[503] Dun and Bradstreet. 2006. Zapdata industry report. Available at www.zapdata.com [Accessed May 2006].

Table z-5. Market Analysis by State: Underground Coal Mining.[504]

State	# Businesses	% Total
Total	**287**	**100**
Kentucky	79	27.5
West Virginia	58	20.2
Pennsylvania	48	16.7
Virginia	21	7.3
Ohio	12	4.2
Tennessee	12	4.2
Alabama	7	2.4
Illinois	7	2.4
Indiana	6	2.1
Utah	6	2.1
Colorado	4	1.4
Maryland	4	1.4
Nevada	4	1.4
Wyoming	3	1
Montana	2	0.7
Oklahoma	2	0.7
Arizona	1	0.3
California	1	0.3
Delaware	1	0.3
Georgia	1	0.3
Missouri	1	0.3
New Mexico	1	0.3
New York	1	0.3
North Dakota	1	0.3
South Dakota	1	0.3
Texas	1	0.3
Washington	1	0.3
Puerto Rico	1	0.3

Table z-6 presents market data for various mining segments involved in the subsurface extraction of minerals, excluding coal mining. The total number of businesses engaged in these mining segments is approximately one-half the number engaged in underground coal mining, and total sales are approximately one-third of sales generated from underground coal mining. In Table z-6, only those eight-digit SIC specialties related to mining are shown.

[504] Dun and Bradstreet. 2006. Zapdata industry report. Available at www.zapdata.com [Accessed May 2006].

Table z-6. Number of Businesses by Mining Specialty, Excluding Coal (1231, 1011, 1021, 1031, 1041, 1044, 1094, 1099).[505]

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)
1231-9904	Underground mining, anthracite	6	101	62.6
1011-0103	Underground iron ore mining	3	26	2.6
1021-0103	Underground copper ore mining	5	950	428.3
1031-0100	Lead ores mining *	10	1,268	1,276.5
1031-0101	Cerussite mining*	1	2	0.3
1031-0200	Zinc ores mining*	5	351	42.7
1031-0203	Willemite mining	1	1	0.2
1041-0103	Underground gold mining	36	595	48.4
1044-0103	Underground silver mining	3	7	0.2
1094-9903	Radium ore mining, nec*	1	5	0.1
1094-9905	Uranium ore mining, nec*	39	576	1,661
1094-9906	Vanadium ore mining, nec*	1	0	N/A
1099-0101	Aluminum ore mining*	14	203	94.3
1099-0104	Beryllium ore mining*	2	1,863	196.8
1099-0200	Palladium group ores mining*	3	1,266	447.8
1099-0300	Platinum group ores mining*	2	6	0.8
1099-0400	Rare-earth ores mining*	3	23	1
1099	Other metal mining	17	290	1,725.9
	Total	**152**	**7,533**	**5,989.5**

Sales figures are in millions.
*May include both surface and underground mining.

Underground Mining Equipment Sales

Data obtained from the U.S. Census Bureau indicate that over 11,000 units of underground mining equipment were sold in 2004 (see Table z-7). The total value of underground mining equipment shipments was $466.4 million in 2004, up from $411.7 million in 2003 but down from $476.0 million in 2002.[506] Disaggregated information, according to specific applications (e.g., shuttle cars, underground loaders), was not available.

Table z-7. Manufacturers' Shipments of Mining and Mineral Processing Equipment: Underground Mining Machinery (except parts sold separately), 2004.[507]

Product Description	Units Sold	Value ($1,000)
Underground mining machinery (except parts sold separately)	11,634	396,037
Continuous mining machines, borer, ripper, auger and drum	219	192,570
Face haulage vehicles, rubber-tired, self-propelled	183	39,584
Support vehicles, rubber-tired or track-mounted	233	32,346
All other underground mining machinery	10,999	131,537

[505] Dun and Bradstreet. 2006. Zapdata industry report. Available at www.zapdata.com [Accessed May 2006].
[506] U.S. Census Bureau, Manufacturing and Construction Division. 2006. Annual Survey of Manufacturers (ASM). Available at http://www.census.gov/mcd/asm-as2.html [Accessed May 2006].
[507] US Census Bureau. 2006. MA333F - Mining Machinery and Mineral Processing Equipment. Available at http://www.census.gov/cir/www/333/ma333f.html [Accessed May 2006].

U.S. Coal Industry Diesel Vehicle Inventory

The U.S. Mining Safety and Health Administration (MSHA) maintains a current inventory of all diesel vehicles in the U.S. coal industry – for both surface and subsurface mining. Table z-8 presents the number of nationally registered diesel specialty vehicles used by coal mining companies, from the MSHA's National Diesel Inventory. While this inventory is useful, it does not include diesel vehicles used in metal/non-metal mines, and does not include battery-powered mining vehicles.

Table z-8. Number of Nationally Registered Diesel Specialty Vehicles used by Coal Mining Companies.[508]

Vehicle Type	# Registered Nationally
Personnel Carrier (Mine Tndr, Mantrip, Rabit, Bosbusy, Ribrnr)	1,421
Load-Haul-Dump (Scooptram, Front End Ld, Bobcat, LHD, Unildr)	460
Locomotive	176
Forklifts	154
Shuttle Cars (Torkar, Electrical, Ramcar)	124
Haul Truck (30 Ton Cap. or Less) (Ram-Car, Teletram, Coal-Haul)	78
Other: Diesel Generators	31
Total	**2,444**

Major manufacturers of mining vehicles include Joy Mining Machinery (roof bolters, shuttle cars), Caterpillar (underground LHD vehicles), Sandvik Mining and Construction (underground LHD vehicles), Damascus Corporation (diesel and battery utility vehicles), and Trident S.A. (mine locomotives, loaders).

MARKET TRENDS

To enter the mining industry, new power sources for mining vehicles must offer three clear benefits over competing technologies: Promote worker health and safety, improve productivity, and lower operating cost.

PEM fuel cell-powered specialty vehicles in underground mining applications offer potential benefits in each of the above areas. Conventional technologies for underground mining vehicles do not provide both acceptable worker health and safety and high productivity at the same time. Diesel engines have the horsepower to maintain higher levels of productivity in underground mining operations, but they raise health and safety concerns. Ventilation is necessary to reduce worker exposure to harmful diesel emissions when diesel engines are used. The growing use of diesel engines in the mining industry and uncertainties about the long-term health impacts of exhaust emissions have been the focus of attention of mining companies, researchers, and regulatory agencies in recent years. Equipment that improves air quality and reduces noise provides potentially important benefits to worker health and safety, but in the case of battery-powered vehicles, there can be a productivity compromise due to their lower power output. Fuel cells could potentially lower operating costs by reducing the need for ventilation, a major operating expense for mining companies, while also meeting worker health and safety and productivity requirements. PEM fuel cell-powered vehicle's quiet operation offers an advantage,

[508] Mine Safety and Health Administration. 2006. National Diesel Inventory. Available at https://lakegovprod1.msha.gov/DieselInventory/ViewDieselInventoryExternal.aspx [Accessed May 2006].

as hearing damage is one of the most common occupational health hazards in the mining industry.

The mining industry has begun to investigate the potential for fuel cells to be used in underground mining vehicles. Two fuel cell demonstration projects involving underground mining vehicles have been conducted. These demonstration projects are briefly described below.

- **Mine Loader Demonstration –** Funded through DOE's Hydrogen Program from 2001 to 2006, a joint venture between Vehicle Projects LLC and the Fuelcell Propulsion Institute aimed to develop a mine loader powered by a fuel cell and demonstrate the loader in an underground Nevada mine. The project also sought to develop metal-hydride storage and refueling capability needed for the vehicle. A hybrid fuel cell-battery power module was integrated into a Caterpillar-Elphinstone R1300 (diesel 165 HP, 123 kW) mine loader. The fuel cell module consisted of 3 PEM stacks (290V, 300A, 87 kW gross power) with an additional 65 kW provided by NiMH batteries. Peak power of the unit was 140 kW. Demonstration targets were 200 miles and operating durability of 1,000 hours. Results of the project are not yet available, but the technology is expected to be demonstrated in working gold mines in Nevada and Canada.[509]
- **Locomotive Demonstration –** Another joint venture of Vehicle Projects LLC and the Fuelcell Propulsion Institute, along with a number of partners, developed the first fuel cell locomotive for mining, with funding provided through DOE's Hydrogen Program. The locomotive, an underground mining haulage vehicle, was manufactured by RA Warren Equipment of North Bay, Ontario. The power plant and metal-hydride storage system were developed by Sandia National Laboratories of Livermore, California. The design objective was to outfit a 4-ton battery-powered locomotive with PEM fuel cells, replacing the lead-acid battery altogether.[510, 511] Specifications of the fuel cell locomotive were as follows:
    - Weight – 30% lighter than the battery version
    - Continuous power – 14 kW gross (2 PEM fuel cell stacks manufactured by Nuvera Fuel Cells with maximum output of 7 kW each)
    - Hydrogen storage – 3 kg
    - Operating time – 8 hours
    - Balance of plant – over 90% efficient
    - Refueling time – 8 times faster than for batteries.

  The team worked with Placer Dome (one of world's largest gold mining companies) to test the locomotive in an operating Ontario mine. Natural Resources Canada (NRCan) performed a cost-benefit analysis considering ventilation savings at the mine, and the results showed an overall benefit of the fuel cell over the diesel locomotive. NRCan has

[509] Barnes, D. 2006. Fuel Cell Powered Front-End Loader Mining Vehicles. FY05 Progress Report from Vehicle Projects to DOE Hydrogen Program. Available at http://www.hydrogen.energy.gov/pdfs/progress05/viii_a_6_barnes.pdf [Accessed December 2006].
[510] Sandia National Laboratory. 2006. Technology Highlight Fuel Cell Locomotive. Available at http://www.ca.sandia.gov/news/locomotive/ [Accessed May 2006].
[511] Miller, A.R. and D.L. Barnes. 2006. Fuelcell Locomotives. Available at http://www.fuelcellpropulsion.org/pdf/European%20FC%20Forum%202002%20(21%20May%2002)%20--%20preprint.pdf#search=%22fuel%20cell%20locomotive%20%22 [Accessed August 2006].

set a goal of completing a fleet changeover from diesel to fuel cell vehicles during 2012-2015.[512]

Hydrogenics, a manufacturer of hydrogen and fuel cell systems, is evaluating potential applications of its HyPM modules in the underground mining market.

MARKET SEGMENT ANALYSIS

To identify the market opportunities for direct PEM fuel cells in the underground mining market, 11 companies were contacted and five responses were received. All five respondents operate underground mines. Three companies are involved in coal mining, and two engage in metal mining activities. The respondents include two small companies, two medium-sized companies, and one large company. Individuals from the Mining Safety and Health Administration (MSHA) and the National Institute for Occupational Safety and Health (NIOSH) also completed interviews.

All of the respondents utilize various types of underground mining specialty vehicles. Specialty vehicles used by the two small mining companies include underground mining loaders (2.5 cu yd, 1.5 cu yd, and 1.25 cu yd capacities), an end dump truck (7 cu yd), a single boom drill jumbo, underground ore haulage truck, an underground rock-bolting jumbo, an underground worker transport tractor, and a utility carrier. One of these companies had 83 and the other had 37 specialty vehicles. The medium and large companies utilized several LHD vehicles (four in one mine; one in a second mine; two in a third mine), utility tractor/supply haulers (three in one mine), a shuttle car for hauling coal (one in each of two mines), extraction and hauling vehicles (two in one mine), a skidsteer loader (one in each of two mines), a road grader (one in each of two mines), one boom truck, one roof bolter, and several pickup trucks (in each of two mines) used as mantrip/personnel transport vehicles. The medium and large companies have over 80 specialty vehicles at one site and over 130 at another.

The large company reported operating 24 hours a day, 7 days a week year-round at some sites, and partial days (5½ to 6 days per week) at others. One of the medium-sized companies reported operating 24 hours a day, 7 days a week year-round; the other company operates some mines 24 hours a day, 7 days a week, while other sites operate 20 hours per day, 5 days per week, with weekend maintenance crews. One of the small companies reported operating 2 shifts per day, 5 days a week; the other operates 2 shifts per day, 7 days a week year-round.

Four of the five respondents stated that specialty vehicle downtime resulted in a loss in productivity and increased operations and maintenance costs. The large coal mining company identified a loss in productivity through decreased movement of materials as the only negative impact of specialty vehicle downtime.

One medium-sized coal mining company reported that there are hundreds of downtime incidents per year involving specialty vehicles. The other medium-sized coal company did not track number of downtime incidents but estimated shuttle car availability at 65% and reported that

[512] Betournay, M.C and M. Laflamme. 2006. Current Development and Future Opportunities of the Fuel Cell Mining Initiative. Presentation at the 2005 CIM Annual General Meeting, Toronto, Canada, April 25, 2006. Available at http://www.mining.ca/www/media_lib/TSM_Presentations/cimcanmet.pdf [Accessed December 2006].

downtime incidents range from 30 minutes to 8 hours. One small metal mining company reported experiencing several hundred downtime incidents per year, and estimated that 1 to 3 occur each day. The other small metal mining company estimated that more than 500 downtime incidents occur each year. The large coal mining company defined downtime as removing a vehicle from service for corrective repair, and reported no incidents of downtime in the past year.

Respondents rated the impact of specialty vehicle downtime on their operations, ranging from not disruptive at all to highly disruptive. All but one characterized downtime greater than 1 hour as highly disruptive. One medium-sized coal company considered an incident lasting 5 minutes to 4 hours as highly disruptive, but an incident lasting over 4 hours as only moderately disruptive, perhaps because backup vehicles would be used in place of the out-of-service vehicle. Another medium-sized coal company considered only incidents of downtime greater than 8 hours as highly disruptive. The large coal company indicated that any vehicle downtime (even less than 5 minutes) was highly disruptive. The two small metal mining companies considered incidents greater than 1 hour to be highly disruptive.

Respondents indicated the type of power system used in their specialty vehicles. One large and one medium-sized coal mining company reported using diesel ICEs and battery electric drive systems. The two small metal mining companies and one medium-sized coal mining company reported using diesel ICEs (no battery-powered vehicles); one small metal mining company reported using propane ICEs as well.

Respondents reported varying operation and maintenance requirements for underground mining specialty vehicles. The large coal mining company stated that daily inspections are conducted on both ICE and battery vehicles, and batteries are replaced or recharged two to three times per week; ICE preventive maintenance is pre-scheduled but times vary by vehicle type. One medium-sized coal mining company reported that its vehicles are serviced at 250 operating hours; this takes two to four shifts for one person to complete. Pickup trucks are serviced every 1,000 miles, which requires 8 hours for one person to complete. The other medium-sized coal mining company noted that one full-time employee is dedicated to servicing and repairing battery vehicles. One of the small metal mining companies stated that maintenance is performed on ICE vehicles at about 250 hours; the other small company reported conducting daily production and preventative maintenance.

Safety concerns for battery vehicle users, as indicated by respondents, included battery or hydraulic fluid fires and risk of explosion due to improper ventilation. Safety concerns identified for ICE engines included diesel emission exposure, diesel fuel or hydraulic fluid fires, and noise.

Respondents rated the importance of various factors in choosing a specialty vehicle. Figure z-1 summarizes the responses for a number of factors. When asked which of these factors were most important, reliability was cited most often, followed by emissions and experience with the system in the past.

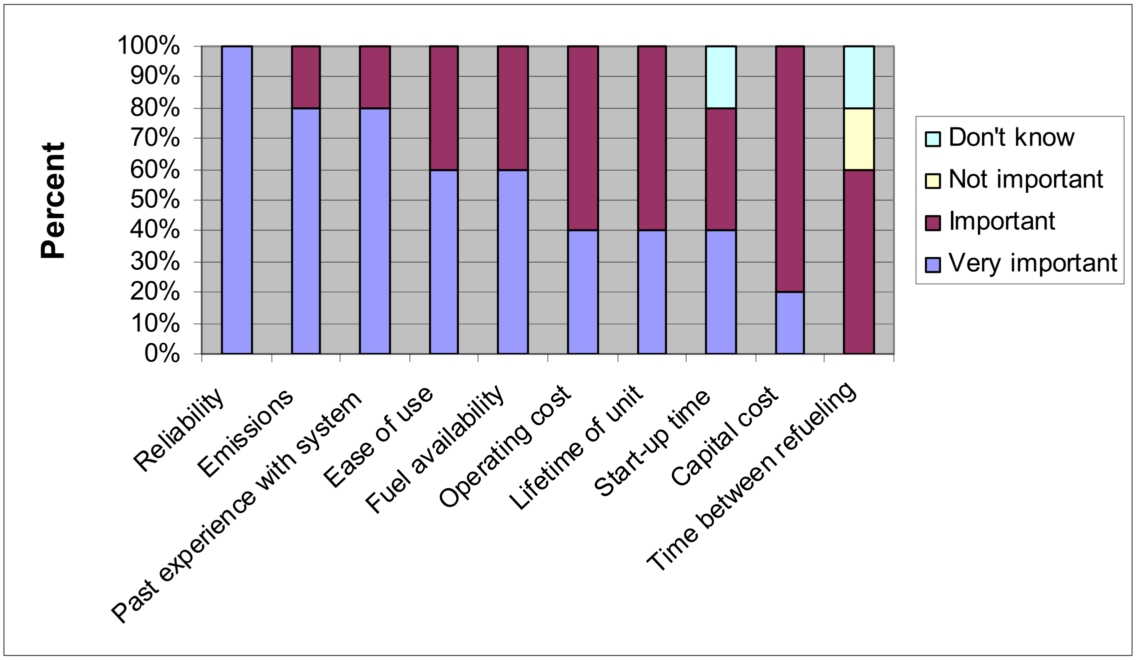

Figure z-1. Summary of Responses: Importance of Various Factors in Choosing an Underground Mining Specialty Vehicle (n=5).

When asked about the performance of battery-powered and ICE-powered specialty vehicles, four respondents rated the overall performance of these vehicles as very good or moderately good. A concern identified by two respondents was that batteries are inconvenient to recharge, and two respondents cited the hazardous emissions associated with ICEs. Other concerns mentioned include the time required to refuel, the time required to swap out batteries, and safety.

Respondents were also asked to rate the performance of their current specialty vehicles on the basis of several factors. Only three of the five respondents completed this question. Figure z-2 summarizes their responses.

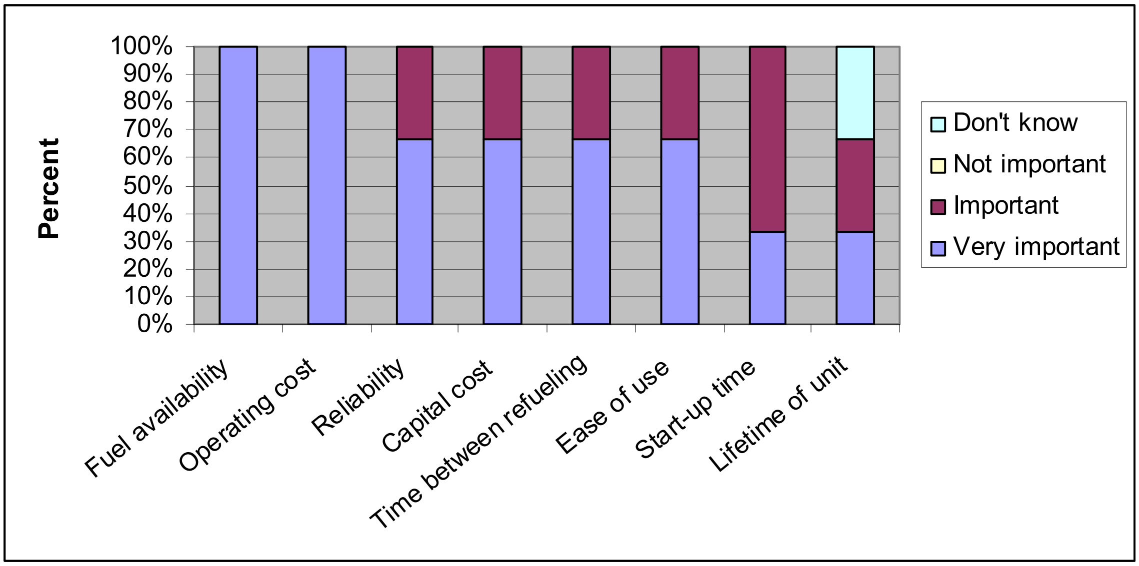

Figure z-2. **Summary of Responses: Performance of Respondents' Current Underground Mining Specialty Vehicles (n=3).**

Four of the five respondents anticipated a growing demand for specialty vehicles in the industry. One respondent noted that the industry is moving underground as surface pits are being depleted.

Two of the five respondents have considered alternatives to their current vehicle technologies: one has investigated biodiesel and ultra-low sulfur diesel, and the other has considered coal haulage vehicles powered by a trailing cable. Four respondents were aware of PEM fuel cells as alternatives to existing power sources, but none of those respondents thought PEM fuel cells were likely to compete with existing technologies in specialty vehicles for mining. Reasons identified were: cost, concern about the safety of introducing hydrogen in underground mines, lack of experience and familiarity with the technology, and a perceived "recharge time" and effective duty cycle per charge. Three of four companies expressed concern about using hydrogen as a fuel.

Respondents were asked about the rationale for making capital purchase decisions in their companies. In four companies, decisions about capital investments in underground mining vehicles are made using a return on investment analysis. Two companies consider payback period in making purchase decisions.

Four of the five respondents agreed to be contacted again.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

The market for PEM fuel cell-powered specialty vehicles is potentially an attractive one for certain mining vehicle applications. Approximately 11,000 units of underground mining equipment were sold in the U.S. in 2004. While many specialty vehicles, such as heavy duty LHD trucks, have larger power requirements than PEM fuel cells may be capable of supplying, certain applications provide a reasonable fit in terms of size requirements (e.g., personnel carriers and shuttle cars).

The opportunity to reduce emissions in underground mines is the key value proposition for PEM fuel cells in the mining industry. Ventilation in underground mines represents a substantial proportion (an estimated 40%) of power consumption costs. While battery-operated vehicles do not have the emission problems associated with diesel ICEs, the need to recharge and replace them can translate into lost productivity, particularly in mines that operate 24 hours a day, 7 days a week.

Additional drivers to adopt fuel cells over existing technologies include high power density, low temperature and pressure operation, component durability, and higher efficiency than diesel engines.[513] Also, respondents in this analysis cited reliability as being more important than capital cost, which suggests that the market may be willing to pay a higher price for fuel cells' reliability.

Other factors favor the adoption of PEM fuel cells in the underground mining industry:

- There is an identifiable number of potential users (approximately 450 companies) concentrated in the states of Kentucky, West Virginia, and Pennsylvania
- Growth in the industry is anticipated due to a growing emphasis on domestic coal as a fuel source and growth in underground mining activities as surface mines are depleted
- PEM fuel cell demonstration projects are paving the way for fuel cell technology in the underground mining industry.

Still, important barriers remain to PEM fuel cell use in underground mining vehicles. While PEM fuel cell mining vehicles have been tested, the mining industry in general lacks experience and familiarity with fuel cell technology, and may have concerns about the use of hydrogen, particularly in a safety-conscious industry. While there is manufacturer interest in this sector, mining vehicles are not yet commercially available and therefore will not be ready for introduction in the near term. However, the potential performance and safety advantages that PEM fuel cells offer over existing technologies, coupled with the expected growth of the domestic industry, make this a potentially attractive market in the mid-term. LHD trucks and personnel carriers may represent more promising applications, compared to locomotives, due to their wider user in mines and applicability in other industrial environments.

[513] Miller, A. 2000. Tunneling and Mining Applications of Fuel Cell Vehicles. Fuel Cells Bulletin (July): 5-9.

RESEARCH SUMMARY:
SPECIALTY VEHICLES – UNMANNED AERIAL VEHICLES (UAVs)

MARKET SEGMENT DESCRIPTION

The U.S. Department of Defense (DoD) defines an unmanned aerial vehicle (UAV) as a "powered, aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or non-lethal payload."[514] Payloads carried by UAVs include cameras, sensors, other types of surveillance equipment, and communications equipment. In military applications, UAVs are designed for use in missions deemed too "dull" (i.e., likely to cause excessive fatigue), "dirty" (e.g., sampling in a radioactive zone), or "dangerous" (e.g., conducting surveillance in enemy territory) for manned aircraft to perform.[515] Table aa-1 identifies the SIC and NAICS classifications that cover manufacturing of UAVs.

Table aa-1. SIC and NAICS Codes for UAV Manufacturing.

2-Digit SIC Code	37 – Transportation equipment
4-Digit SIC Code	3721 – Aircraft and parts
NAICS Code	336411 – Aircraft manufacturing

To date, the primary user of UAVs, also referred to as unmanned aerial systems (UASs), has been the U.S. government, particularly the military. DoD has budgeted $1,662,000,000 for UAS-related research and development (R&D) in the FY05-FY09 President's Budget (see Figure aa-1); the bulk of this spending will focus on broad technology initiatives (e.g., sensing and control technologies) and weaponization.[516] UAVs are also being used increasingly by U.S. governmental civilian agencies for applications ranging from border protection to disaster recovery and search and rescue operations.[517] Federal agencies that are most likely to use UAVs include the U.S. Department of Homeland Security (DHS) (disaster recovery, search and rescue, and border protection operations), the U.S. Department of Agriculture Forest Service (fire monitoring), and the U.S. Geological Survey (USGS) (remote sensing activities).

UAVs have tremendous potential to be used in commercial remote sensing applications, as well. It has been suggested that commercial spending on UAV R&D could equal that of the military within 15 years. However, the FAA has yet to develop regulations governing the safe operation of UAVs in U.S. airspace, which has delayed widespread commercial use of these vehicles and raised concerns about unregulated uses.[518]

UAVs are available in a wide range of sizes and capabilities, depending on their applications. Small UAVs are typically man-portable and can be hand-launched or bungee-launched, whereas

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[514] U.S. Department of Defense. 2001, as amended through 2006. Department of Defense Dictionary of Military and Associated Terms. Joint Publication 1-02. Available at http://www.dtic.mil/doctrine/jel/new_pubs/jp1_02.pdf [Accessed June 2006].
[515] U.S. Department of Defense. 2005. Unmanned Aircraft Systems Roadmap – 2005-2030. Available at http://www.fas.org/irp/program/collect/uav_roadmap2005.pdf [Accessed June 2006].
[516] U.S. Department of Defense. 2005. Unmanned Aircraft Systems Roadmap – 2005-2030. Available at http://www.fas.org/irp/program/collect/uav_roadmap2005.pdf [Accessed June 2006].
[517] AeroVironment. 2006. AeroVironment: Beyond the Military. Available at http://www.avsuav.com/non_flash/products_beyond_the_military.php [Accessed June 2006].
[518] Jewell, J.E. 2005. White Paper: Commercial Use Of Unmanned Aerial Vehicles (UAVs): Surveying the Regulatory Landscape. Published by UAV MarketSpace. Available at http://www.rfglobalnet.com/downloads/Detail.aspx?docid=7f26ca33-51c0-40f0-a0ab-a878c18a3d53&sd=Ni8xOS8yMDA2IDI6NTA6MTcgUE0%3d [Accessed June 2006].

large UAVs are launched via remote control. UAVs range in size from extremely compact (AeroVironment's smallest product, the WASP Micro Air Vehicle, has a wingspan of 1.37 feet and weighs 0.6 lbs[519]) to extremely large (Northrop Grumman's Global Hawk has a wingspan of up to 130.9 feet and weighs approximately 15,400 lbs, minus fuel and payload[520]). Small UAVs are typically used in low-altitude (≤ 1,000 ft) applications and are powered by batteries, which limit endurance (typically ≤ 120 minutes). Generally, large UAVs such as the Global Hawk are used for long-endurance (> 24 hour) operations in high altitudes (> 30,000 feet).

Costs vary widely among available vehicles. Micro-sized UAVs may cost $5,000 or less.[521] Slightly larger, man-portable UAVs average $25,000 to $30,000 per vehicle. The high-altitude, long-endurance UAVs, manufactured by companies such as General Atomics and Northrop Grumman, range in price from $0.39 million to $26.5 million per aircraft (associated support systems not included).[522] Unmanned aircraft use a wide range of power systems; the most common appear to be ICEs (including traditional gas turbines and reciprocating engines) and batteries.

Many UAVs are manufactured with ICEs or jet engines. These vehicles run on automobile gasoline, aviation gasoline, diesel fuel, or several varieties of jet fuel. Large UAVs powered by ICEs range in weight from approximately 375 lbs to over 45,000 lbs and in power from < 30 HP (22 kW) to well over 900 HP (671 kW). Small ICE-powered UAVs are also on the market; these range in weight from 10 to 40 lbs and have payload capacities ranging from 3 to 12 lbs (horsepower not available).[523]

Smaller, lower-altitude, and shorter-duration UAVs tend to run on electric batteries. Small UAVs typically weigh less than 20 lbs and have a payload capacity of less than 3 lbs,[524] which allows them to be hand-launched or bungee-launched. Specific voltage requirements for electric UAVs were not available from the manufacturers. However, a recent report estimated upper-level power requirements for small UAVs (operating on 24V battery packs) to be approximately 300 W for initial power and 100 W for cruising power.[525] Lead acid and NiCd batteries are widely used, and some manufacturers are using Li-ion batteries, as well.[526]

A key metric used to ascertain propulsion system performance in UAVs is specific power (SP). Reciprocating engines for aircraft generally are capable of producing one horsepower/lb of engine weight (746 W/lb), and today's fuel cells are approaching this same level; however, Li-

[519] AeroVironment. 2005. Wasp Datasheet. Available at http://avsuav.com/pdf/datasheet_wasp.pdf [Accessed June 2006].
[520] U.S. Department of Defense. 2005. Unmanned Aircraft Systems Roadmap – 2005-2030. Available at http://www.fas.org/irp/program/collect/uav_roadmap2005.pdf [Accessed June 2006].
[521] Dickerson, L. 2005. Wasp UAV Could Be Provided to U.S. Marines. Forecast International/Unmanned Vehicles Forecast. Available at http://www.forecastinternational.com/abstract.cfm?recno=114375 [Accessed June 2006].
[522] U.S. Department of Defense. 2005. Unmanned Aircraft Systems Roadmap – 2005-2030. Available at http://www.fas.org/irp/program/collect/uav_roadmap2005.pdf [Accessed June 2006].
[523] U.S. Department of Defense. 2005. Unmanned Aircraft Systems Roadmap – 2005-2030. Available at http://www.fas.org/irp/program/collect/uav_roadmap2005.pdf [Accessed June 2006].
[524] U.S. Department of Defense. 2005. Unmanned Aircraft Systems Roadmap – 2005-2030. Available at http://www.fas.org/irp/program/collect/uav_roadmap2005.pdf [Accessed June 2006].
[525] Naimer, N., B. Koretz, and R. Putt. 2002. Zinc-Air Batteries for UAVs and MAVs. Electric Fuel Corporation. Available at http://www.electric-fuel.com/defense/UVS02.pdf [Accessed June 2006].
[526] U.S. Department of Defense. 2005. Unmanned Aircraft Systems Roadmap – 2005-2030. Available at http://www.fas.org/irp/program/collect/uav_roadmap2005.pdf [Accessed June 2006].

ion batteries have approximately half this level of SP.[527] SP is directly related to endurance, which explains why battery-powered UAVs are not capable of remaining airborne for nearly as long as those powered by ICEs.

MARKET SIZE

Current data on the size of the UAV manufacturing market are provided below. The number of UAV manufacturers is captured within SIC Code 3721 (Aircraft), which is represented in Table aa-2. Note that this SIC Code includes all types of aircraft and that UAV manufacturers represent only a small proportion of the total.

Table aa-3 represents potential users of UAVs, including: military organizations and DHS (SIC Code 9711 – National security); government agencies involved in environmental research and remote sensing activities (SIC Code 8733 - Noncommercial research organizations); forest management and fire monitoring organizations (SIC Code 0851 - Forestry services); and search and rescue services (SIC Code 8999 - Services, Not Elsewhere Classified). Commercial entities have not been included in this analysis, since any attempt to predict which commercial markets will use UAVs once FAA regulations have been established would be purely speculative. In Tables aa-2 and aa-3, only the eight-digit SIC specialty categories deemed most relevant to UAV manufacturing and use are shown.

Table aa-2. Number of UAV Manufacturers – Industry: Aircraft (3721).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)
3721-0000	Aircraft	860	101,128	54,315.5
3721-0100	Motorized aircraft	18	1,046	220
3721-0101	Airplanes, fixed or rotary wing	142	33,565	61,873.30
	Total	**1,020**	**135,739**	**116,408.80**

Sales figures are in millions. Source: www.zapdata.com, accessed June 2006.

Table aa-3. Number of Potential UAV Users – Industries: National Security (9711); Noncommercial Research Organizations (8733); Forestry Services (0851); Services, Nec (8999).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)
9711-0000	National security	1,256	110,305	N/A
9711-0400	National security, level of government	5	0	N/A
9711-0401	National security, federal government	62	1,031	N/A
9711-0402	National security, state government	19	200	0.1
9711-0403	National security, county government	13	516	N/A
9711-0404	National security, local government	6	151	N/A
9711-9901	Air Force	1,819	279,503	N/A
9711-9902	Army	3,304	250,184	N/A
9711-9904	Marine Corps	1,079	35,966	0.1
9711-9906	National Guard	2,608	90,478	2.6
9711-9907	Navy	2,182	249,060	0.1
8733-0000	Noncommercial research organizations	5,147	62,308	7,599.9
8733-9901	Physical research, noncommercial	134	2,961	325
8733-9902	Research institute	1,415	52,353	5,457.2

[527] U.S. Department of Defense. 2005. Unmanned Aircraft Systems Roadmap – 2005-2030. Available at http://www.fas.org/irp/program/collect/uav_roadmap2005.pdf [Accessed June 2006].

8733-9904	Scientific research agency	924	33,697	3,377.5
0851-0000	Forestry services	3,387	15,250	578.5
0851-0100	Forest management services	461	2,353	115.3
0851-0101	Forest management plans, preparation of	155	1,203	40.7
0851-0102	Reforestation services	279	4,602	239.9
0851-9901	Fire fighting services, forest	760	4,642	197.5
0851-9902	Fire prevention services, forest	212	1,337	46.8
0851-9903	Pest control services, forest	75	418	33.4
0851-9904	Timber cruising services	52	176	10.6
0851-9905	Timber estimating services	42	155	26.5
0851-9906	Timber valuation services	66	402	23.9
8999-9904	Search and rescue service	482	4,245	134.2
	Total	**25,944**	**1,203,496**	**18,210**

Sales figures are in millions. Source: www.zapdata.com, accessed June 2006.

The largest manufacturers of UAVs are AAI Corporation; AeroVironment, Inc.; The Boeing Company; General Atomics Aeronautical Systems, Inc.; Honeywell; L-3 BAI Aerosystems; Lockheed Martin; and Northrop Grumman Corporation.

MARKET TRENDS

Unmanned aircraft represent a relatively new and still-developing market; as such, their manufacturers may be more likely to explore alternative power sources than manufacturers of vehicles that are widely used and well-established (e.g., commercial aircraft or automobiles). UAV manufacturers are currently exploring a variety of propulsion alternatives, including scramjets, reciprocating chemical muscles, beamed power, nuclear isotopes, and fuel cells.[528]

In an effort to develop a small UAV that can conduct surveillance missions for 24-hour periods, researchers at the U.S. Naval Research Laboratory designed the Spider-Lion, a fuel cell-powered vehicle. In 2006 the vehicle completed two successful test flights, marking the first time a fuel cell-based UAV had flown for several hours. The Spider-Lion's first flight lasted for 1 hour and 43 minutes, and the second lasted for 3 hours and 19 minutes. Both flights ended when the compressed hydrogen supply was exhausted.[529]

Years earlier, a solar/fuel cell hybrid UAV was developed by AeroVironment under NASA's Environmental Research Aircraft and Sensor Technology program. The Helios Prototype ran on solar power during the day and fuel cells at night. It was designed to reach altitudes at or near 100,000 feet while completing scientific or telecommunications relay missions lasting for weeks or months without using consumable fuels. In 2003, the Helios and its experimental power system were destroyed when the plane sustained structural failures and crashed into the Pacific Ocean.[530]

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[528] U.S. Department of Defense. 2005. Unmanned Aircraft Systems Roadmap – 2005-2030. Available at http://www.fas.org/irp/program/collect/uav_roadmap2005.pdf [Accessed June 2006].
[529] Boland, R. 2006. Experimental fuel cell power system expands flight capabilities. Fuel Cell Today. Available at http://www.fuelcelltoday.com/FuelCellToday/IndustryInformation/IndustryInformationExternal/NewsDisplayArticle/0,1602,7437,00.html [Accessed June 2006].
[530] National Aeronautics and Space Administration. 2005. Past Projects – Helios Prototype. Available at http://www.nasa.gov/centers/dryden/history/pastprojects/Erast/helios.html [Accessed June 2006].

MARKET SEGMENT ANALYSIS

To identify the market opportunities for direct PEM fuel cells in UAVs, manufacturers and others familiar with these vehicles were contacted. UAV users were not contacted; it was assumed that military personnel would not be able to share tactical or potentially sensitive information. As non-military UAV markets are fragmented, no attempt was made to contact users. Four organizations were contacted, and two responses were received (one detailed and one general interview).

Respondents included a small but rapidly growing manufacturer of small UAVs and a U.S. Army contractor who has helped to develop small UAVs in the past. The manufacturer currently sells various battery-powered UAVs to the U.S. military but is developing a large, liquid hydrogen-fueled UAV and an ICE-powered UAV that runs on JP8 fuel.

Perceptions of UAV downtime and maintenance requirements differed between the two respondents. The manufacturer felt that downtime was not a significant issue, since small UAVs have been fine-tuned for optimal performance as a result of extensive combat testing. The U.S. Army contractor noted that the maintenance requirements for small UAVs are significant and that UAVs often have to return to base before completing their missions due to limited battery life. The U.S. Army contractor elaborated that regular maintenance is necessary because UAVs break apart upon landing; this impact may damage UAV components. The respondent estimated that maintenance represents 10 to 20% of the costs of a UAV. In direct contrast with this estimate, the manufacturer noted that very little maintenance is required for UAVs.

In general, both respondents seemed pleased with the performance of batteries as a power source. However, both respondents emphasized the pressure to increase flight duration without increasing the weight of the vehicle. Neither respondent perceived any safety issues with the use of existing power sources.

The manufacturer was aware of the potential for PEM fuel cells to power UAVs. This manufacturer is currently conducting feasibility studies on various alternative fuels in response to a need for increased flight duration; studies are being conducted on JP8-fueled ICEs and PEM fuel cells for small UAVs. The manufacturer indicated that fuel cells must improve upon battery performance by a factor of 2 in order to overcome logistical issues, increased costs, durability, and reliability concerns associated with existing fuel cell systems. The manufacturer reported that the most important factor when considering alternatives is performance (i.e., whether the alternative can provide extended flight duration without increasing airplane weight). The next most important factor is cost, and the third most important is logistics. The manufacturer was unsure whether fuel cells would be a viable power source for UAVs, citing hydrogen storage as a potential barrier as the container would need to withstand tremendous force upon impact. The respondent added that fuel cells may be feasible in niche applications (e.g., remote military operations) only; at this time, fuel cells do not make sense practically. The manufacturer was unsure whether customers would have concerns over the use of hydrogen as a fuel.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

Recent testing of an experimental fuel cell system in a small UAV demonstrated several key advantages to using a PEM fuel cell in such vehicles. The most important advantage, from a tactical perspective, is increased endurance. While small UAVs powered by traditional engines can fly for about 8 hours, battery-powered UAVs can remain airborne for approximately 1 hour. PEM fuel cells provide extended flight duration, compared to batteries (over 3 hours in one test flight), and increased efficiency over ICEs. Other key drivers for using fuel cells are ease of use (systems start up immediately) and the fact that fuel cell-powered UAVs are more difficult to detect than aircraft powered by small engines, since the PEM fuel cell system is nearly silent and has a low heat signature.[531] Any fuel cell system used in UAVs would have to be sensitive to the weight limitations of the vehicle.

The opportunity for PEM fuel cells in UAVs will likely be limited to small UAVs (< 10 lbs) in the foreseeable future, as existing PEM fuel cell technology is not capable of powering a large UAV or other aircraft. While the military market may be less sensitive to cost than commercial markets, the technology does not appear to be ready for broad deployment into military applications in the near term. PEM fuel cells must address concerns about the capital cost, reliability, and demonstrate significantly higher performance compared to current battery alternatives in order to attract broader interest from this market.

[531] Boland, R. 2006. Experimental fuel cell power system expands flight capabilities. Fuel Cell Today. Available at http://www.fuelcelltoday.com/FuelCellToday/IndustryInformation/IndustryInformationExternal/NewsDisplayArticle/0,1602,7437,00.html [Accessed June 2006].

RESEARCH SUMMARY:
SPECIALTY VEHICLES – UNMANNED UNDERWATER VEHICLES (UUVs)

MARKET SEGMENT DESCRIPTION

Unmanned underwater vehicles (UUVs) are pilot-less autonomous or remotely controlled vehicles that are developed to perform tasks that would be impossible or too risky for larger watercraft.[532] The U.S. Navy is pursuing the development of UUVs for use in nine critical missions, including: (1) maritime intelligence, surveillance, and reconnaissance; (2) mine countermeasures; (3) anti-submarine warfare; (4) inspection and identification; (5) oceanography; (6) communication; (7) payload delivery; (8) information operations; and (9) time-critical strike operations. To perform these missions, the U.S. Navy is planning for the development of four general classes of UUVs: man-portable (ranging from ~25 lb to > 100 lb displacement with a diameter between 3" and 9"); light-weight (~500 lbs displacement with a diameter of 12.75"); heavy weight (< 3,000 lb displacement with a diameter of 21"); and large (~20,000 lb displacement with a diameter > 36").[533] UUVs have also been used in commercial and academic applications to conduct deepwater surveys (e.g., for oil and gas exploration), perform oceanographic research, and collect various other types of data. Table bb-1 identifies the SIC and NAICS classifications that cover manufacturing of UUVs.

Table bb-1. SIC and NAICS Codes for UUV Manufacturing.

2-Digit SIC Code	37 – Transportation equipment
4-Digit SIC Code	3731 – Ship building and repairing
NAICS Code	336611 – Ship building and repairing

As indicated above, UUVs are being developed in numerous shapes, sizes, and configurations, depending on their applications and operating environments. The vehicles can be designed to accommodate a wide variety of payloads. In 2000, the U.S. Navy estimated the costs of UUVs to be $1,000 per lb at low or prototype production rates and $100 per lb at higher production rates.[534]

The energy source selected for a UUV application is driven primarily by mission requirements for speed and endurance. Increased energy capacity is required to accommodate long-endurance, high payload power, or high-speed missions. No existing energy system is capable of meeting all mission needs and vehicle design constraints.

Representative options for UUV energy sources (based on the capabilities and characteristics of current technologies) are primary or rechargeable lithium batteries for smaller vehicles, and power plants (fuel cells or hybrid energy systems) for larger vehicles.[535] Other technologies used to power UUVs include NiCd and silver-zinc rechargeable battery systems. The main

[532] Crawford, M.G. 2005. MILNET Brief: Unmanned Underwater Vehicles - UUVs. Available at http://www.milnet.com/pentagon/UUVs.html [Accessed April 2006].
[533] U.S. Department of the Navy. 2004. The Navy Unmanned Undersea Vehicle (UUV) Master Plan. Available at http://www.chinfo.navy.mil/navpalib/technology/uuvmp.pdf [Accessed June 2006].
[534] U.S. Department of the Navy. 2000. The Navy Unmanned Undersea Vehicle (UUV) Master Plan. Available at http://www.npt.nuwc.navy.mil/UUV/UUVMP.pdf [Accessed June 2006].
[535] U.S. Department of the Navy. 2004. The Navy Unmanned Undersea Vehicle (UUV) Master Plan. Available at http://www.chinfo.navy.mil/navpalib/technology/uuvmp.pdf [Accessed June 2006].

limitation of current rechargeable batteries is their inability to sustain extended runtimes, which are often required for tactical UUV missions.[536] In its 2004 UUV Master Plan,[537] the U.S. Navy summarized benefits and drawbacks of typical UUV power sources, as shown in Table bb-2.

Table bb-2. UUV Energy Options versus Vehicle Size.

All Size UUVs	Large UUVs Only (21" with Difficulty)
• **$LiSOCl_2$ Primary Batteries** *Benefits:* High energy density (> 200 Wh/lb) *Drawbacks:* Expensive (capital investment, per sortie) Very difficult to replenish at sea Safety issues that may be acceptable (but desirable to eliminate) • **Li-Ion Rechargeable Battery** *Benefits:* Rechargeable Moderate range per sortie (75 Wh/lb; 100 Wh/lb stretch) Improved safety over $LiSOCl_2$ *Drawbacks:* Expensive initial capital investments	• **Hybrid Diesel – Li-ion** *Benefits:* Replenishable (Diesel / JP fuels) Low per sortie cost and probably reasonable capital investment cost Low risk for high energy density (> 400 Wh/lb w/snorkel) Improved safety over $LiSOCl_2$ *Drawbacks:* Increase system complexity (reliability?) Operational constraint (snorkel) (e.g., 80-hr dived, 4-hour surface) • **Fuel Cells** *Benefits:* Replenishable (depending on reactant storage options) High energy density (~150 Wh/lb) *Drawbacks:* High initial cost TBD Safety (H_2 and O_2 sources) Relatively immature technology

Source: Adapted from U.S. Department of the Navy. 2004. The Navy Unmanned Undersea Vehicle (UUV) Master Plan.

As detailed in the 2004 UUV Master Plan, lithium-based batteries have the highest energy density among available battery technologies. Because of their relatively small size, these batteries are easily configured to fit within most UUV configurations. However, there is a tremendous cost penalty associated with using primary lithium-based batteries in large applications (> 500 lb batteries), since the batteries are discarded after use. In such cases, battery cost may exceed UUV cost. Rechargeable batteries are less costly over time; furthermore, they have a safety advantage because they can be shipped in a discharged state.[538]

For larger vehicles, fuel cells and hybrid diesel/battery power plants are more attractive due to their higher energy density and potentially lower operating costs.[539] Hybrid systems are not an optimal choice for smaller vehicles due to the need for support equipment to operate the power plant; however, they have significant advantages over battery systems in larger vehicles, as shown in Table bb-2. Also, hybrid diesel systems are widely available, low-risk, and low-cost.

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[536] EurekAlert. 2000. Future power source for undersea vehicles. Available at http://www.eurekalert.org/pub_releases/2000-03/OoNR-Fpsf-0503100.php [Accessed June 2006].

[537] U.S. Department of the Navy. 2004. The Navy Unmanned Undersea Vehicle (UUV) Master Plan. Available at http://www.chinfo.navy.mil/navpalib/technology/uuvmp.pdf [Accessed June 2006].

[538] U.S. Department of the Navy. 2004. The Navy Unmanned Undersea Vehicle (UUV) Master Plan. Available at http://www.chinfo.navy.mil/navpalib/technology/uuvmp.pdf [Accessed June 2006].

[539] U.S. Department of the Navy. 2004. The Navy Unmanned Undersea Vehicle (UUV) Master Plan. Available at http://www.chinfo.navy.mil/navpalib/technology/uuvmp.pdf [Accessed June 2006].

Comparatively, fuel cell technologies are still quite costly.[540] Hybrid diesel systems are associated with one major tactical disadvantage: the need for air, which requires them to resurface and recharge.[541]

Sparse information is publicly available regarding the size of UUV power systems. However, a recent solicitation for extended-duration UUV power systems set performance targets for the propulsion system in the 5 to 10 kW range and for peak power levels in the 30 to 40 kW range.[542]

MARKET SIZE

Current data on the size of the UUV manufacturing market are provided below. Manufacturers of UUVs are captured within SIC Code 3731 (Ship Building and Repairing), which is represented in Table bb-3.

The user market for UUVs is somewhat difficult to quantify because it is so wide-ranging and not fully established. Primary user market is the DoD. In addition, a wide range of SIC categories deemed likely to utilize UUVs is captured in Table aa-3. These categories include various types of scientific consultants (SIC Code 8999 - Services, Not Elsewhere Classified); engineering services, including petroleum engineering, (SIC Code 8711); surveying services (SIC Code 8713); commercial physical and biological research establishments (SIC Code 8731 - Commercial Physical Research); noncommercial research organizations (SIC Code 8733); and environmental consultants (SIC Code 8748 - Business Consulting, Not Elsewhere Classified). Also included are government agencies that may be involved in environmental monitoring (SIC Code 9511 - Air, Water, and Solid Waste Management) and military organizations (SIC Code 9711 - National Security). It should be noted that the market for UUVs may be broader than represented here. In Tables aa-2 and aa-3, only the eight-digit SIC specialty categories deemed most relevant to UUV manufacturing and use are shown.

Table bb-3. Number of UUV Manufacturers – Industry: Shipbuilding and Repairing (3731).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)
3731-9906	Submersible marine robots, manned or unmanned	11	139	9.2
	Total	**11**	**139**	**9.2**

Sales figures are in millions. Source: www.zapdata.com, accessed June 2006.

[540] U.S. Department of the Navy. 2004. The Navy Unmanned Undersea Vehicle (UUV) Master Plan. Available at http://www.chinfo.navy.mil/navpalib/technology/uuvmp.pdf [Accessed June 2006].
[541] Annati, M. 2005. UUVs and AUVs come of age. Military Technology. Available at http://www.fuelcelltoday.com/FuelCellToday/IndustryInformation/IndustryInformationExternal/NewsDisplayArticle/0,1602,6217,00.html [Accessed June 2006].
[542] FedBizOpps. 2005. A – Defense Sciences Research and Technology: UUV Power Systems, SOL BAA05-19, Addendum 7. FBO Daily Issue of May 13, 2005, FBO #1264 Modification. Available at http://www.fbodaily.com/archive/2005/05-May/13-May-2005/FBO-00805485.htm [Accessed June 2006].

Table bb-3. Number of Potential UUV Users - Industries: Services, Nec (8999); Engineering Services (8711); Surveying Services (8713); Commercial Physical Research (8731); Noncommercial Research Organizations (8733); Business Consulting, Nec (8748); Air, Water, and Solid Waste Management (9511); National Security (9711).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)
8999-0500	Weather related services	203	1,041	49.3
8999-0700	Earth science services	2,304	5,417	239.8
8999-0701	Geological consultant	1,387	3,846	275.5
8999-0702	Geophysical consultant	287	1,150	188.4
8999-0703	Natural resource preservation service	821	5,433	296.9
8999-0900	Scientific consulting	3,623	7,170	309.3
8999-9904	Search and rescue service	482	4,245	134.2
8711-0000	Engineering services	32,947	469,821	74,438.602
8711-0300	Petroleum, mining, and chemical engineers	114	1,256	474.7
8711-0303	Petroleum engineering	370	5,824	295.2
8711-9903	Consulting engineer	19,350	219,009	30,660.5
8711-9904	Designing: ship, boat, machine, and product	1,118	15,302	2,090.2
8711-9905	Electrical or electronic engineering	2,978	29,822	3,394.2
8711-9908	Marine engineering	387	3,749	479.7
8711-9909	Professional engineer	2,006	11,884	734.5
8713-0000	Surveying services	11,019	65,339	2,871.3
8713-9900	Surveying services, nec	197	1,247	80.6
8731-0000	Commercial physical research	5,879	107,022	10,775.3
8731-0100	Biological research	1,244	17,254	2,917
8731-0200	Commercial physical research	761	50,849	16,680.6
8731-0300	Natural resource research	286	2,889	759.7
8731-0302	Environmental research	1,129	12,162	827.7
8733-0000	Noncommercial research organizations	5,147	62,308	7,599.9
8733-0100	Noncommercial biological research organization	172	4,487	385.6
8733-0102	Biotechnical research, noncommercial	200	3,077	265.9
8733-0203	Educational research agency	540	7,625	1,232
8733-9901	Physical research, noncommercial	134	2,961	325
8733-9902	Research institute	1,415	52,353	5,457.2
8733-9904	Scientific research agency	924	33,697	3,377.5
8748-0400	Systems analysis & engineering consulting services	1,593	11,355	1,460.9
8748-9905	Environmental consultant	13,779	104,734	10,958.3
8748-9906	Fishery consultant	343	1,070	87.9
9511-0000	Air, water, and solid waste management	2,507	97,677	N/A
9511-0100	Environmental agencies	274	11,092	0.3
9511-0102	Environmental protection agency, government	357	34,690	0.1
9511-0103	Environmental quality and control agency, government	143	7,336	N/A
9511-0400	Air, water, and solid waste management, level of government	12	41	N/A
9511-0401	Air, water, and solid waste management, federal government	13	156	N/A
9511-0402	Air, water, and solid waste management, state government	38	355	N/A
9511-0403	Air, water, and solid waste management, county government	157	2,876	N/A
9511-0404	Air, water, and solid waste management, local government	420	5,594	N/A

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)
9711-9902	Army	3,304	250,184	N/A
9711-9904	Marine Corps	1,079	35,966	0.1
9711-9905	Military training schools	116	2,357	0.1
9711-9906	National Guard	2,608	90,478	2.6
9711-9907	Navy	2,182	249,060	0.1
	Total	**126,349**	**2,113,260**	**180,126.7**

Sales figures are in millions. Source: www.zapdata.com, accessed June 2006.

Major UUV manufacturers include BAE Systems, Inc., and its subsidiary, Atlas Elektronik GmbH; The Boeing Company; C&C Technologies Survey Services; Lockheed Martin; and International Submarine Engineering Ltd.

MARKET TRENDS

The market for UUVs is still very much an emerging one. Viable energy sources for UUVs must permit high voltages, have a large capacity for energy storage, and deliver stored energy safely and reliably over extended discharge periods. Energy sources must also be relatively cheap, environmentally harmless, and capable of a long shelf life.[543]

At least one commercially available UUV is powered by an aluminum oxide fuel cell.[544] Additionally, the Naval Undersea Warfare Center demonstrated a semi-fuel cell power source consisting of a hybrid system that utilizes both a hydrogen fuel cell and silver-zinc batteries. The semi-fuel cell system impressed researchers with its compactness, long shelf life, and increased energy output compared to standard silver-zinc batteries alone.[545]

MARKET SEGMENT ANALYSIS

To identify the market opportunities for direct PEM fuel cells in UUVs, individuals with experience working with these vehicles were contacted. Because UUVs are most often used in military operations, it was assumed that military personnel or DoD contractors who manufacture the vehicles would not be able to share potentially sensitive information. Three individuals with experience in UUVs were contacted, and two informal interviews were conducted.

One respondent was aware of the potential for fuel cells to be used in UUVs. This user noted that much of the U.S. Navy's fuel cell work in the past had focused on diesel fuel reforming, a process that converts diesel fuel for use in a fuel cell. More recently, the U.S. Navy has become interested in alternate fuels (other than diesel). The U.S. Navy is currently engaged in a joint program with the United Kingdom to investigate a PEM fuel cell that operates on sodium borohydride via direct electrochemical reduction. The same respondent indicated that there are two UUV communities – tactical and oceanographic. Tactical units are larger and launched from a submarine; these are still in development. Most of the vehicles available today are intended for oceanographic applications, including pipeline monitoring and monitoring of undersea wires.

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543 EurekAlert. 2000. Future power source for undersea vehicles. Available at http://www.eurekalert.org/pub_releases/2000-03/OoNR-Fpsf-0503100.php [Accessed June 2006].

544 C&C Technologies. 2005. C-Surveyor AUV Description. Available at http://www.cctechnol.com/site40.php [Accessed June 2006].

545 EurekAlert. 2000. Future power source for undersea vehicles. Available at http://www.eurekalert.org/pub_releases/2000-03/OoNR-Fpsf-0503100.php [Accessed June 2006].

Regarding the potential for using fuel cells in UUVs, one respondent noted that UUV designers are limited by weight and volume. Fuel cells are used in some submarines, which are larger and therefore not as limited by weight and volume. Using a fuel cell in such vehicles allows them to stay underwater for weeks instead of just days. Historically, UUVs have been small for oceanographic purposes and larger for tactical purposes, but some UUV designers are beginning to consider making the vehicles even larger than tactical models. From a propulsion perspective, this would open up the possibility of using fuel cells because the engineers would not be as limited by weight and volume.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

Secondary research suggests that Li-ion batteries are sufficient for short, repetitive missions; however, certain situations are more conducive to fuel cell or hybrid use. Higher power density is required for large UUVs, prompting the use of fuel cells or hybrid propulsion systems. PEM fuel cells would permit extended run times that are not currently possible using rechargeable batteries.[546] PEM fuel cells also have the advantage of being closed-cycle, which allows them to operate continuously until all on-board fuel is consumed.[547] However, PEM fuel cells raise concerns because they represent a relatively immature technology.[548] Also, PEM fuel cells have shorter lives than hybrid systems and must eventually be refurbished. Hybrid diesel power plants have vastly superior energy capacity compared to present fuel cell technology. Hybrid diesel systems are also less costly, though fuel cell costs are expected to decrease over time.[549]

Primary research indicates that large UUVs have greater potential for using fuel cells than small, oceanographic models. As mentioned above, this is primarily due to fewer design restrictions in larger UUVs. Because fuel cells are still very much in the early test phase in UUVS, this is not considered a likely near-term market for PEM fuel cells.

546 Annati, M. 2005. UUVs and AUVs come of age. Military Technology. Available at http://www.fuelcelltoday.com/FuelCellToday/IndustryInformation/IndustryInformationExternal/NewsDisplayArticle/0,1602,6217,00.html [Accessed June 2006].
547 U.S. Department of the Navy. 2004. The Navy Unmanned Undersea Vehicle (UUV) Master Plan. Available at http://www.chinfo.navy.mil/navpalib/technology/uuvmp.pdf [Accessed June 2006].
548 Annati, M. 2005. UUVs and AUVs come of age. Military Technology. Available at http://www.fuelcelltoday.com/FuelCellToday/IndustryInformation/IndustryInformationExternal/NewsDisplayArticle/0,1602,6217,00.html [Accessed June 2006].
549 U.S. Department of the Navy. 2004. The Navy Unmanned Undersea Vehicle (UUV) Master Plan. Available at http://www.chinfo.navy.mil/navpalib/technology/uuvmp.pdf [Accessed June 2006].

RESEARCH SUMMARY:
SPECIALTY VEHICLES - WHEELCHAIRS

MARKET SEGMENT DESCRIPTION

Wheelchairs are used by people who find walking difficult due to illness, injury, or disability. Electric or powered wheelchairs are designed for use by people with limited use of their arms, since these vehicles do not require the user to roll the wheels manually. A joystick is commonly used to regulate the chair's speed and direction, though specialized control systems are available to accommodate individual user needs.[550] Table cc-1 identifies the SIC and NAICS classifications that cover manufacturing of wheelchairs.

Table cc-1. SIC and NAICS Codes for Wheelchair Manufacturing.

2-Digit SIC Code	38 – Measuring, analyzing, and controlling instruments; photographic, medical and optical goods; watches and clocks
4-Digit SIC Code	3842 – Surgical appliances and supplies
NAICS Code	339113 – Surgical appliance and supplies manufacturing

Powered wheelchairs typically fall into one of two categories, based on their configuration: 1) traditional style, which is basically an adapted version of a traditional manual wheelchair, and 2) platform style, which consists of a seating system mounted on a powered base. Many specialized wheelchairs are also available for specific uses, such as raising the user to a standing position, tilting and reclining the user, or enabling the user to climb stairs. Most powered wheelchairs fall into the platform-style category.[551] The wheelchair base is usually rectangular (though it can be circular to allow for a tight turning radius) and has four to six wheels. Rear- and front-wheel drive models are the most common, though mid-wheel drive models are available, as well. Most powered wheelchairs can be used both indoors and outdoors.

Wheelchairs range in weight from approximately 75 lbs to over 200 lbs without batteries.[552] Batteries (depending on type) can add 20 to 100 lbs to the weight of the vehicle.

Power wheelchairs are driven by an electric drive system that powers the chair's wheels. Rechargeable lead acid, gel cell, or sealed wet batteries may be used in wheelchairs. Gel cell batteries are less likely to leak and require less maintenance than other battery types. Also, some airlines will only transport powered chairs that use gel cell batteries.[553] All batteries are intended to be recharged daily, using a battery charger that plugs into a standard electrical wall outlet.

The type and size of batteries used determine the range and power capabilities of a powered wheelchair. Many chairs operate on two 12V, deep-cycle batteries. Among the many size codes of deep-cycle batteries available, wheelchairs typically use Group U1, Group 22, Group 24, and

[550] ORC Macro. 2006. Fact Sheet on Powered Wheelchairs. Available at http://www.abledata.com/abledata_docs/Powered_Wheelchairs.htm [Accessed June 2006].
[551] ORC Macro. 2006. Fact Sheet on Powered Wheelchairs. Available at http://www.abledata.com/abledata_docs/Powered_Wheelchairs.htm [Accessed June 2006].
[552] Information obtained through review of wheelchair products available for online sale at 1-800-wheelchair.com. Category: Power Wheelchairs. Available at http://www.1800wheelchair.com/asp/view-category-subcats.asp?Category_id=298&src=sn [Accessed June 2006].
[553] ORC Macro. 2006. Fact Sheet on Powered Wheelchairs. Available at http://www.abledata.com/abledata_docs/Powered_Wheelchairs.htm [Accessed June 2006].

Group 27 batteries.[554,555] Group U1 batteries typically range in capacity from 34 to 40 amp-hours; Group 22 batteries range from 43 to 55 amp-hours; Group 24 batteries range from 70 to 85 amp-hours; and Group 27 batteries range from 85 to 105 amp-hours (note: all ranges are approximate).[556] Group 24 batteries provide a reasonably long range and are growing increasingly popular among wheelchair designers.[557]

Wheelchairs are somewhat unusual compared to other specialty vehicles in that their costs are not typically borne by the end-users. Wheelchair expenses are primarily funded by private medical insurance and government programs such as Medicare and Medicaid.[558] An online review of retail prices for products offered by major wheelchair manufacturers indicated that traditional powered wheelchairs typically range from $1,300 to $5,200, with an average price of approximately $2,500. Platform wheelchairs range from $1,400 to $11,000, with an average price of approximately $5,500.[559] Deluxe or specialized models can far exceed average prices.[560] Additional information about unit costs is provided in Tables cc-3 and cc-4.

MARKET SIZE

Current data on the size of the wheelchair manufacturing market are provided below. SIC Code 3842, covering manufacturing of wheelchairs, is represented by Table cc-2. Only the eight-digit SIC Code specialty relevant to wheelchairs is shown. Note that this specialty encompasses all wheelchair manufacturers, not just makers of electric models.

Table cc-2. Number of Wheelchair Manufacturers - Industry: Surgical Appliances and Supplies (3842).

SIC Code	SIC Description	Number of Businesses	Total Employees	Total Sales ($)
3842-0420	Wheelchairs	176	4,494	1,232.7
	Total	**176**	**4,494**	**1,232.7**

Sales figures are in millions. Source: www.zapdata.com, accessed June 2006.

Data specific to powered wheelchairs and specialized wheelchairs, which may include some powered models, are presented in Tables cc-3 and cc-4. Table cc-3 illustrates demand for standard powered wheelchairs from 1992 through 2012 (anticipated). Table cc-4 illustrates demand for specialized wheelchairs. As evidenced by these tables, demand for standard powered wheelchairs has been decreasing as a percentage of the wheelchair market and is expected to drop from 28.2% in 2002 to 25.9% in 2012. However, sales of standard powered wheelchairs are expected to increase from 80,000 in 2002 to 125,000 in 2012. Unit costs also are expected to increase over this same time period. Demand for specialized wheelchairs, on the other hand, is expected to increase as a percentage of total wheelchair sales from 2002 to 2012, with sales of bariatric wheelchairs (designed

[554] ORC Macro. 2006. Fact Sheet on Powered Wheelchairs. Available at http://www.abledata.com/abledata_docs/Powered_Wheelchairs.htm [Accessed June 2006].
[555] DiGiovine, C.P. and R. Cooper. 2000. Battery Power & You: How to Choose. SpinLife.com, LLC. Available at http://www.spinlife.com/spintips/spintipsdetails.cfm?artid=121&typeid=171 [Accessed June 2006].
[556] Northern Arizona Wind & Sun, Inc. 2006. The Ultimate FAQ for Deep Cycle Battery Basics and Information. Available at http://www.windsun.com/Batteries/Battery_FAQ.htm#Using%20a%20deep%20cycle%20battery%20as%20a%20starting%20battery [Accessed June 2006].
[557] ORC Macro. 2006. Fact Sheet on Powered Wheelchairs. Available at http://www.abledata.com/abledata_docs/Powered_Wheelchairs.htm [Accessed June 2006].
[558] Wikimedia Foundation, Inc. 2006. Wheelchair. Available at http://en.wikipedia.org/wiki/Wheelchair [Accessed June 7, 2006].
[559] Information obtained through review of wheelchair products available for online sale at 1-800-wheelchair.com. Category: Power Wheelchairs. Available at http://www.1800wheelchair.com/asp/view-category-subcats.asp?Category_id=298&src=sn [Accessed June 2006].
[560] ORC Macro. 2006. Fact Sheet on Powered Wheelchairs. Available at http://www.abledata.com/abledata_docs/Powered_Wheelchairs.htm [Accessed June 2006].

to meet the needs of obese patients), in particular, expected to nearly double between 2002 and 2007.[561] Specialized wheelchairs can be either manual or powered; therefore, the figures in Table cc-4 are not intended to represent the market for powered wheelchairs exclusively.

Table cc-3. Demand for Standard Powered Wheelchairs and Other Personal Mobility Devices: 1992-2012.

	1992	1997	2002	2007	2012
Wheelchair Market ($ million)	321	508	745	1050	1450
Percent (%) powered	30.5	28.9	28.2	26.2	25.9
Standard Powered Wheelchair Sales ($ million)	98	147	210	275	375
Cost ($)/Unit	2175	2450	2625	2750	3000
Standard Powered Wheelchair Sales ($000's)	45	60	80	100	125
Powered Scooters Sales ($ million)	88	143	205	300	425
Cost ($)/Unit	1175	1360	1520	1715	1890
Powered Scooters Sales (000's)	75	105	135	175	225

Source: Adapted from The Freedonia Group, Inc. 2003. Wheelchairs & Other Personal Mobility Devices to 2007. Report Number 1745.

Table cc-4. Demand for Specialized Wheelchairs: 1992-2012.

	1992	1997	2002	2007	2012
Wheelchair Market ($ million)	321	508	745	1050	1450
Percent (%) specialized	22.7	29.3	34.9	40.5	43.1
Specialized Wheelchair Sales ($ million)	73	149	260	425	625
Sports	30	70	115	175	250
Bariatric	7	23	60	115	175
Pediatric	12	17	25	35	50
Other Specialized	24	39	60	100	150
Cost ($)/Unit	1325	1490	1675	1890	2085
Specialized Wheelchair Sales ($000's)	55	100	155	225	300

Source: Adapted from The Freedonia Group, Inc. 2003. Wheelchairs & Other Personal Mobility Devices to 2007. Report Number 1745.

The user market for powered wheelchairs is expected to grow steadily through 2012. In 2002 there were 1.8 million wheelchair users; this figure is expected to reach 2.1 million and 2.4 million by 2007 and 2012, respectively.[562]

Major wheelchair manufacturers include Invacare Corp.; Medline Industries, Inc.; Graham-Field Health Products, Inc.; Electric Mobility Corp.; Sunrise Medical Inc.; Pride Mobility Products Corp.; Hoveround; and Convaid Inc.

MARKET TRENDS

Major wheelchair manufacturers do not appear to be devoting significant resources to identifying alternative power sources. Batteries are viewed as convenient and safe energy sources for these vehicles. However, a few companies were found to be conducting R&D in this area.

[561] The Freedonia Group, Inc. 2003. Wheelchairs & Other Personal Mobility Devices to 2007. Report Number 1745. Cleveland, OH, The Freedonia Group, Inc.
[562] The Freedonia Group, Inc. 2003. Wheelchairs & Other Personal Mobility Devices to 2007. Report Number 1745. Cleveland, OH, The Freedonia Group, Inc.

In 2003 a Canadian fuel cell manufacturer, Palcan Fuel Cells Company, supplied several PEM fuel cell products to Chinese organizations, including a 1.5 kW PEM fuel cell stack for use in a wheelchair.[563]

Also in 2003, Kurimoto, Ltd. of Japan developed a fuel cell wheelchair in cooperation with Asia Pacific Fuel Cell Technologies, which was demonstrated at the 15th World Hydrogen Energy Conference. The wheelchair is powered by a 250 W PEM fuel cell, is just under one meter high, and weighs about 80 kg.[564] It has a range of 38 miles and runs 3.7 mph.

Besel of Spain is working with fuel cell maker Axane (France), and electric wheelchair manufacturer Meyra (Germany) to engineer and test a wheelchair. The wheelchair has a 500 W fuel cell with two 2-liter Hydrogen cylinders at 700 bar stored under the seat. Market launch is expected to be just a couple of years away.[565]

In 2006, Suzuki Motors announced that it had produced a prototype fuel cell wheelchair – the MIO. The MIO is a motor-driven cart powered by a methanol cell that is backed up by a Li-ion battery. The wheelchair can run 25 miles or more with one recharge (4 liters) of methanol solution.[566]

MARKET SEGMENT ANALYSIS

To identify the market opportunities for direct PEM fuel cells, wheelchair manufacturers were contacted. Ten manufacturers were contacted, and three responses were received. No users were contacted, as it was not considered feasible to identify wheelchair users.

One large power wheelchair manufacturer and two medium-sized manufacturers of personal mobility devices and other types of healthcare equipment responded. One manufacturer offered power wheelchairs only, whereas the other two offered power wheelchairs as well as manual and specialized (e.g., racing) models. All manufacturers offered electric (battery-powered) wheelchairs.

Regarding downtime, all manufacturers noted that it would be devastating to anyone who depends on a wheelchair for mobility. However, two of the three manufacturers pointed out that downtime is extremely rare, since users know they must recharge their batteries daily.

O&M requirements for wheelchairs are minimal. The industry switched to sealed lead-acid or absorbed glass mat (AGM) batteries years ago, which do not require refilling. The batteries are recharged using a charger, which plugs into a standard electrical outlet. One wheelchair manufacturer that also offers personal mobility scooters noted that users sometimes forget to recharge these scooters, which are frequently left in cars for days at a time. The same manufacturer noted that wheelchair users occasionally forget to recharge their chairs every night.

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563 The Freedonia Group, Inc. 2003. Wheelchairs & Other Personal Mobility Devices to 2007. Report Number 1745. Cleveland, OH, The Freedonia Group, Inc.
564 Adamson, K. 2005. Fuel Cell Today Market Survey: Niche Transport (Part 1). Fuel Cell Today (August).
565 Adamson, K. and M. Hugh. 2006. Hannover Fair, Fuel Cell and Hydrogen Group Exhibit Event Report. Fuel Cell Today (February 5, 2006).
566 No author. 2006. Suzuki unveils fuel cell-powered wheelchair. Fuel Cell Today (September 27, 2006). Available at: http://www.fuelcelltoday.com/FuelCellToday/IndustryInformation/IndustryInformationExternal/NewsDisplayArticle/0,1602,8256,00.html [Accessed October 2006].

In general, manufacturers seemed pleased with the performance of batteries in their products. No safety concerns were identified. However, one manufacturer noted that batteries add a significant amount of weight to the vehicles.

All three manufacturers were aware of PEM fuel cells as a potential substitute for batteries; one had significant experience with fuel cells based on a past position with a major automaker. Two of the three manufacturers have considered using fuel cells as a power source; however, one respondent commented that there are no commercially available fuel cell products for his company to try and that the technology is impractical in its current stage of development. The other manufacturer has been investigating the use of PEM fuel cells in an on-board charging system. This system is based on a small fuel cell that can run continuously from a hydrogen cylinder. It will be used to charge the batteries that power the vehicle (instead of using an electrical outlet). The unit being tested is approximately the size of a shoebox and is not expected to be production-ready for at least 2 years.

Manufacturers evaluate alternative power sources by considering what is safest, most reliable, and most practical for the user. The respondent who is investigating the fuel cell-based charging system suggested that some of his customers would pay for the convenience of not having to plug in their wheelchairs. Reliability, quietness, and ability to meet the power draw requirements of the vehicle were identified as key factors in selecting an alternative power source. One manufacturer indicated that fuel cells would be a viable power source for wheelchairs, but only as a supplement to batteries (i.e., in a charging system). The same respondent indicated that the technology would need to be developed enough to lower costs and improve hydrogen storage issues before it could be commercially feasible. However, many wheelchair users already have oxygen tanks attached to their chairs; therefore, they are familiar with handling compressed gas cylinders.

Several barriers to fuel cell use were identified, including high cost, maintenance requirements, and the lack of a practical hydrogen distribution system. One manufacturer pointed out that wheelchair users are often economically limited; the respondent also suggested that it would be difficult to improve upon the convenience of current recharging methods.

Perceptions of hydrogen safety issues were mixed. One manufacturer felt that customers would not have a problem. Another was unsure, and the third felt that his customers might have an issue with using hydrogen.

Similarly, interest in working with the DOE to develop fuel cell-based wheelchairs was mixed. One manufacturer was eager to be considered for such a collaboration, while the other two were reluctant to commit one way or the other. All three manufacturers agreed to be contacted again if needed.

POTENTIAL OPPORTUNITIES FOR PEM FUEL CELLS

There appears to be potential for the PEM fuel cells to power wheelchairs, and potentially as supplemental power source to battery systems. Wheelchair manufacturers are aware of PEM fuel cells and at least a few have considered them as an alternative power source. Several prototypes are under development and are expected to be commercially ready in the next few years. Primary research did not suggest that wheelchair users are actively seeking a replacement for batteries, which have no emissions and can be conveniently recharged in the home. However, recharging is a daily burden that, as one wheelchair manufacturer noted, users sometimes forget or are unable to do before going to sleep. A hybrid fuel cell/battery system would eliminate the need for nightly recharging.

Because the competing technology is relatively clean and safe, added convenience and practicality would be the main drivers for using PEM fuel cells in wheelchairs. These include vehicle weight reduction, if heavy lead-acid batteries were entirely replaced by a fuel cell, and elimination of the need for daily recharging with combination fuel cell/battery power.

Barriers to fuel cell use in wheelchairs include:

- Cost of hydrogen fuel
- Lack of commercially available PEM fuel cell systems appropriate for use in wheelchairs, as prototype systems are still thought to be a few years away from market entry
- Lack of practical hydrogen distribution system; wheelchair users are often travel-restricted and must have fuel delivered to them.

While it is not known how users would react to hydrogen as a fuel source, it is thought that this will not be a barrier as many wheelchair users require oxygen and are familiar with the use of gas storage tanks.

Finally, the fact that wheelchairs are often paid for by Medicare instead of the user could be either a driver or barrier to entry. The government has significant buying power and a policy that creates incentives for Medicare patients to demonstrate PEM fuel cell technology could have a measurable impact on the market. Without such direction from the government, however, individual users may have little leverage in requesting more costly, experimental wheelchair systems through their Medicare programs.

In general, this market is ripening but given the maturity of the technology, it does not represent a likely near-term market. User interest in the technology should be monitored to determine what the potential for PEM fuel cell powered wheelchairs may be in the mid-term.

Battelle

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