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AN ANALYSIS OF LESSONS LEARNED AND BEST PRACTICES FROM FUEL CELL APPLICATIONS WITH AN EMPHASIS ON HYDROGEN TECHNOLOGY

by

CLINTON ALEX COTTRELL

A THESIS

Presented to the Faculty of the Graduate School of the

MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

In Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE IN ENGINEERING MANAGEMENT

2009

Approved by

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ABSTRACT

In its review of the Department of Energy's Research Development and Demonstration (RD&D) plan for hydrogen, the National Academies recommended a study of lessons learned from technologies developed for stationary fuel cell power systems. Thus, the motivation for this thesis is to study and identify the lessons learned and best practices from prior stationary fuel cell power programs.

To understand how to prepare for this technology, this study conducted a thorough investigation of past stationary alternative power projects to assess the opportunities for future stationary power efforts, and how this information can be used to meet objectives for future fuel cell programs. Fuel cell markets and applications are studied to analyze the current advantages/disadvantages of each fuel cell type versus their coinciding applications. These advantages and disadvantages can be used by potential fuel cell end-users to aid in deciding if a fuel cell would be feasible for the intended application.

Other results include conclusions drawn from a stationary fuel cell survey, which was distributed through the National Fuel Cell Council and to the attendees of the 2008 Fuel Cell Seminar. The survey results include a synopsis/critical analysis of lessons learned from previous stationary power programs, which has been taken into consideration in order to make recommendations related to RD&D strategies that incorporate lessons learned and best practices from relevant hydrogen fuel cell stationary power efforts.

ACKNOWLEDGMENTS

I would first and foremost like to thank my advisor, Dr. Scott E. Grasman, for sharing his knowledge and guidance. I would also like to thank my committee members Dr. Suzanna Long and Dr. Katie Grantham Lough. Special acknowledgements go to The Department of Energy for funding my research. Of course, none of my accomplishments would have been possible without the constant support of my parents, Bill and Cindy Cottrell. Thank you for giving me the opportunity and tools needed to succeed.

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1. INTRODUCTION

1.1. MOTIVATION OF STUDY

The scientific community has experienced a renewed interest in hydrogen as an energy carrier due to the benefits of hydrogen as an alternative energy source. Initial support for hydrogen as an energy carrier began in the 1920s, but interest slipped during World War II since the technology at the time didn't provide much use in the war efforts. A second wave was initiated in the 1960s, but again support dwindled after the energy crisis subsided in the 1970s. Historically, when traditional energy prices rise, there is a profoundly correlated rise of interest in alternative fuel technology, but when the prices fall, the interest tends to dwindle quite significantly. With such fluctuating support, especially in the crucial area of research and development, fuel cell and hydrogen markets still face an uphill battle in regard to mass market penetration. However, the differentiating factor with this current wave of interest is that, unlike the previous two, it has gained support from industry, as well as a continuously growing level of government backing. This government backing is caused by a growing understanding of the need to decrease the national dependence on foreign oil and decrease the environmental impacts caused by our current transportation and energy usages. For example, working with industry, academia, and the national labs, the Department of Energy (DOE) has developed a long-term plan for moving toward widespread implementation of hydrogen technologies [1].

Fuel cells are a compelling and challenging subject in the field of stationary and portable alternative power applications. The use of hydrogen in fuel cells is widely known to be much more electrically efficient when compared to incumbent technologies, e.g., internal combustion engines in backup power applications. The use of fuel cells leads to higher quality of energy with fewer waste products, but the higher electrical efficiency of fuel cells does not always compensate for their high initial costs. In other words, the vast majority of fuel cell applications have yet to be proven cost competitive.

It is quite valuable to study the lessons learned from past and current stationary and portable fuel cell power programs and to investigate the best practices applied throughout the lifetimes of such programs. The results presented in this thesis address the most significant obstacles of the fuel cell projects, how these obstacles were approached, outcomes of the programs (based on whether specific site power requirements were met and whether the expected financial success was realized), and how this information can be used to meet objectives for future distributed stationary and portable power systems.

The purpose of this thesis is to evaluate both previous and existing fuel cell applications in order to provide future fuel cell users with a better initial understanding of the best way to confront significant obstacles and how to best meet the objectives of their planned fuel cell stationary power systems. The lessons learned from the programs are used in order to establish best practices and provide recommendations for a hydrogen strategy that addresses opportunities for hydrogen in power generation systems based on both technical and financial feasibility.

1.2. FUEL CELL BACKGROUND AND LITERATURE REVIEW

As stated in the introduction, the latest wave of interest in hydrogen has its roots in the 1960s and 1970s [2]. Starting in the late 1990s, researchers began to evaluate potential alternative energy infrastructures with strong arguments advocating hydrogen as an alternative fuel [3-6]. Although numerous ideas have been presented in regard to meeting the projected increased hydrogen demands created by the introduction of hydrogen vehicles, the development of a hydrogen infrastructure is one of the main unsolved issues impeding the migration to a sustainable hydrogen economy. In addition, the need to alleviate the strain on the existing power grid, while still meeting the projected power demands, through the use of alternative distributed stationary power generation is of primary importance.

While the literature on stationary power generation is quite vast, only a select few will be presented. Adamson [7] conducted a market survey of large stationary applications and found there to be a slight increase in fuel cell sales from 2007 to 2008. Brdar et al. [8] profiled a variety of projects in both manufacturing and service sectors, including the value propositions and objectives, and worldwide analysis is provided that relates drivers, market potentials, and industrial partners. On a regional basis, Nishikawa [9] provided a description of a current large-scale demonstration in Japan, Garibaldi [10] presented a summary of Italian hydrogen parks and projects, and Tulloch [11] outlined a business plan for the Hebridean Hydrogen Park in the UK. Thousands of other fuel cell projects from all over the globe can be found in the links provided in Appendix A.

To develop a hydrogen infrastructure, a variety of production and distribution options should be considered. Prospects for building a hydrogen energy infrastructure were presented in Ogden [4], which reviewed the current status of technologies for hydrogen production, storage, transmission, and distribution, plus described potential areas for future research. Figure 1.1 shows a visualization of the challenges hydrogen faces in regards to fuel source, production, distribution, storage, and utilization.

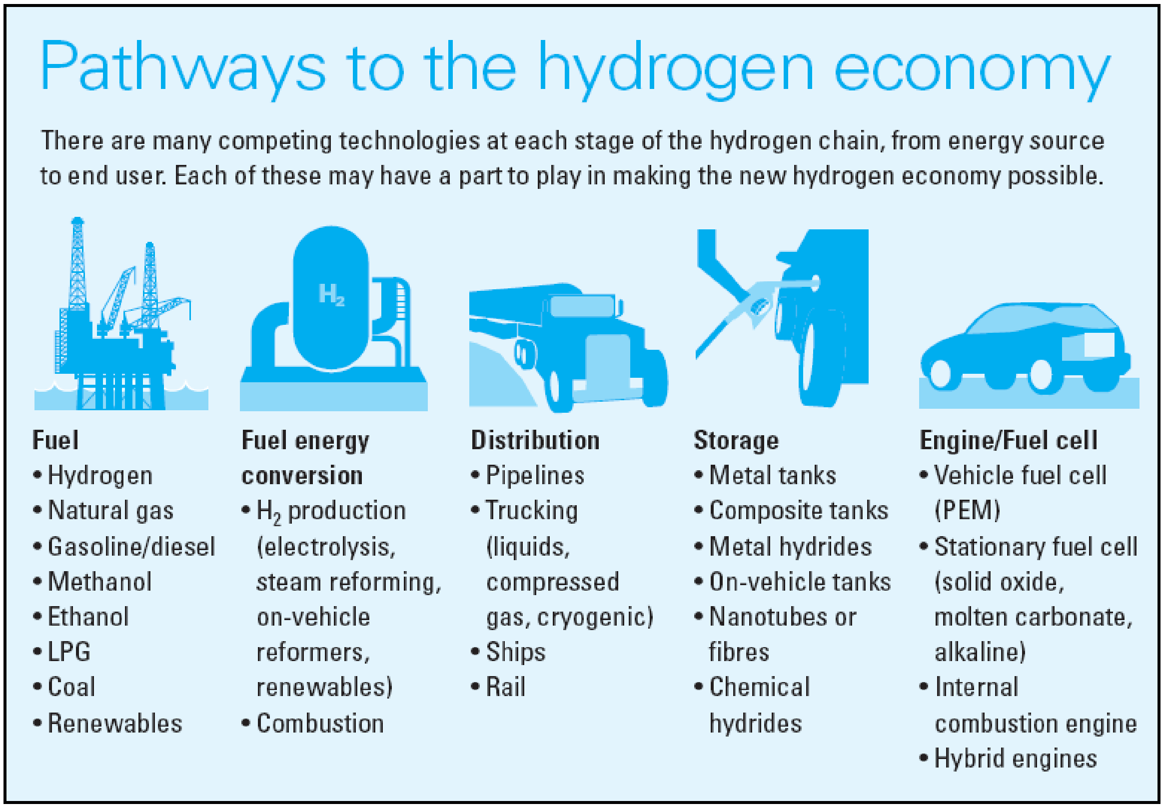


Figure 1.1. Hydrogen Pathways [12]

Mintz et al. [13] discussed several infrastructure alternatives and the associated cost of the delivered hydrogen. A self-reported limitation of the study is that the analysis assumed little effect from technology and infrastructure maturation; nor does it consider phased technology development. Winebrake and Creswick [14] performed a perspective-based scenario analysis of various production methods using the analytic hierarchy process. While the paper provides a comparison of various supply mechanisms, it does not discuss the implementation of a suitable supply network. Cook [15] discussed the key investment points for fuel cells as well as various reasons for the slow adoption of fuel cells in the mass market. Cruden et al. [16] presented a view on the current state of commercialization of fuel cell technology for stationary power applications and provided an overview of fuel cells as a form of distributed generation within the context of a highly distributed power system. Ricci et al. [17] gave an in-depth critical review of literature regarding public perceptions and acceptance of hydrogen.

Technical fuel cell basics are discussed in great detail in the Fuel Cell Handbook [18], which also contains a large amount of information regarding the dominant fuel cell types: Polymer Electrolyte Membrane (PEM) Fuel Cells, Alkaline Fuel Cells (AFC), Phosphoric Acid Fuel Cells (PAFC), Molten Carbonate Fuel Cells (MCFC), Solid Oxide Fuel Cells (SOFC), and Direct Methanol Fuel Cells (DMFC). Figure 1.2 shows which fuels are predominantly used in popular fuel cell applications.

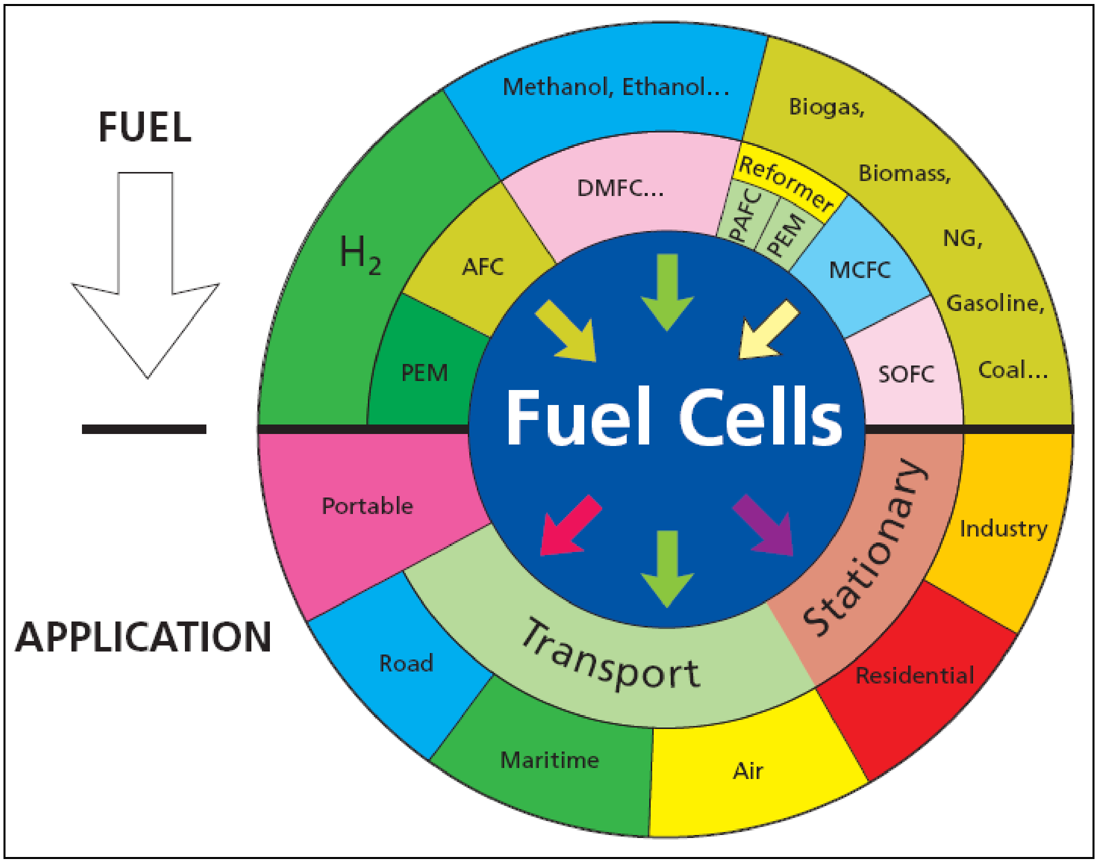


Figure 1.2. Fuel Source vs. Fuel Cell Application [19]

Mueller et al. [20] discuss the off-grid applications for SOFCs and the capability and limitations of such applications. Elgowainy et al. [21] analyzes the early market applications for material handling vehicles (MHV), as well as the applications for distributed power generation, including applications for PAFC, SOFC, and MCFC, and PEM fuel cells. Varkaraki et al. [22] provide results for a successful test of a PEM fuel cell used in an uninterruptable power supply (UPS) application. Braun et al. [23] discuss the use of SOFC in residential and combined heat and power (CHP) applications, whereas Zabalza et al. [24] show a feasibility analysis of CHP applications for PAFC, MCFC, SOFC, and PEM fuel cells. Mahadevan et al. [25] show an in depth analysis of the cost effectiveness of backup power and MHV with use of PEM fuel cells.

During the literature review process, it was discovered that there was little literature regarding lessons learned or established best practices in each fuel cell application and related fuel cell types. The remainder of this thesis is organized as follows. Section 2 gives a description of the approach and methodology, Section 3 describes the results of a survey distributed by the author, Section 4 lays out the lessons learned from previous fuel cell programs, Section 5 provides the best practices developed during the study, and Section 6 gives the final conclusions of this study.

2. STUDY DESCRIPTION

2.1. APPROACH AND METHODOLOGY

Over the past two decades, a number of approaches have been used to encourage the application of alternative fuels and related technologies in transportation and stationary systems. Most of these approaches have failed because of the lack of a real marketplace, shifts in government policies, and/or the relative lack of interests from industry. Lessons learned with respect to the lack of success and widespread market acceptance of previous alternative fuel technologies, as well as other technologies developed for transportation and stationary power systems should be used to provide recommendations for future hydrogen infrastructure development strategies. Therefore, this study will analyze different strategies utilized in past and existing power generation systems, perform a critical and encompassing review of literature on existing strategies (implemented or theoretical) for the development of hydrogen infrastructure, and obtain necessary data for development of strategic suggestions.

Though supported by the DOE, both DOE and non-DOE funded projects were included in the study. As stated in the Introduction, Appendix A lists a consolidation of fuel cell installation databases that were used to identify fuel cell projects around the world. The lessons learned from these programs were used to develop best practices aimed at avoiding repeating the mistakes of prior-technology-introduction programs through recommendations for a hydrogen strategy, specifically opportunities for hydrogen in stationary power generation systems.

In addition to literature review and analysis of past projects, a survey was conducted, relevant conferences were attended, meetings with fuel cell users were held, and specific fuel cell site visits took place in order to identify the different challenges and opportunities for producing and using hydrogen as an energy carrier. Participants involved with decommissioned fuel cell sites proved to be quite informative since they have a vast knowledge concerning projects from start to finish, as well as answers to questions pertaining to why past projects have either succeeded or failed.

The survey was developed to gather general information of respondents' fuel cell programs and was initially distributed to the National Fuel Cell Council and attendees of the 2008 Fuel Cell Seminar. This pool of potential survey respondents was selected to participate because, in their line of work, they were the most likely candidates to have had experience with stationary fuel cell powered programs. The survey's primary target audience was end-user fuel cell customers rather than the fuel cell manufactures/suppliers in order to discover the strategies used for the introduction of alternative stationary power technology at the end user level. A workshop was then held at the 2009 National Hydrogen Association Conference and Expo to follow-up the initial results from the survey and to gather opinions on near-term market hydrogen applications and policy recommendations.

The survey solicited relevant data regarding past and existing stationary and portable fuel cell programs to determine:

- technology status at the time of introduction,
- strategies used for the introduction of the alternative stationary and portable power technology,
- environmental benefits or impacts,
- overall consumer behavior and attitudes towards to new technology,

- industry participation or lack thereof,
- impact of infrastructure availability,
- cost-effectiveness of the program with respect to the program's overall investment vs. market success or failure,
- description of challenges and how such challenges were approached and overcome, and
- the major achievements of the programs or justification for lack of success.

2.2. SURVEY DEVELOPMENT

The survey contained 37 questions and took approximately 15 minutes to complete. Along with many quantifiable questions used to determine size, year and type of application, many of the survey questions were open-ended in order to solicit personal opinions for lessons learned and best practices. Though such data may not always be quantifiable, it is vital to recognize and understand specific opinions of the end users if accurate conclusions are to be drawn regarding what actions need to be taken and what recommendations need to be made to avoid the complications past users have had to endure.

The survey was developed with tools from the website http://www.surveymonkey.com. The survey is separated into nine sections comprised of questions based on similar topics. The first section describs the survey as a whole so the potential respondent could decide whether or not to participate, the next four sections are based around the respondents fuel cell program (mainly quantifiable data), the next three sections are based around the opinions of fuel cell markets and applications, and the last section asks the respondents to provide optional contact information. The development of each section will now be discussed briefly. (The survey responses will be discussed in Section 3 and full survey raw data is compiled in Appendix A)

2.2.1. Part 1: Survey Description. Part One contains two questions. Question 1 explains the study's background information, confidentiality information, and asks if the respondent would like the final results of the survey emailed to him/her. Question 2 asks if the respondent is willing to answer any follow-up questions that may arise after his/her responses were reviewed.

2.2.2. Part 2: Program Data. Part Two contains nine questions. Questions 3 to 6 inquire about the date of implementation and location of each fuel cell project. Questions 7 to 11 ask about the type of application, manufacturer, fuel, and energy source of the respondent's fuel cell program.

2.2.3. Part 3: Program Data Continued. Part Three is a seven question (Questions 12 to 18) extension of Part Two that inquirs about the available and actual operation time of the fuel cell, the number and size (kW) of units used in operation, co-generation and tri-generation capabilities, and the technology status at the time the fuel cell was introduced.

2.2.4. Part 4: Outcomes. Part Four contains three questions meant to gain information regarding the success or failure of the respondents' fuel cell projects. The first question of this section, Question 19, asks for major achievements of the respondent's fuel cell program, Question 20 asks the respondent to rate the availability of infrastructure required to meet their needs, and Question 21 asks whether the fuel cell project was cost-effective.

2.2.5. Part 5: Lesson Learned. Part 5 contains three questions that ask the respondents to identify the most significant obstacles in the programs and how those obstacles were approached (Question 22), the general consumer behavior and attitudes toward the fuel cell applications (Question 23), and the role of codes and standards in the installation (Question 24).

2.2.6. Part 6: Early Market Applications. Part Six contains three questions aimed at soliciting the opinions of the respondent related to early fuel cell markets. Question 25 asks the respondents to give their opinion as to what applications are most promising for early market introductions, Question 26 asks the respondents what role they believed niche markets played in early market applications, and Question 27 asks what technological or policy breakthroughs are needed to implement hydrogen applications.

2.2.7. Part 7: Policy Instruments. Part Seven is based around the respondents' opinions of government involvement in the fuel cell industry. Question 29 asks what should/can be done related to policy to promote technical R&D and market competitiveness, and Question 30 asks what sort of technical and economic synergies (with, for example, transportation or competing technologies) can be leveraged. Questions 31, 32, and 33 ask about different government support, initiatives, and tax incentives that were used in the respondents' fuel cell programs. Questions 34 and 35 ask whether government support affected their decision to install a fuel cell and whether the installation of a fuel cell was a response to government regulations.

2.2.8. Part 8: Any Additional Info. Question 36 asks the respondents to provide any additional input they might have regarding early market development strategies for stationary power generation.

2.2.9. Part 9: Contact Information. Question 37 asks the respondents to provide their contact information if they were interested in receiving the results from the study or if they volunteered for follow-up questions in Question 2.

3. EARLY MARKET DEVELOPMENT STRATEGIES FOR STATIONARY POWER GENERATION SURVEY RESULTS

The analysis of the results from the survey is a key step in the main goal of the research: to develop lessons learned from stationary power generation in regards to Ahydrogen fuel cell analysis. The results highlighted in this section from 82 respondents who took this survey. Full detailed and unaltered input (e.g. misspelled words) may be found in Appendix B.

3.1. PROGRAM DATA (PARTS TWO AND THREE, QUESTIONS 3 TO 18)

Question 3 asked to provide information on how many years had elapsed between initial planning and implementation of the respondent's fuel cell project. It is important to evaluate this duration of time so as to better understand how much time was used for risk analysis, budget management, cost-benefit analysis, and verifying that their site met applicable codes and standards. From information acquired during the NHA workshop, which will be discussed in Section 5, codes and standards play a pivotal role between initial planning and implementation due to the fact that local regulating commissions can delay the building of on-site hydrogen storage. This delay is often due to improper steps taken to insure the site was up to applicable codes and standards. Of the respondents who were able to answer the question with confidence, 63.9% of the respondents stated the time between initial planning and implementation was 2 years or less. This shows quick action was taken to get a large majority of the projects operational and that few obstacles stood between initial planning and actual implementation. Also, from the information acquired in Question 4, two-thirds of the projects became operational between the years of 2005 and 2008, which shows there has been a large push for fuel cell implementation in recent years. This push is most likely due to factors including support for alternative energy solutions, rising energy costs, and the current mainstream energy production environmental impacts.

The duration of time in which the fuel cell was in operation is also a critical statistic for this study since initial planning incorporates a significant portion of initial costs. Figure 3.1 shows that the largest percentage (44.83%) of the respondent's fuel cell programs are still in operation, which indicates a correlation to a trend of increasing life expectancy of fuel cells. Although the 24.14% of projects with less than one year of operation seems to point to the contrary, further analysis of the data shows that most of these projects purpose was to prove and demonstrate the concept. Since proof of concepts and demonstrations rarely last longer than one year, it is apparent why 24.14% of the respondents had a project whose lifespan was within such a timeframe.

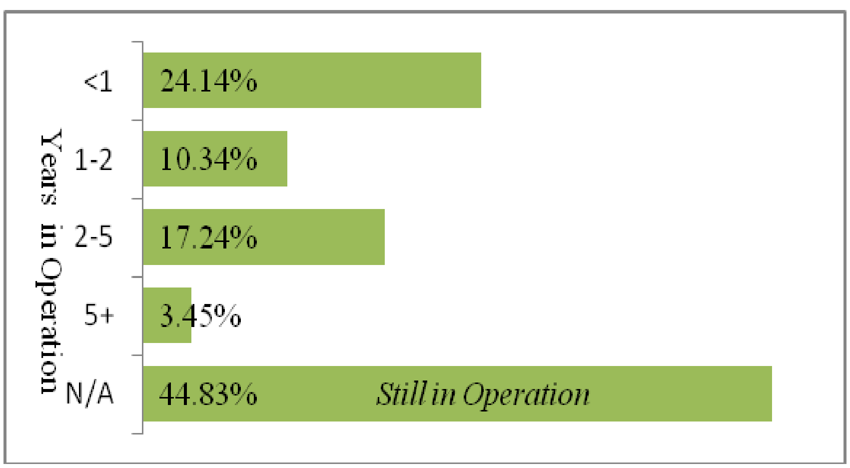


Figure 3.1. Responses to Question 5, "If the fuel cell is no longer operational, how many years did it operate?"

Question 6 asked about the geographic locations of the fuel cell site. The leading state represented in the survey was California with 5 respondents but there were fuel cell sites located from coast to coast in the United States and also sites located in Canada and Europe.

Another important round of questions asked the respondents to discuss the types of application implemented in their programs (Question 7), which type of fuel cell was installed (Question 8), the fuel cell manufacturer (Question 9), and what type of fuel was used in the program (Question 10). Not surprisingly, the vast majority of fuel cell projects were fueled by hydrogen and natural gas, 54.05% and 24.32% respectively, with other fuel sources being JP-8 (kerosene based Jet Propellant), LPG (Liquefied Petroleum Gas), and methanol. From the results from Question 11 it is shown that of those programs which used hydrogen, many used on-site renewable resources such as wind, solar, and biomass. This supports many fuel cell advocates' opinions that suggest hydrogen could be the future for alternative energy stationary power applications.

The popular types of applications used by the pool of respondents were backup power, material handling equipment, and grid independent power. As shown in Figure 3.2, backup power is the dominant application used by the respondents.

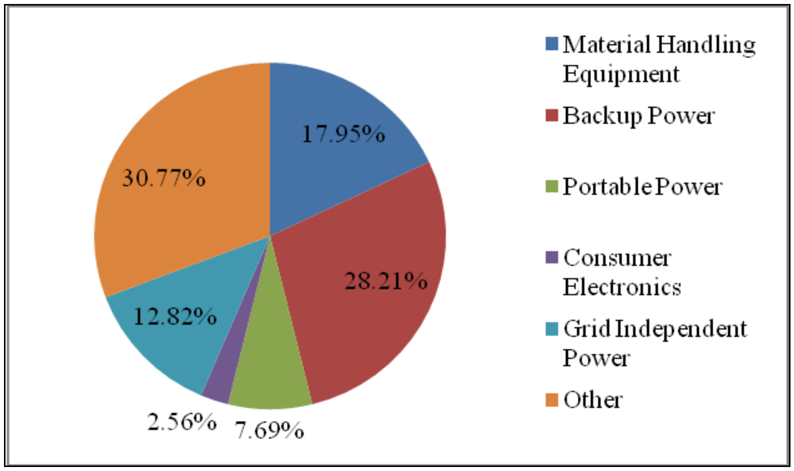


Figure 3.2. Responses to Question 7, “What type of application was implemented in your program?"

Due to this result, it was not surprising to discover that 66.67% of the programs used Proton Exchange Membrane (PEM) fuel cells as shown in Figure 3.3. PEMs are the leading type of fuel cells used in backup power due to their potential to have significant cost advantages over battery and battery-generator systems when run-time capability of up to three days is sufficient [25].

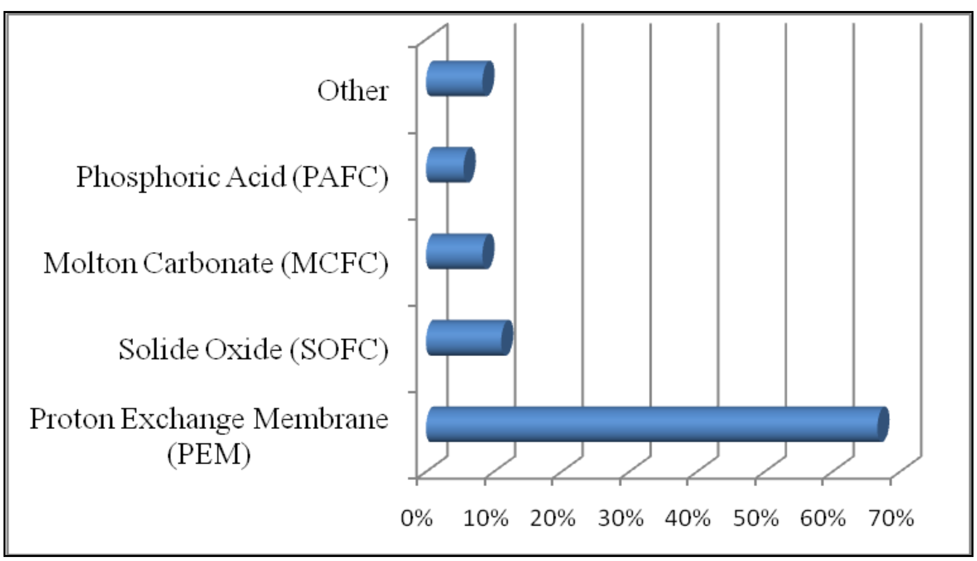


Figure 3.3. Responses to Question 8, “What type of fuel cell was installed?"

Intriguingly, of those types of applications shown in Figure 3.3, 30.77% were grid connected systems, which encourages optimism for future fuel cell projects that wish to take advantage of grid connected systems and the opportunities they provide for backup power and reliability [26].

Figure 3.4 shows the percentage of time fuel cell was available to operate. As can be seen in Figure 3.4, the percentage of time the respondents' fuel cells were available for operation gave mostly optimistic results with 63.3% being available over 90% of the project lifetime.

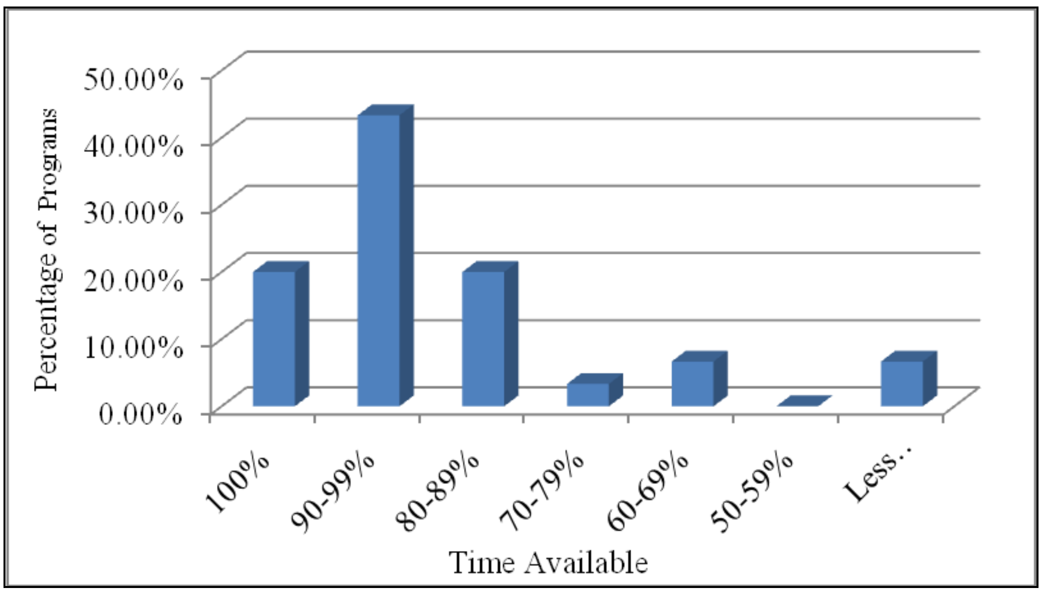


Figure 3.4. Responses to Question 12, "What percentage of time was the fuel cell available to operate?"

Figure 3.5 shows how many units were in operation in each fuel cell program (Question 13). This data ties together both of the previous figures since there is a correlation between PEM fuel cell systems and the normal need for just one unit to operate backup power and MHV installations. Since the majorities of respondents' applications were PEM fuel cells and were either backup power or MHV, as shown in Figures 3.3 and 3.2 respectively, it was not surprising to discover that a 61% majority of applications needed only one unit to fulfill the programs functionality. (Data from Question 14 and Question 15 will not be discussed as it only reaffirms the data shown in Figure 3.4 and Figure 3.5 but this data is included in Appendix A)

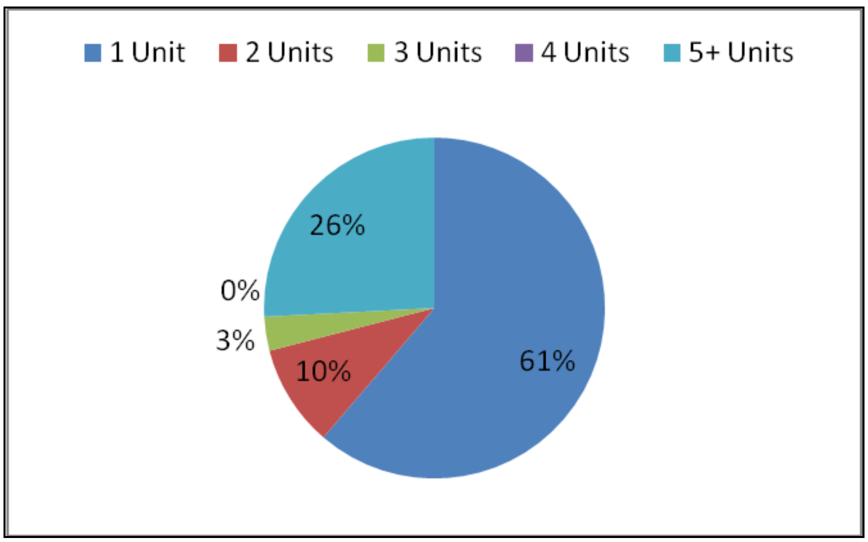


Figure 3.5. Responses to Question 13, "How many units are in operation on the site?"

Questions 16 and 17 asked if the respondents' fuel cell program employed co-generation with CHP or tri-generation with combined heat, hydrogen, and power (CHHP), respectively. eight of the respondents' fuel cell programs used CHP and only one of the respondents employed a CHHP strategy. Since CHP and CHHP is rarely used in back-up and MHV applications it is apparent why these numbers are so low. Through further analysis of each response it was discovered that the respondents who used fuel cells such as SOFC, MCFC, and PAFC in their program took advantage of the opportunities CHP provides, which is encouraging since it shows that these fuel cells are being used to their full electrical efficiency potential.

The respondents' were also asked to compare their programs to the technology status at the time of introduction (Question 18). Of the respondents who were able to answer the question with confidence, 68.0% stated that their program was considered experimental technology at the time of introduction, with the other 29.0% and 13.0% stating their programs were proven technology and state-of-the-art technology, respectively. This shows that many fuel cell customers are willing to take risks with experimental technology.

3.2. OUTCOMES (PART FOUR, QUESTIONS 19 to 24)

This section of the survey pertains to the overall outcomes of the respondents' fuel cell programs. Question 20 (shown graphically in Figure 3.6) asked each respondent to rate the availability of infrastructure required to meet their needs for the overall system, fuel cells, independent components, and the fuel used.

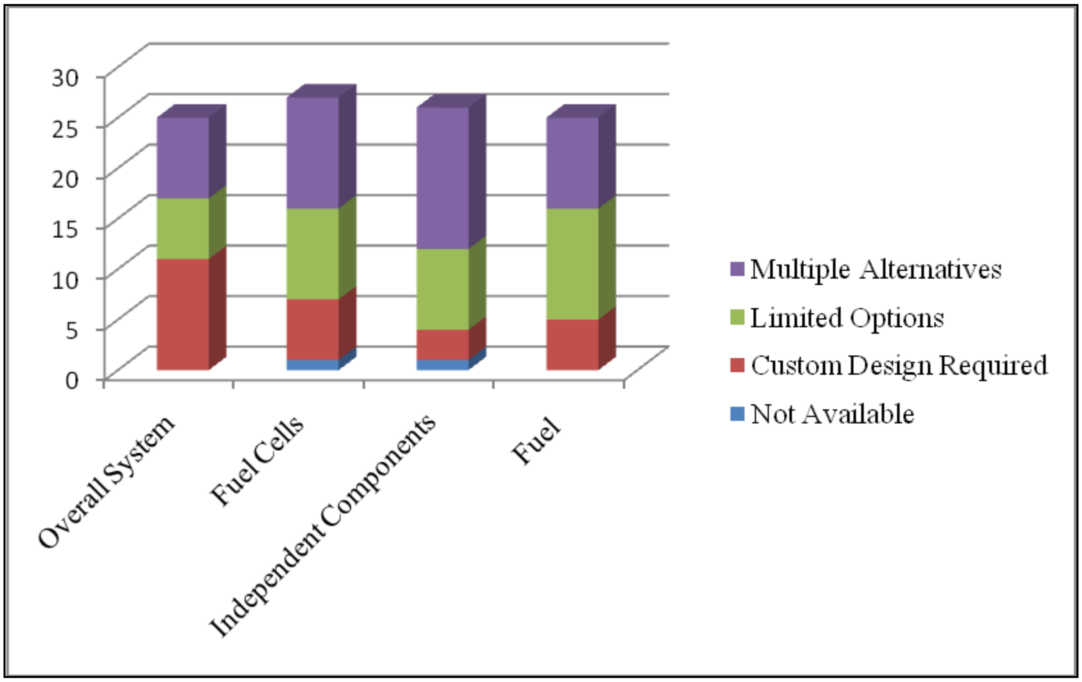


Figure 3.6. Responses to Question 20, “How would you rate the availability of infrastructure required to meet your needs?”

The largest percentage of respondents said the overall system required custom design. Also shown in the second column of Figure 3.6 is that, depending on the application used, there was the possibility of multiple alternatives or limited options in regards to using fuel cells. The majority of respondents said there were multiple alternatives for the independent components used in their program, but the majority of respondents were also limited by which fuel could be used.

As shown in Figure 3.7, the range of answers was wide when the respondents were asked to describe the cost-effectiveness of the program in terms of investment vs. market success/failure (Question 21).

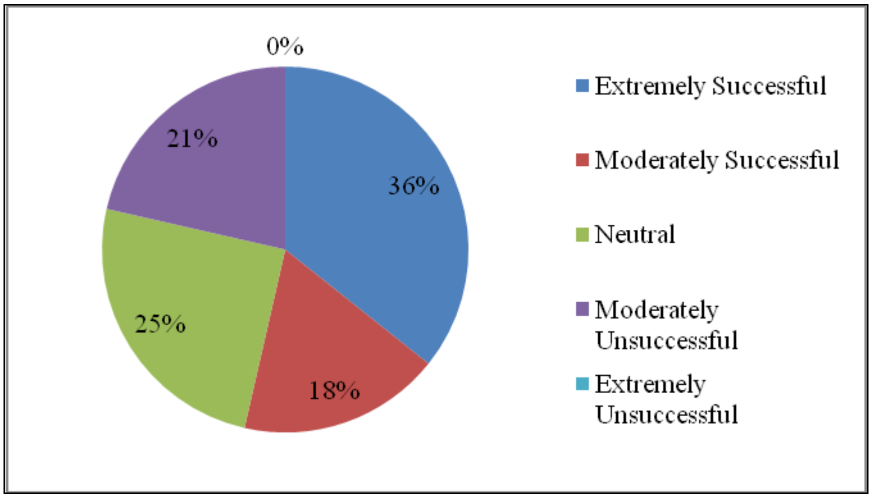


Figure 3.7. Responses to Question 21, "How would you describe the cost-effectiveness of the program (investment vs. market success/failure)?"

Comparing results shown in Figure 3.7 with Question 19 ("What were the major achievements of your program?"), respondents who deemed their program a success highlighted that their fuel cells operated excellently without the need for constant maintenance, the high initial costs were subsidized by various government programs, the ability to promote "green" behavior, and the repeatability of their successful demonstrations. The explanations for unsuccessful programs included a success in proving technology but the total investment did not lead to proving the cost effectiveness of the fuel cell solution, high initial investment, and varying regional energy prices. Programs which were in need of constant large scale power for primary power applications discovered problems pertaining to constant fuel cell durability along with significant delays in acquiring spare parts for critical components that failed under operation.

3.3. LESSONS LEARNED (PART 5, QUESTIONS 22 TO 24)

Question 22 asked the respondents to describe the most significant obstacles in the applications and how those obstacles were approached and Question 24 asked what role codes and standards played in the installation process. (The answers to Question 23, which asked about consumer behavior and attitudes, are not discussed since the answers strongly correlate with the study done by Ricci et al. [28].) The answers to Questions 22 and 24 varied depending on the size and application used in each program, but there were still best practices that were compiled from the given data. Such best practices for possible obstacles include the following.

- A ready supply of spare parts for parts prone to breaking down should be kept in stock due to the amount of time it takes to receive spare parts on a moment's notice.
- The use of alternative energy tax cuts should be leveraged to reduce overall cost of fuel cell project.
- For on-site hydrogen storage installations, consult the local fire marshal early in the planning stage to alleviate from complications which may arise in the installation phase.

3.4. EARLY MARKET APPLICATIONS (PART 6, QUESTIONS 25 TO 28)

According to the respondents answers to Question 25, backup power, MHV, and CHP are the most promising fuel cell markets for current and future operation. Reasons for this opinion include the reliability to support critical load systems, already proven technology through demonstrations, and electrical efficiency compared to conventional systems. This advances optimism for PEM fuel cells due to their ability to provide reliable backup power for critical load applications, e.g., server rooms or telecommunication towers, and their dominant role in the MHV market. Question 26 asked the respondents what role they believed “niche” markets play in early market applications. Many respondents believe niche markets to be very important to early market applications. Niche markets are also described to provide adoption potential through established value propositions, as well as their ability to support higher risks. Best practices for niche markets include the following.

- Use niche markets to show a value proposition for fuel cell adoption.
- Niche markets can be used to demonstrate feasibility in hopes of bringing down the manufacturing cost curve.
- Military can be leveraged in niche markets as it has been successfully leveraged in the past for early market development (e.g., GPS units and the Internet).

Question 27 asked what technological (or policy) breakthroughs are needed to implement hydrogen applications and Question 28 asked the respondents to give suggestions for early market development strategies. The responses to these questions show that there needs to be breakthroughs in hydrogen storage and infrastructure for there to be a feasible push for hydrogen as a dominant energy carrier in the near future.

3.5. POLICY INSTRUMENTS (PART 7, QUESTIONS 29 TO 35)

A wide variety of answers were compiled regarding Question 29, which asked for suggestions for early market development strategies. According to the survey results, there should be more government funded fuel cell grants and programs, rebate programs should be encouraged instead of, or in addition to, tax credit programs, and there should be aggressive public/private partnerships to underwrite early adopters. Proponents also suggested that if government programs, such as DOE, were to purchase systems for government sites to prove fuel cell system reliability and potential cost effectiveness then they would be leading the way for others to follow.

Question 30 asked what sort of technical and economic synergies can be leveraged. The majority of respondents believed that the transportation sector could be leveraged for the stationary sector if the use of hydrogen in the transportation sector were to become a mass market application. A reason for this opinion is due to the belief that if hydrogen was a popular fuel for transportation then a hydrogen infrastructure would then already be in place for the stationary sector to use to its advantage.

The data from the results to Question 31 ("Are other developments, e.g., green technologies, an incentive, an impediment, or irrelevant to H2 technologies?") show that a vast majority of 84.6% of our respondents believe other developments, such as "green" technologies, are an incentive to hydrogen technologies rather than an impediment.

Question 32 asked the respondents to state what government agencies can do to help create markets. A consolidation of the recommendations provided from Question 32 is shown below.

- The DOE needs to create public/private partnerships with incentives.
- Develop and standardize codes and standards for the nation as a whole.
- Continue to offer hydrogen training to local fire marshals and building officials, which will help take the mystique of hydrogen away.

Question 33 asked what, if any, type of support was received to offset the cost of the fuel cell program. Most respondents said their program was financially supported by some sort of government funding and from Question 34 it was found out that 72.7% of those respondents said this support positively affected their decision to implement a fuel cell project.

Question 35 asked if the installation of the fuel cell was in response to government regulations. Only one of the respondents said his/her program was in response to government regulations, whereas all others said the installation of a fuel cell was part of a corporate initiative. This supports the growing number of corporations who are beginning to implement alternative energy efforts in response to the current public opinion of the world’s irresponsible energy usage.

4. STATIONARY AND PORTABLE FUEL CELL MARKET TRANSFORMATION AND APPLICATIONS WORKSHOP

As stated in Section 2, under the coordination of researchers from Missouri S&T, a workshop was conducted at the 2009 National Hydrogen Association Conference and Expo. The workshop presented the initial results from the survey described in the previous section and was intended to solicit opinions on near-term market fuel cell applications and policy recommendations. The attendees at the workshop divided into two groups based on personal interest. The first group discussed fuel cell applications and the second group discussed policy recommendations.

The application group held an in-depth discussion on why certain fuel cell applications were starting to gain ground in the marketplace while others were either not gaining ground or falling back in the market. Not surprisingly, the rise of sales in the backup power (especially in the telecommunication/radio tower market) and the material handling vehicle (MHV) sectors were credited to the fact that these two applications have recently proven to be more efficient in regard to both electrical efficiency and cost effectiveness when compared to traditional technology. Tables 4.1 and 4.2 shows data presented by Battelle, which evaluates the cost effectiveness of backup power and MHV respectively [15].

Table 4.1. PEM Fuel Cell Backup Power Cost Effectiveness [25]

	Battery/ Generator	PEM Fuel Cell Without Tax Incentive	PEM Fuel Cell With Tax Incentive
8-hour run time	-	-	-
52-hour run time	$61,082	$61,326	**$56,609**
72-hour run time	$47,318	$33,901	**$32,014**
176-hour run time	**$75,575**	$100,209	$95,295

Table 4.2. PEM Fuel Cell MHV Cost Effectiveness [25]

	3kW PEM Fuel Cell Paired With Integral NiMH Battery, For Pallet Trucks		
	Battery-Powered	PEM Fuel Cell Powered Without Incentive	PEM Fuel Cell Powered With Incentive
Net Present Value of Capital Costs	$17,654	$23,835	$21,004
Net Present Value of O&M Costs	$127,539	$52,241	$52,241
Net Present Value of Total Costs of System	$145,193	$76,075	**$73,245**

Advantages and lessons learned from these two specific fuel cell applications provide additional insight as to why these fuel cell technologies have become the front-runners in the attempts for mass market penetration.

4.1. STATIONARY

4.1.1. Backup Power. Backup power has become one of the dominant fuel cell applications with potential for introduction in the mass market. Using Proton Exchange Membrane (PEM) fuel cells for backup power when the normal electric grid is out of operation has recently been proven to be a cost competitive option. In the United States alone there are over 200,000 cell phone or radio towers that can benefit from using fuel cells as their main critical backup power application. Shown below is a consolidation of the main lessons learned from previous and current hydrogen fuel cell backup power programs.

- Requires less maintenance than generators due to the lack of moving parts.
- A recent Battelle study shows PEM fuel cell are cost effective when backup runtime is less than 72 hours [15].
- Energy is needed to keep the fuel cell warm in the winter and fuel starvation is a major challenge in very harsh climates.
- Integration of the pressurized electrolyser with the hydrogen and oxygen storage units is not straightforward due to slightly different tank pressures [27].
- Power produced by fuel cell is costly when it is fueled by hydrogen produced from grid electricity.

4.1.2. Combined Heat and Power (CHP). Aside from the fact that CHP fuel cell applications are considered “green", they also have the highest electrical efficiency when compared to any other application in the market today. Other reasons for potential customer’s consideration of CHP to provide either secondary or primary power are the unstable gas and oil markets and the dramatically rising grid electric costs. Also, the recent financial crisis has shown just how unpredictable markets for the near future can be. Bompard et al. [28] points out that using fuel cells for residential power is still in its infancy in regard to becoming cost effective. However, the lessons learned from previous CHP applications will prove to be very valuable to potential CHP operators and customers.

- Installation and commissioning of CHP projects usually take longer than expected.
- The development of pre-packaged, pre-engineered systems may advance the market more quickly.
- Provides a good economic fit between offsetting electrical loads and meeting on-site thermal needs.

From the workshop, the policies group concluded that although natural gas is not a renewable resource, the increased efficiency of fuel cell CHP systems can enable significant energy savings when using the natural gas reforming process. The energy benefits derived from the higher efficiency of fuel cells needs to be rewarded in a better way through policy in order to help increase the penetration rate.

4.1.3. Grid Independent Power. Grid independent power is not usually cost efficient when compared to the cost of standard utility options, except in remote and inaccessible locations where grid extension is very costly [29]. The main purpose and reason for such high costs is due to the fact that it is completely independent of the standard power grid and is therefore unaffected by grid fluctuations and downtimes. Regardless of the lack of cost effectiveness, there are still lessons to be learned from previous installations.

- Effective but costly way of meeting new environmental emission codes and standards.
- Viable if the electrical load is ultra sensitive to standard utility voltage fluctuations.

4.2. PORTABLE POWER

4.2.1. Material Handling Vehicles (MHV). The MHV sector of the fuel cell market has also proven to be cost competitive when compared to battery powered incumbent technology as long as there is a high utilization of the MHVs. In other words, as shown in Table 4.2, if there is an adequate amount of operational downtime (8 hours) to allow the batteries of traditional MHV to charge, then fuel cells are not a financially viable option. Elgowainy et al. [21], Mahadevan et al. [25], and Thomas [29] all show reasons as to why MHV is one of the predominant fuel cell applications to date. Hydrogen powered fuel cell MHV applications can also be used as a promotional tool for industry to advertise their use of alternative power technology while still maintaining cost efficiency. The acquired lessons learned highlight reasons why MHV is an ever increasingly commercially viable option over incumbent battery MHV technology.

- Workers must be retrained to operate fuel cell equipment due to changes in standard safety protocol.
- Allows for rapid refueling (few minutes instead of multiple hours).
- No degradation of power over usage time. (i.e. fuel cells provide constant power without voltage drop until hydrogen is completely depleted)
- Hydrogen fuel cells are beneficial in both cost effectiveness and increased productivity if there is non-stop operation (i.e. three eight hour shifts) [25].

4.2.2. Small Portable Power. This is a sector of the fuel cell market that has great potential, especially for use in the military. With the growing need for electrical power for military missions, the total weight of power sources to be carried along on a mission is ever increasing. Agnolucci [30] further discusses these benefits. The lessons learned from these applications are listed below.

- Fuel cells are much lighter than generators or batteries.
- Create a noise free electrical power source.
- Continuous power supply; eliminates the necessity of having to interrupt the mission for battery recharge.

4.2.3. Specialty Vehicles. Another small sector of portable power is in the domain of specialty vehicles (e.g., airport baggage trucks, utility vehicles, and personnel transporters). There are a few installations that utilize the advantages of such applications but they have yet to prove to be cost effective when compared to the traditional equipment used for such functions. The lessons learned from these few installations are mainly based around publicity and are listed below.

- Convenient mode of transportation.
- Provide publicity for using alternative/renewable energy for power.
- Can be used to educate the public about hydrogen fuel cell technology.

5. RECOMMENDATIONS FOR BEST PRACTICES

By acquiring fuel cell customer/end-user opinions on the current status of the stationary fuel cell market, we have gained great insight related to establishing recommendations for future stationary and portable fuel cell end users customers and how to foster mass market penetration.

Table 5.1 compares the various fuel cell technologies based on stationary applications that work best when applied to different scales of power requirements.

Table 5.1. Stationary Fuel Cell Applications

	Proton Exchange Membrane	Phosphoric Acid Fuel Cell	Molten Carbonate Fuel Cell	Alkaline Fuel Cell	Solid Oxide Fuel Cell
< 1 kW	Power				CHP
	CHP				
	Testing				
1 - 5 kW	**CHP**	**Backup**		**Backup**	**Residential Power**
	Backup	Testing		Testing	**Testing**
	MHV				CHP
5 - 250 kW	**Backup power**	**Power**	**CHP**		CHP
	Auxiliary Power	**CHP**			**Commercial Power**
	CHP	**Backup**			
	H2 generation				
250 kW - 1 MW		**CHP**	**CHP**		CHP
> 1 MW		Power	CHP		

The applications in bold are more common applications, whereas the applications not in bold are applications that are not as common but are none the less a part of the market of their particular sectors. Table 5.1 is recommended to be used by potential fuel cell end users to decide if their project can feasibility be powered by current fuel cell technology.

5.1. STATIONARY APPLICATION RECOMMENDATIONS

The stationary fuel cell market has been steadily increasing around the world, but there are still large obstacles impeding the path to large market penetration. One of those obstacles is the high initial costs associated with stationary fuel cell applications. Recommendations to subsidize those high initial costs will now be discussed.

An increase in alternative energy tax cuts and/or the implementation of alternative energy subsidies are recommended. These programs would reduce the overall cost of the fuel cell project and can be justified by a fuel cell application's ability to:

- reduce carbon and other airborne emissions,
- reduce overall waste,
- increased reliability,
- quiet operation,
- and promote alternative energy technology advancement.

Another recommendation is to increase support for R&D in hydrogen storage technologies. Hydrogen storage is the leading cost factor in middle to large scale fuel cell applications (10kw – 1 MW) and if further R&D was funded in this sector then the overall cost of stationary fuel cell applications could be reduced.

If on-site hydrogen production is a necessity in the fuel cell project, use of renewable energy (e.g., solar and wind) is recommended, especially at locations using PEM fuel cells, due to the high cost of creating hydrogen from standard grid electricity. One survey respondent stated the cost of on-site hydrogen production from grid electricity was on the order of $4.00 per kg. Current government tax reductions and subsidies can be used to minimize the cost of installing an on-site renewable energy system. Also, as can be seen in Table 5.1, using CHP in fuel cell applications is quite popular and is recommended to be used in all applicable future fuel cell installations since using CHP provides a good economic fit between offsetting electrical loads and meeting thermal on-site thermal needs.

As shown in Table 4.1, using fuel cell technology in the small scale backup power sector is cost effective when compared to the incumbent battery/generator backup power solution. Providing this information to potential fuel cell customers is pivotal to mass market penetration for fuel cells in stationary applications.

5.2. PORTABLE APPLICATION RECOMMENDATIONS

The portable fuel cell market has not shown a large amount of growth due to high costs when compared to incumbent technologies. As with stationary applications, further R&D is needed. It is recommended that the military be leveraged to show the advantages of fuel cells. Fuel cells are much lighter than battery/generator applications and emit very low amounts of noise. In the past, the military has been used as a catalyst for future mass market penetration. For example, GPS units were adopted by the military despite their high costs; due to the advancements made through the support of the government they were introduced to the mass market at a lower cost. This case can also be made for the advancement of fuel cells in portable applications.

As shown in Table 4.2, one portable application that has proven to be cost effective is MHVs. In fact, using fuel cells in the MHV sector is both cost effective and it increases productivity of workers due to the fact that the rapid refueling of hydrogen fuel cells eliminates the downtime caused by using battery powered MHVs. It is recommended to promote this recent advancement to further advocate fuel cells in portable power applications.

5.3. APPROACHING THE MASS MARKET

Fuel cell technology still faces an uphill battle in terms of mass market penetration. Even though the backup power and MHV applications have proven to be cost effective, safety and investment fears still loom in the back of potential customer's minds. Dwyer and Tanner [35] stated that "barriers to entry are the obstacles a potential entrant must overcome in order to compete in the market." The barrier to entry for stationary and portable fuel cell technology in terms of mass market growth is overcoming the consumer fears associated with hydrogen technology. Many consumers who are uneducated in the field of hydrogen technology believe that hydrogen is unsafe for use by the average citizen. The public must be made aware that hydrogen is not only safe, but has also proven to be cost effective in many applications in the mass market (e.g., backup power and MHV). If a large majority of the public no longer felt that hydrogen technology is unsafe, then the fostering of innovative government policy would be less cumbersome. A reduction in customer fears would also help policy makers more easily grant funding for the R&D recommendations described in Section 5.1 and Section 5.2.

6. CONCLUSION

Fuel cells are a compelling and challenging subject in the field of stationary and portable alternative power applications. The need to address the lessons learned from previous fuel cell projects is addressed in this thesis. These lessons learned should be used to establish best practices to alleviate from mistakes make by past fuel cell users.

In this thesis, an initial literature review was conducted to determine the state of knowledge in regard to lessons learned in fuel cell applications. Based on this review, a survey was conducted to gather further lessons learned from the end-user's perspective. A follow-up workshop was held to determine the near term fuel cell markets and acquire fuel cell policy recommendations. Using the knowledge gained in the literature review, survey, and workshop, recommendations for best practices in stationary and portable fuel cell applications were made.

By acquiring the fuel cell customer/end-user's opinion on the status of the stationary and portable fuel cell markets as they stand today we have gained knowledge pertaining to what steps need to be taken and what recommendations need to be made in order to bring more customers into the fuel cell market.

Future work will include a final follow-up survey distributed to the attendees of the 2009 Fuel Cell Seminar and a final report written for the DOE. Future work should also continue to address technical, economic, and social barriers to widespread market growth.

APPENDIX A

FUEL CELL INSTALLATION DATABASES AND HYDROGEN ORGANIZATIONS

Project Databases

1. **Fuel Cells 2000 Database** (www.**fuelcells**.org/info/**database**front.html)
   This database catalogues stationary fuel cell installations worldwide - past, present and some planned. There have been thousands of fuel cells installed around the world since the early 1980s. Some locations in the database have more than one fuel cell unit on site, so check each listing to learn more.

2. **Roads to Hydrogen Database**
   (http://195.166.119.215/roads2hycom/pub_database.html)
   This database contains information on hydrogen and fuel cell related activity throughout Europe. Users can search for information on technology developers, hydrogen infrastructure, and early adopter projects in relation to Hydrogen and Fuel Cell technology. The database can search for what is happening in a specific European region as well as by topic, allowing stakeholders to obtain an initial understanding of what is happening in their locality or in their field of research. Begin by selecting an activity area.

3. **ERDC-CERL Fuel Cell Databse**
   (http://dodfuelcell.cecer.army.mil/res/site_list.php)
   The Department of Defense (DoD) Residential PEM Demonstration Project began in the Fiscal Year 2001 (FY01). Congress appropriated $3.6M to demonstrate domestically-produced, residential-scale, stationary Proton Exchange Membrane (PEM) fuel cells at military facilities, managed by the Fuel Cell Team at the United States Army Engineer Research and Development Center / Construction Engineering Research Laboratory (ERDC/CERL). Subsequent project funding in the amounts of $3.4M, $4.3M, and $2.4M have resulted in the continuation of these projects in Fiscal Years 2002, 2003, and 2004, respectively. Each individual site will also have a final report detailing the fuel cell installation, maintenance, performance, etc.

Hydrogen Organizations

1. **United States Fuel Cell Council (**http://www.usfcc.com/)
2. **National Hydrogen Association (**http://www.hydrogenassociation.org/)
3. **DOE Hydrogen Program (**http://www.hydrogen.energy.gov/)
4. **Fuel Cell & Hydrogen Network (**http://www.fuelcell-nrw.de/index.php?id=23)
5. **World Hydrogen Energy Conference (**http://www.whec2010.com/)
6. **Fuel Cell Today (**http://www.fuelcelltoday.com/)
7. **Fuel Cell 2000 (**http://fuelcells.org/)
8. **MiniHydrogen (**http://minihydrogen.dk/en/)
9. **Fuel Cell Works (**http://www.fuelcellsworks.com/)
10. **Fuel Cell Markets**
    (http://www.fuelcellmarkets.com/fuel_cell_markets/1,1,1.html)
11. **World Fuel Cell Council (**http://www.fuelcelleurope.org/)
12. **Fuel Cell Standards (**http://www.fuelcellstandards.com/)
13. **Hydrogen and Fuel Cell Safety (**http://www.hydrogenandfuelcellsafety.info/)

APPENDIX B
RAW SURVEY DATA

Early Market Development Strategies for Stationary Power Generation

1. The purpose of this survey is to provide critical information in support of a U.S. Department of Energy study that will consider opportunities for stationary applications in order to make recommendations related to research, development and demonstration (RD&D) strategies that incorporate lessons learned and best practices from relevant national and international stationary power efforts, as well as cost and environmental modeling of pathways. The study will analyze the different strategies utilized in power generation systems and will identify the different challenges and opportunities for fuel cell applications. We are requesting that you provide information for fuel cell operation and demonstration programs with which you have participated. All information provided will be kept confidential and you are free to skip any question. We expect the survey to take 15 minutes to complete. Thank you for your time in completing this survey. If you wish to receive the results of this study, please check the appropriate box below. Contact information will be requested at the end of the survey.

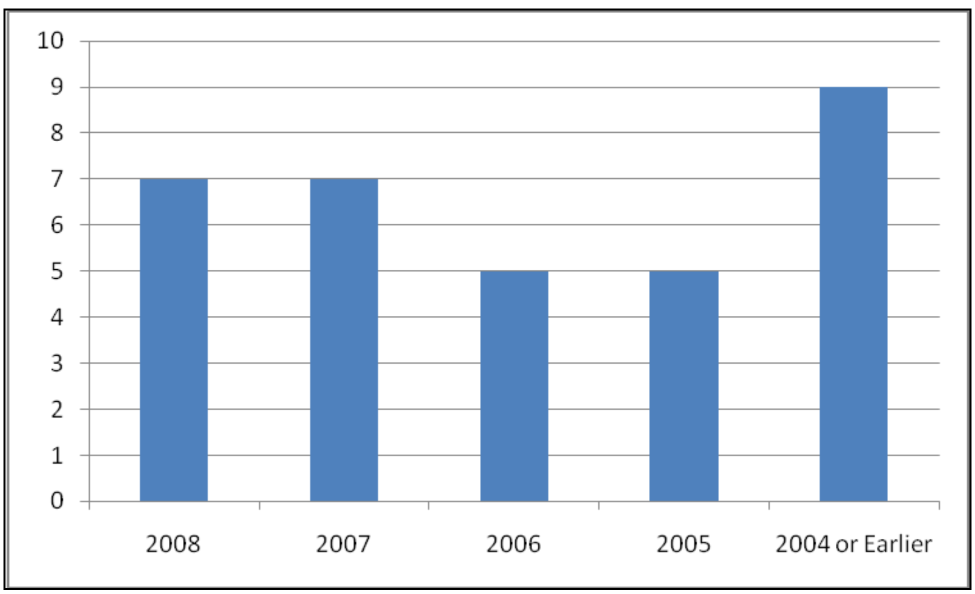
	Response Percent	Response Count
Yes	89.0%	73
No	11.0%	9
answered question		82
skipped question		1

2. May we contact you with any follow-up questions related to your comments?

	Response Percent	Response Count
Yes	80.0%	64
No	20.0%	16
answered question		80
skipped question		3

3. How many years elapsed between initial planning and implementation?	Response Percent	Response Count
<1	22.2%	8
1-2	41.7%	15
2-5	22.2%	8
5+	13.9%	5
answered question		36
skipped question		47

4. In what year did the fuel cell become operational?	Response Count
	33
answered question	33
skipped question	50



Answers to Question 4

5. If the fuel cell is no longer operational, how many years did it operate?	Response Percent	Response Count
<1	24.1%	7
1-2	10.3%	3
2-5	17.2%	5
5+	3.4%	1
N/A	44.8%	13
	answered question	29
	skipped question	54

6. Where was the site of your project located?	Response Percent	Response Count
City/Town:	96.9%	31
State:	71.9%	23
ZIP:	46.9%	15
Country:	84.4%	27
	answered question	32
	skipped question	51

7. What type of application was implemented in your program?

	Response Percent	Response Count
Material Handling Equipment	23.3%	7
Backup Power	36.7%	11
Portable Power	10.0%	3
Consumer Electronics	3.3%	1
Grid Independent Power	16.7%	5
Grid Connected Systems	**40.0%**	**12**
Other (please specify)		9
answered question		30
skipped question		53

Respondent	Other Answers to Question 7
1	mCHP - 1 kW
2	Hydrogen Fuel Cell Hybrid Bus
3	Military power supply, 5 kW net
4	stationary demonstration and test facility
5	Fuel Cell Bus
6	Demonstration Unit
7	Demonstration
8	Demonstration
9	I am a stack component supplier in this response.

8. What type of fuel cell was installed?

	Response Percent	Response Count
Proton Exchange Membrane (PEM)	**73.3%**	**22**
Solid Oxide (SOFC)	13.3%	4
Molten Carbonate	10.0%	3
Phosphoric Acid	6.7%	2
Other (please specify)		5
answered question		30
skipped question		53

Respondent	Other Answers to Question 8
1	High temperature PEM
2	hydrogen fueled ICE genset
3	High Tempature PEM
4	Aluminum-Air Alkaline
5	Alkaline

9. Please specify your fuel cell manufacturer (not required)?

	Response Count
	25
answered question	25
skipped question	58

Respondent	Other Answers to Question 9
1	Dantherm Power / SerEnergy
2	Plug Power
3	Hydrogen Engine Center
4	Hydrogenics
5	Plug Power
6	Plug Power
7	APC/Hydrogenics
8	Hydrgenics
9	Avista Labs, ReliOn, Ballard, Nuvera, Plug Power
10	ClearEdge Power
11	Altek Fuel Group, Inc.
12	Ballard
13	IdaTech, LLC
14	Hydrogenics
15	Plug Power, Nuvera, Hydrogenics
16	Altergy
17	Nedstack
18	Fuji Electric
19	Dupont, Hydrogenics, Ballard, Intelligent Energy
20	Westinghouse
21	Fuel Cell Energy
22	Versa Power Systems Inc.
23	Ballard
24	Prohibited by NDA.
25	UTC / ONSI

10. What was/is the type of fuel used?

	Response Percent	Response Count
Hydrogen	71.4%	20
Natural Gas	32.1%	9
Other (please specify)		8
answered question		28
skipped question		55

Respondent	Other Answers to Question 10
1	LPG
2	JP8
3	Industrial Aluminum
4	Low sulfur diesel and JP-8
5	methanol water mixture
6	Methanol
7	Synthetic Diesel, S8, JP-8
8	Municipal ADG, Industrial ADG

11. If Hydrogen, what is the energy source?

	On-Site	Off-Site	Response Count
Solar	100.0% (2)	0.0% (0)	2
Wind	100.0% (2)	0.0% (0)	2
Natural Gas	25.0% (2)	75.0% (6)	8
Biomass	50.0% (1)	50.0% (1)	2
Grid Power	100.0% (3)	0.0% (0)	3
Other	44.4% (4)	55.6% (5)	9
		answered question	20
		skipped question	63

12. What percentage of time was the fuel cell available to operate?

	Response Percent	Response Count
100%	20.0%	6
90-99	43.3%	13
80-89	20.0%	6
70-79	3.3%	1
60-79	6.7%	2
50-59	0.0%	0
less than 50%	6.7%	2
	answered question	30
	skipped question	53

13. How many units are in operation on the site?

	Response Percent	Response Count
1	61.3%	19
2	9.7%	3
3	3.2%	1
4	0.0%	0
5+	25.8%	8
answered question		31
skipped question		52

14. Indicate the number of each size (kW) fuel cell in the system?

	0	1	2	3	4	5	Rating Average	Response Count
<1 kW	66.7% (2)	33.3% (1)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	1.00	3
1-5	9.1% (1)	36.4% (4)	0.0% (0)	0.0% (0)	9.1% (1)	45.5% (5)	1.00	11
5-10	44.4% (4)	33.3% (3)	0.0% (0)	0.0% (0)	0.0% (0)	22.2% (2)	1.00	9
10-50	14.3% (1)	57.1% (4)	28.6% (2)	0.0% (0)	0.0% (0)	0.0% (0)	1.00	7
50-100	50.0% (2)	50.0% (2)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	1.00	4
100-250	50.0% (3)	16.7% (1)	16.7% (1)	16.7% (1)	0.0% (0)	0.0% (0)	1.00	6
>250	66.7% (2)	33.3% (1)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	1.00	3
answered question								30
skipped question								53

15. How many hours have the individual fuel cell systems operated?		
		Response Count
		26
	answered question	**26**
	skipped question	**57**

Respondent	Other Answers to Question 15
1	18,000
2	400
3	100
4	200 HOURS
5	150
6	?
7	Development platform - various FCPM versions installed
8	1500 to 2000 hours each
9	100861 hrs total 10 systems 10086 average per system range from 7.2K to 17K per system
10	20
11	700
12	1500-2000
13	10,000 +
14	1,100
15	2000
16	200?
17	300-600
18	100
19	700
20	36,000+
21	about 5000
22	~20 - 24 hours
23	5000?
24	4
25	1000+
26	Not compiled

16. Is the system employing co-generation (combined heat and power)?	Response Percent	Response Count
Yes	26.7%	8
No	73.3%	22
answered question		30
skipped question		53

17. Is the system employing tri-generation (heat, power, and hydrogen)?	Response Percent	Response Count
Yes	4.2%	1
No	95.8%	23
If Yes, please explain the usage of the hydrogen?		1
answered question		24
skipped question		59

Respondent	**Explanation to Yes Answer on Question 17**
1	On site hydrogen generation and fuel cell grid power

18. How did this application compare to the technology status at the time of introduction?

	Response Percent	Response Count
Proven Technology	29.0%	9
State-of-the-Art	12.9%	4
Experimental Technology	**67.7%**	**21**
Please explain:		17
answered question		**31**
skipped question		**52**

Respondent	**Answers to Question 18**
1	There have been no other field installations of HT PEM stacks anywhere in the world at present.
2	The vendor told us this was proven technology we feel thatwe have helped them de-bug their product
3	The first fuel cell is actually on a client site: so a proven technology.
4	At the time of supply the fuel cell was stated as proven technology but it was really experimental.
5	This was the second generation of continuous run PEM fuel cell systems. Learning from Gen 1 was included in Gen 2 design but was not proven technology at the time
6	This was not bleeding-edge experimental but we were the first install of a new product.
7	Microchannel steam reforming of liquid military fuels for running PEM fuel cells.
8	Initial integration of a JP-8 fuel processor with a SOFC in a test bed.
9	This was a first of its kind, with a PEM electrolyzer, compressor, composite hydrogen storage, and a PEM fuel cell, all installed onto a small trailer.
10	NYSERDA funded demo program to evaulate usefulness
11	facility is used for system development
12	We are demonstrating the use of fuel processing and PEM fuel cells for military power generators.
13	First ever large (>25 kW) SOFC system
14	Versa Power Systems Inc demonstrated two, 3kW each, systems. Both for the US DOE SECA program. In both cases, the DOE-NETL system technical can cost audit metrics were met, without exception.
15	I think it was one of the first
16	Prohibited by NDA.
17	These were commercial units.

19. What were the major achievements of your program?		
		Response Count
		26
	answered question	26
	skipped question	57

Respondent	Answers to Question 19
1	Providing energy services to DOD site under comercial terms and conditions, use of ITC and SGIP funds
2	The queen visited providing a major photo op. Installation has not been a major embarrasment as many initial fuel cell installations have proven to be (please see UTC, Plug Power, Acumentrics, Sulzer-Hexis, Fuel Cell Technology/Siemens, Etc.)
3	Quick operator acceptance
	Partnership with local economic development council
4	Improving integration and efficiency of wind/PV-coupled hydrogen production systems as energy storage and transportation fuel.
5	Develop a back up power system which deliver a power of 30kVA.
	a excellent fiability of starting up.
6	low cost, and increase of power
7	Operational in harsh climate but because of construction work in the vicinity the test was interfered with.
8	German TUV certification.
	H2 FC Hybrid System developed that could be replicated and deployed in multiple units to various end users and European regions, for demo and field testing purposes.
9	If gave a real world view of the areas that need to be overcome before the 5 kW PEM fuel cell will be a reality for grid power. Could not withstand cold winter winds when not in operation. Stack life is way to short. Cost of power was about $ 4.00/kWh.
10	surpassed previous milestones for system and stack life in a fileded system operating in its intended application. I.e. it was "real world" not a laboratory environment
11	This was the first real attempt at a real commercial product that I know of in the fuel cell arena.
	This was the first time in the world that a hydrogen fuel cell system has been installed in a commercial office tower in a downtown core of a city.
12	Operable demonstrations of a fuel cell power generator at over 50 locations (it was transported to customer locations and trade shows.)
13	RELIABILITY, SIMPLICITY AND SAFETY IN OPERATION, USE OF NON-FOSSIL INEXPENSIVE FUEL (INDUSTRIAL ALUMINUM), COMPLETELY GREEN
14	Initial operation of a SOFC on low-sulfur logistics fuels without forming coke.
15	commercial purchase of mobile fuel cell system, seemless replacement of the current technology used in electric forklifts (lead acid batteries), short duration of refueling compared to battery charging, longer run times in between refuelings compared to battery charge life
16	1. Which designs seemed to work best.
	2. How well they worked in the forklifts
17	close collaboration between SMB's and HAN University.
18	Over 500 hours of operation. Over 100 live demonstrations both invited and public. Significant cost reduction over the course of four generations of units.
19	Zero voltage degradation, 46% electrical efficiency, demo'd high availability of and potential for tubular SOFC; formed the basis for commercialization of the technology.
20	Implementation on municipal or industrial ADG with waste heat recovery to feed back to the plant. Development of "islanding" mode for grid loss.
21	* >95% availability;
	* >38% peak eff;
	* steady state durability of less than 2% per 1000h decay across-- + 1000 hours steady state, followed by 10 transients, followed by 500 hours steady state
	* state of the art performance power density of ~0.3W/cm2
	* units delivered to successfully meet the US DOE metrics for both, Fuel Cell Energy, and Cummins Inc.
	* operations on real pipeline natural gas
	* systems commissioned in the VPS factory, and then successfully transported across country and re-installed, with factory performance replicated: for the FCE contract, the VPS 3-1 System was transported to DOE-NETL Morgantown WV, and run for an additional 1700 hours; for Cummins Inc (Cummins Power Gen in Minn MN), the VPS M-1 System was sent ti Minneapolis MN, and run for another 1700 hours.
22	Mass deployment at critical Homeland Security site.
23	it worked, and proved the concept
24	Showed integrated system on kW-scale
25	Demonstrated low cost, large scale production capability of stack components within tight tolerances and repeatability.
26	Showing that a fuel cell can meet customer needs for hot water while providing reliable grid-connected power.

20. How would you rate the availability of infrastructure required to meet your needs?					
	Not Available	Custom Design Required	Limited Options	Multiple Alternatives	Response Count
Overall System	0.0% (0)	**44.0% (11)**	24.0% (6)	32.0% (8)	25
Fuel Cells	3.7% (1)	22.2% (6)	33.3% (9)	**40.7% (11)**	27
Independent Components	3.8% (1)	11.5% (3)	30.8% (8)	**53.8% (14)**	26
Fuel	0.0% (0)	20.0% (5)	**44.0% (11)**	36.0% (9)	25
				answered question	**28**
				skipped question	**55**

21. How would you describe the cost-effectiveness of the program (investment vs. market success/failure)? Please describe potential reasons for success or lack of success.

	Response Percent	Response Count
Extremely Successful	35.7%	**10**
Moderately Successful	17.9%	5
Neutral	25.0%	7
Moderately Unsuccessful	21.4%	6
Extremely Unsuccessful	0.0%	0
Please explain why it was either successful or unsuccessful.		25
answered question		**28**
skipped question		**55**

Respondent	**Answers to Question 21**
1	The Navy is saving $250,000k per year in energy costs.
2	Still unknown. Should system prove reliable (2 years, >10,000 hours), it will be extremely successful.
3	We believe that we can run fuel cells for almost the same price as we can run batteries.
4	This is a research endeavor and systems were intentionally undersized to test various configurations.
5	a little expensive
6	a lot of investment now for a lack of client. It's difficult to enter in the back up power market
7	MOnitoring was needed more than often because of security shut down. But with a remoter monitor it became much easier.
8	System developed has gone on to commercial sales of a dozen further units in a half dozen various jurisdictions in three countries in Europe.
9	The vender did not have a product that was close to meeting the requirements of home operation or cost effectiveness. Stack life was a major problem along with start/stop operation, winter weather, energy to keep the fuel cell warm, and fuel starvation.
10	Successful in proving the technolgy, but total investment required did not lead to proving the cost effectivness of the fuel cell solution
11	The project cost was comparable to installing a standard generator backup system.
	having all our power within the envelope of our office space is a real plus.
12	Battelle has used its MEPS (multipurpose electric power system) based on reforming military fuels to suppy hydrogen to PEM fuel cells to advance the system integration of fuel cell power systems.
13	Backup UPS systems using PEM technology were somewhat successful. PEM and solid oxide technologies for distributed generation (prime power) were extremely unsuccessful. You can get all of our results at www.harc.edu/fuelcell.
14	very high initial cost was subsidized by government, but will still take several years to recover, customer is reaping benefits of marketing its proactive "green" behaviour
15	That demonstration was a springboard for Hydrogenics becoming a leader in fuel cell backup power generation. As well, it lead to partnerships with APC and CommScope/Andrew.
16	The test unints were relatively sturdy, i.e. not too much down time. They performed most of the tasks required. Our customers will determine whether they are financially viable.
17	N/A
18	Customers are coming forward willing to pay for additional (expensive) one-off protypes prior to our ramping up production after 2010 that would make the units more affordable.
19	It was intended to demo technical viability not cost effectiveness
20	From the customers standpoint the installation went smooth and the operation exceeded their expectations.
21	The accomplishments in question 18 were completed in 2.5 years. The project success benefitted from a $50MM private investment prior to the initiation of the subject US DOE SECA project.
22	Successful in that it operates without constant maintenance and has performed its tasks without failure.
23	with much more costly fuel, it can be justified
24	As a component supplier it was successful in demonstrating repeatability, reproducability and processing capability for meeting low cost targets.
	Lack of success was out of my control areas.
25	The cost of natural gas made the energy prices higher than other utility options.

22. Describe the most significant obstacles in your application. How were these obstacles approached?	
	Response Count
	24
answered question	**24**
skipped question	59

Respondent	**Answers to Question 22**
1	Siting...negotiation
2	For the overall project, choosing/designing stack technology and stack which would have a reasonable chance for commercial viability shold the demonstration prove successful. LT PEM and SOFC were first choices, HT produced by another developer (IRD) was third choice. Serenergy in conjunction with Dantherm was fourth choice.
3	Understanding the pricing structure of our difference options - fuel supplies do not like to sell you infrastructure (or even quote on it) they only want to lease it to you.
4	- the price il the most significant obstacle, but a large cost reduction is applied now
5	Spare parts took long time to arrive, ACDC adapters broke down, some circuit board gave up.
6	1. Finding a suitable vehicle platform from a cooperative OEM.
	2. Development of a custom dc-dc converter.
	3. Requirement for extensive testing under the widest possible conditions.
7	The vender of the fuel cell was only in the project for the short term and not the long hall.
8	Overcomming the issues with developing technologies from an isolated site. This lead to the development of system diagnostics and data transmission infastucture useful for debugging problems remotely
9	Firstly there were the issus of fire safety. This is an old office tower.
	Resolving this required lots of consultation between the engineering staff and the fire departments staff.
	Secondly there are also issues here of cooling. Unlike standard backup power systems the room cooling had to be powered by the fuel cell system also.
10	Balance of Plant components, that are appropriately sized and have the necessary reliability were difficult, sometimes impossible to obtain.
11	Fuel cell durability was a significant problem for primary power units.
12	NONE
13	- availability of complete battery replacement fuel cell systems that would physically fit into our trucks, so we had to work closely with Plug Power on the integration of one of their units into our trucks
	- availability of fuel and high capital cost of on-site H2 storage, so government support was essential and available
14	It was 6 years ago so its hard to remember. I believe the system integration effort was the most difficult part, and getting parts for failed components
15	Education (safety and how to use it).
	Initial funding to get started took about 12 months to get.
16	local safety regulations.
	approached by collaborating with the city of Arnhem
17	Cost of speciality components. Approached by transferring the scientific developments out of the laboratory (scientists) and into the hands of engineers. The next step is transferring the designs to manufacturing.
18	European codes and standards. Lots of mods were needed to get a CE mark equivalent
19	Transportation. Installing large (250 kW and multi-MW) plants in remote sites was challenging. Overcoming customer discomfort with new technololgy was probably the biggest hurdle.
20	for residential SOFC applications, simultaneously hitting the metrics, with no room for slippage:
	* Cost of Electricity (COE): at no more than a 15% adder to what the customer is presently "paying"
	* cost: at <$2000/kW;
	* life: at 5 years with less than about 10% degradation in performance
	* reliability: with minimum to no maintenace required of the owner/customer
	* >50% efficiency to ensure 12 months of operational duty cycle-- to meet the COE requirements
21	Interior AC wiring. The site required the services of trained electricians to sort out the existing, jumbled electric system so that key circuits could be backed up. This had nothing to do with fuel cells, and would have been a requirement for generator deployments as well.
22	no large problems, just lots of small ones.
	the solution is development, and testing....
23	NA
24	The size of the units were smaller than the utility was normally operating and due to the small size, they did not put enough emphasis on the normal preventative and periodic maintenance for the units.
	The heat recovery system design was a challenge that took significant engineering time to resolve.
	Some confusion existed over the design of pressure retaining components, but this was resolved quickly by the manufacturer

23. Describe the general consumer behavior and attitudes toward your application. Was there governmental/industry/consumer participation?	
	Response Count
	25
answered question	**25**
skipped question	**58**

Respondent	Answers to Question 23
1	Generally negative at first because the project was imposed upon teh base utility staff without their inital buy-in.
2	Government financed industry consortium including nations largest utility and other deep pockets. There has been overal optimism from all - next installations will be for college dormitories, i.e. imbedded in technological research environment.
3	Everyone involved in our project worked with us and wanted to help us implement and make this program successful.
4	The system is not available for consumer use. Government and industry participation.
5	Customers think generally that it is a great system, but are not ready to change their diesel genetors yet.
	The decrease of the petrol cost isn't in our favor.
	There is project like H2E or JTI which help the firm like us to subsidize several projects.
6	All were very positive but did not expect much.
7	State government financial support (43%) including assistance to find and convince the first follow-on customers. Public transport organizations generaly have no interest in more expensive solutions - they are all severely cash-strapped. Small low-speed ultra-urban buses are extremely niche.
8	At the beginning all parties were engaged but as time went on the vender began to back away from the project saying it was out of scope with their fuel cell.
9	There was governmental particpation. Seemed to be genuine interest in technology and learning about it with a cautious skepticism about the current issues facing the technology. Most everyone understand what the longer term possibilities it could bring if the cost / reliability can be improved
10	Because this is a back end service there is not a lot of consumer knowledge of what is being done here.
11	Cutsomers (military personnell) were very favorably impressed by the low noise and efficient operation of the unit.
12	Our program was an industrial consortium. Our grid connected system demonstration required the participation of the local utility.
13	NO GOVERNMENTAL/INDUSTRY PARTICIPATION
14	Operators of fuel cell units really liked the quick refuelling and felt proud to be using a "green" technology. The customer was glad that government subsidies were available to allow them to purchase this technology.
15	There was industry and consumer participation.
16	No customer participation, yet.
	New York State provided funds through NYSERDA to pay for infrastructure.
17	N/A
18	Response to seeing an operating unit is VERY favorable. Company investment in the basic platform, and customer (government/industry) interest in customization of the basic platform to specific applications has been very good also.
19	Yes, all very supportive
20	Gov't (local, state, and federal) plus utility plus industry support was critical for success. Had to comfort a lot of people at many levels on the reliability and performance of fuel cells.
21	Government Participation: US DOE SECA-NETL-- extreme support
	Industry:
	* FCE-- a stationary fuel cell committed company-- extreme support
	* Cummins-- a mobile fuel cell for RV APU-committed company-- strong commercial focus and product development support
22	Greatly appreciated and embraced by the customer.
23	yes, and it was good support,
24	NA
25	One system was at a hospital. The hospital was very supportive and appreciative of the system and its savings.

24. What role did codes and standards play in installation?	
	Response Count
	23
answered question	23
skipped question	60

Respondent	Answers to Question 24
1	Adherence to IEEE 1741 and CA Ruel 21
2	INstallation will help determine codes and standards.
3	Our economic development people laid all of the ground work for us - we have had no code or standard issues. The biggest issue we have had is people asking us if we followed code, when I ask them what code they are unable to answer.
4	NREL and Xcel Energy reviewed codes heavily. Government installations, at least at NREL, go above and beyond the available codes.
5	The fact there is no a lot of codes or standards in the Hydrogen storage, is benefit for us and for our customer.
6	very small.
7	Road Certification required, otherwise no point in the project.
8	This project started with CNG codes and helped write the hydrogen codes for the State of Michigan.
9	Systems were certified to ANSI FC1 fuel cell standard. This helps with agency approval and customer acceptance that the machine is safe
10	Because of onsite hydrogen storage issues. The codes and standards for this type of installation have been a huge issue.
	If it were not for the active participation of the Fire Department, whos approval we require, We could not have gotten this project approved at all.
11	Mil Spec standards have been used to guide the design of the system. A Spiral Design approach is being implemented where top priority items (based on histograms of reliability and cost) are advanced to a milestone extent to move the technology forware.
12	Very little.
13	Local marshalls and other regulating comissions delayed the building of the on-site storage, but a means to meet all the requirements was finally found
14	Some C&S came into play.
15	Had to learn local codes to install.
	Participated with UL to write standard UL-2267
16	Applicaiton of safe laboratory practices. Applications to local fire marshalls for permission to operate.
17	Huge. See # 22
18	Critical for mechanical and electrical connection to the site. Electrical code was the most stringent.
19	Little at this point. However--VPS standard engineering practices require that applicable codes and standards be taken into consideration throughout.
20	Very little. The state fire marshal's office reviewed the installation and approved (stamped) the drawings. SFM followed wrong code language, but upon final inspection gave the green light for all future installations in New Mexico.
21	a lot, the units were done to the applicable codes, and met them
22	NA
23	There was some question about the design of pressure parts, but this was quickly resolved by the manufacturer. No other code or standard issues were identified.

25. In your opinion, what applications are most promising for early market introduction?	
	Response Count
	26
answered question	**26**
skipped question	**57**

Respondent	Answers to Question 25
1	CHP, energy storage using Redux or ZB regenerative fuel cells, hydrogen-cogeneration, integration with Consentrated Solar Power systems.
2	Critical backup using LT PEM and hydrogen fueled MHV (forklifts). CHP for high temp mature technologies (100-400 kW PAFC, 300 kW - 2.4 MW MCFC). mCHP and long-haul truck APU when HT PEM and/or SOFC can be proven reliable.
3	Forklift / Material handling
4	Hybrid System.
5	Ships
6	UPS (Backup), Material handling vehicles, Urban Transit Buses and Renewable Energy.
7	Locations or applications that have a high cost of electricity.
8	Any application where the current cost of electicity to fuel cost ratio is sufficient to make the efficiency improvement of the fuel cell vs. traditional equipment look attractive
9	First the applications need to be relatively price insensitive.
	In our case we would have spent 300K to put pipe from the basement to the roof if we wanted to run a standard generator.
	300K buys a lot of fuel cell.
10	Military power generation. Remote power generation.
11	Backup power looks promising. The Nuvera system for materials handling equipment looked promising. The primary power application looks very bad.
12	Real direct production of hydrogen from renewable energies in a new, not known process in ONE step only that means without reforming and aslo without electrolysing!
13	PORTABLE (20W - 1,500W) AND STATIONARY UPTO 10, 000W.
14	Military Gensets, vehicle APUs, remote power
15	material handling
16	For PEM fuel cells: back-up power, forklifts, buses
17	24-7 High-throughput distribution centers (fastest ROI)
18	educational applications
19	Military power generation. Materials handling equipment. Remote power.
20	Base load, CHP applications, such as hospital or internet servers for large systems, and telecom sites for small ones
21	Base load power near metropolitan areas.
22	residential/small commercial (3 to 10kW); and large commercial/small industrial (500kW to 10MW); possibly RV APU
23	Back-up power for critical loads and material handling.
24	small portable systems
25	Back-up residential power.
26	Combined heat and power applications, to reduce carbon emissions.
	Back-up power applications, both standby and normally operating to support critical systems.
	Combined power and hydrogen systems to support fleets of hydrogen vehicles.

26. What do you believe is the role of "niche" markets in early market applications?	
	Response Count
	25
answered question	**25**
skipped question	**58**

Respondent	Answers to Question 26
1	Niche no more...assult maintstream markekts dominated by incumbant technologies
2	Large-scale commercial testing and manufacturing (aree mass production price reductions realized?) and overall public awareness of fuel cell technology.
3	The more overall demand the better
4	I think theses "niche" markets must show the exemple. It is a good thing to have these " niche" market.
5	Very important as display and convincing old fashioned engineers that the technology is viable.
6	In the UPS and Material Handling sectors, the role of niche markets is negligible. In the Bus sector, the role of niche products is greater.
7	The niche market is key to proving the fuel cell for the general market.
8	Niche markets present an opportunity to bridge the gap from government funded programs to mass market. They provide the second step for hardenging the technology in real applications in a an environment that is more cost tolerant and acceptance to less than 5-9's reliable product
9	These markets perfect and hone the products.
	Think of it this way.
	The automotive industry came from the stationary power area.
	First there were engines to make power for industrial applications than someone got the wacky idea of putting one of these on a wagon.... The rest is history.
10	Niche cusomers more so than markets are needed. Champions in industry who seek to leapfrog current technology and as the early adopters drive the technology advancements forward. (i.e., increasing TRL levels)
11	Niche markets are extremely important because a value proposition must be established for adoption.
12	The future market for hydrogen and fuel cells will be luxory good with new, today unknow sedrvice and added value!
13	THERE IS NO CONTENDER PRODUCT IN THE MARKET
14	Important first markets to demonstrate feasibility and begin to march down the manufacturing cost curve.
15	to establish a solid base of manufacturers for the parts used to make the fuel cell systems
16	"Niche" markets are important. They will initiate the roll-out toward mass commericialization.
17	same as #24
18	Niche markets are very important to gain manufacturing experience and attracting capital for expansion.
19	Huge, since they can often support higher costs
20	Everyone is in a race to be third. They want to see it working somewhere else (preferably at least two other places) in an application the same or similar to theirs. Niche markets don't grow the business.
21	could be vital; however, without a continuum of applications to transition to, that require little to no custom modification of the satck and system, the company will wallow when it attempts to transition to the "middle market," in its "valley of death."
22	Shows the path for the rest of the world.
23	there are much lower risks in small markets than in a mass market. it is a rare company that will risk a new product on a mass market, the costs of a large recall are very high
24	Let the military takes these.
25	All markets are "niche" markets. There is no reason to characterize any market as especially small or unique. All markets are unique. All markets have unique sizes.

27. What technological (or policy) breakthroughs are needed to implement H2 applications?	
	Response Count
	26
answered question	26
skipped question	57

Respondent	**Answers to Question 27**
1	Increased demand for H2 as energy carrier, demonstrate on-site hydrogen generation CSD...materials handeling most early adopter
2	Policies include massive public awareness as to inate 'green' nature and safety of fuel cells and hydrogen. Dispell majority held myths of Hindenburg and H-bomb and build awareness of non-automotive applications (Bridgestone-Firestone has factory going 100% hydrogen fueled fork lifts - will its ads during the Superbowl mention this?). HT PEM and SOFC needed to be more forgiving to hydrogen impurities.
3	Improved reliablity. Once H2 cataches on local supply of hydrogen will help reduce the cost.
4	A strong policy shift seems the only likely path towards a hydrogen future. Manufacturers of FC's and electrolyzers simply don't have the volume of orders to make the economics work for early adopters.
5	the H2 storage
6	Easier safety classification, meaning: the administrational level needs better training and education.
7	Tax-free status absolutely but additionally Grants and supplementary Loans to buyers and operators of zero-emission technologies.
8	Hydrogen Storage We need a way to store hydrogen in a small volume with high kg mass at low pressure and little energy to retrieve the hydrogen from the storage medium.
9	Overcome the cost barrier to small scale on site generation and develop a workable distribution network for back-up power applications
10	The biggest technical problem we now face is H2 Storage.
	From a policy point of view there need to be incentives for non-standard power products.
11	Compact storage. Efficient production.
12	If H2 consuming technologies worked and were cost effective, the H2 infrastructure would develop to serve them. So far, no H2 fuel cells I've tested work very well.
13	See question 25
14	ALTEK FUEL GROUP Inc. MADE ALL THE TECHNOLOGICAL BREAKTHROUGHS AND IS NEEDED ONLY FINANCIAL SUPPORT.
15	More subsidies by the government are needed for end users of fuel cells to help with the ROI and shorten their return times.
16	(5000 psig) Hydrogen must become a whole lot easier to obtain. Government needs to a program which will roll out hydrogen infrastructure across the country. This is because capitalism does not work in the case of hydrogen refueling stations at this stage of the game.
17	None for our industry
18	electric vehicles
19	H2 only applicaitons need advancements in hydrogen storage technologies.
20	Some way to make H2 from a source other than a hydrocarbon!
21	Don't know. Ran all our fuel cells on methane.
22	Wind and Solar power must be brought to 24/7 reliability. This is enabled through the initial implementation of ,e.g., SOFCs running in straight fuel cell mode, coupled with a separate water electrolyzer; the next breakthrough for commercial viability is to implement reversible, unitized solid oxide devices running in fuel cell mode and electrolyzer mode (SOFCEL).
23	Need to find a means to store liquid hydrogen without as much boil-off, and/or we need a denser means to store gaseous hydrogen.
24	For vary small systems, no breakthroughs
	For large portable, and for autos, a better storage system is needed.
	Nothing larger than a bus should be a H2 system.
25	Left for another discussion.
26	Government agencies need to agree to install fuel cells, even if they are more expensive than inferior incumbent technologies. This needs to be justified based on reduced carbon emissions, reduced waste, reduced airborne emissions, reliability, quiet operation and technology advancement.

28. What suggestions do you have for early market development strategies?	
	Response Count
	25
answered question	**25**
skipped question	**58**

Respondent	Answers to Question 28
1	Provide demonstration funding cost sharing for development of on-site hydrogen generaton CSD using commercial scale AT / CPOX natural gas reformers
2	Makke sure you have three years of financing, locations and/or users for field trials, strong government connections (military being partiularly useful), a plan, great technology, and a good lobbyist.
3	People are very excited about this technology - if you wanted to you could get lots of PR by implementing hydrogen technology.
4	cost reduction
5	Bring in the city planners, the governmental and administrative bodies at an early stage.
6	More National Funded Programs for field testing of near-commercial products like the German N.I.P. National Innovation Program, see http://www.now-gmbh.de/uploads/media/Developmentplan_02.pdf
7	Work on storage, cell stack life and ability to replace a bad cell without replacing a stack.
8	Getting a through understanding of the intended market application and making sure the technology can supply those needs cost effectively given its current and expected future limitations in advance of beginning product development. Economics not technology needs to define acceptable trade offs. The technology needs to fit the market not vice versa.
9	I am not sure I am qualified to comment on this.
10	Federal and State mandates on targets for "new fuel cell power generation." Tax incentives. Informed financial firms willing to finance advanced energy projects.
11	Forget PEM as a solution for primary power. Focus PEM on vehicles and niches. PAFC and MCFC may have some potential for stationary power.
12	To think about, what the potential customer realy needs and were he/she is prepared to pay for. NO governmental introduction programmes, please!
13	TO BRING THIS PRODUCT TO THE MARKET AS SOON AS POSSIBLE.The key to Altek's success in this emerging giant market is the performance advantages Altek's technology presently possesses. Competitors, who are targeting the same market, have been unable to produce a product or technology comparable in performance, cost, and efficiency to Altek's APS 100.
14	Develop military and remote power niches first.
15	Government sponsored programs need to be started with the OEMs that manufacture the vehicles that the fuel cell systems are being used in to provide incentive for them to invest the time needed to bring this technology fully into the material handling market.
16	Rebate programs instead of or in addition to tax credit programs.
17	Education
	Demonstrate ROI examples
18	Fun factor,
	Incorporate students, children
19	Agressive public/private partnerships to underwrite early adopters.
20	Educate the end user...over and over and over and over again.
21	Subsidies are unfortunately required. Time to stop multiple-path federal contract awards; time to implement a true, commercial-like stage and gate process that forces the "best-of" subsystem technologies, components and integrators to team. Fuel Cells will die without a concerted effort to combine the best technolgies, period.
22	Compare the life cycle costs of fuel cells against battery plants, both for back-up power and for material handling applications.
23	persistance, and continous inprovement untill the products are robust enough to sell
24	Go to several "small town America" homes in every State (I.e. 30,000 in each State) and place a residential unit at their home. The only cost to the home owner is a standard utility fee when in use... More left for another discussion.
25	Require fuel cell systems in all new construction for Federal, State and local projects that can benefit from the advantages above.
	Implement fuel cell hydrogen vehicles in fleet applications, supported by stationary combined hydrogen and power systems. Buses are a specific opportunity that needs to be implemented.

29. What should/can be done related to policy to promote technical R&D and market competitiveness?		
		Response Count
		25
	answered question	25
	skipped question	58

Respondent	Answers to Question 29
1	Legisltaive incentives to develop cost effective, small scale (100kg/D) on-site H2 generation for captive fuel cell fleets
2	More financing for partnerships among Universities, industry, utilities, and regulatory segments of government (like Japan, Denmark, EU, German states)
3	Remember that cost matters people will not switch unless it is cheaper that current technology.
4	more information about Hydrogen and fuel cells, more exhibition like Photovoltaic.
5	Take efficiency and RE seriously as fulfilling more than old fashion energy technology
6	Sponsorship of Demos, demos, demos. Field testing, field testing, field testing.
7	We need to give college students and young minds the tools and support to move the technology. Develop funded competition between universities.
8	Need to provide ways to allow the emergent technologies to compete with existing technologies without an economic hurdle. Increase efficiency and limit green house emissions on current technologies with a penalty for not meeting the target whihc would allow the benefits of new technologies to have economic benefit above simple cost of ownership economics
9	Transferable tax credits for R&D.
	It makes it possible for small firms to undertake risky R&D and get funding from small and medium sized investors.
10	Develop a National Energy Policy with teeth.
11	More money all around.
12	Let the entrepeneurs do their work without giving them too much admininstratetive hurdles!
13	AT THIS STAGE ONLY FINANCIAL SUPPORT
14	Increase SBIR/STTR spending and contract size.
15	more programs involving forklift OEMs
16	Show how Fuel Cell benefit companies not just with "Green" arguements but with cost savings or other value statements
17	create a firm framework to tackle all issues, especially those regarding codes and standards
18	Policy needs to direct substantial and steady / long-term funding towards development of products.
19	Provide long term, consistant development funds subject to strict performance reviews and prospective assessments, but NOT subject to annual congressional appropriations.
20	Tax breaks or subsidies for end user. Fuel cells are still too expensive.
21	see question 26 and 27
22	Have a clear cut alternative energy policy to move away from fossil fuels. Industry will then step up as it should.
	Also, need to have a code change that allows composite cylinders to be carried over the road as are DOT cylinders.
23	The current DOE support, and funding for joint university / industry is good, more is always nice, but may not speed things up any.
24	Left for another discussion.
25	There is not policy requirement to promote R&D other than increased R&D funding by the United States Government. Market competitiveness will take care of itself.

30. What sort of technical and economic synergies (with, for example, transportation) can be leveraged?	
	Response Count
	20
answered question	20
skipped question	63

Respondent	Answers to Question 30
1	See above
2	Public transportation is ideal - buses of all sizes with very high profile installations (EU CUTE, winter Olympics in Milan, Whistler, and hopefully summer Olypics in London. Large public government installations such as the bureaucratically challanged Freedopm Tower. Defense is ideal because of the 'price is no object' syndrome (see AFC in Apollo and Space Shuttle) - replacing 60,000 diesel gen sets with fuel cells for polution and noise abatement would be a great program if publicized.
3	Transportation of the hydrogen currently accounts for a significant portion of the cost. The more hydrogen that can be generated locally the cheaper it will be.
4	membran research, H2 storage
5	?
6	Development of Hybrid electric drive trains, including cooperation with emerging battery technologies.
	Combination of renewable energy (wind, PV, electrolysis, H2 from Biomass, etc.).
7	System efficency and reduced emissions but the current state of the technology in terms of performance and cost are not suffiecnt to gain market traction on their own
8	H2 and Transportation should never be used in the same sentence.
	This is the other side of that argument. Over the years transportation has been held out as the ultimate use for fuel cells. This has never happened and I am convinced because of this more mundane applications have been overlooked.
9	Identify the balance of plant components (i.e., storage) common across applications and develop them.
10	Continue to adopt rules that monetize externalities (carbon, NOx, water)
11	Much more beyond todays imagination!!!
12	The government will have to support the early adoptors, but with more large manufacturers like in the auto industry, the subsidies can die out with the lower cost of high volume further devoloped parts.
13	Renewable energy sector (e.g. solar, wind, geothermal) can be linked to the transportation sector via electrolysis.
14	We are helping our friends at BAE learn fuel cells so they can put them on buses
15	Storage technologies for transportation should leverage storage for backup power and materials handling equipment.
16	at most 33% of any one application can be transferred directly to the next. Customization of the stack and system is required when transitioning from one application to the next. "Synergies" is a good sales tool term; practically, it can reduce time and money to the next product by less than 30%.
17	Transportation fueling should be coupled with refueling of cylinders for stationary use.
18	The private car is the most dificult problem, and untill the cost per watt is low enough, the car will wait.
	A solution to hydrogen storage will make an IC hydrogen car easy, and will also benifit a FC car.
19	NA
20	Combined power and hydrogen systems should be used. Combined heat and power systems should be used. Back-up systems should be used. All of these systems should be used by Federal, State and local government agencies instead of inferior incumbent technologies.

31. Are other developments, e.g., green technologies, an incentive, an impediment, or irrelevant to H2 technologies?	Response Percent	Response Count
Incentive	84.6%	22
Impediment	7.7%	2
Irrelevant	7.7%	2
Please Comment		18
answered question		26
skipped question		57

Respondent	**Comments on Question 31**
1	H2 is a clean storage medium and therefore can be utilized in conjuction with any renewable energy schema. Solar thermal hydrogen production (not PV) is an ideal example.
2	The country is going green - this is part of it
3	I think there isn't a lot of development to H2 technologies. These research are only in a fuel cell research.
4	Healthy environment is worth paying for
5	I believe the public equates hydrogen to green technologies any press given to one would benefit the other
6	A rising tide raises all ships.
7	These developments create opportunities, but fuel cell developers will still have to compete successfully.
8	This qustion does nor make sense
9	there is not an ulimited amount of time and money to go around to every technology out there. We need to choose one and push it.
10	The more intermittent, renewable resources are put onto the grid, the more unstable the grid becomes. The instability can be mitigated through the use of electrolyzers which can be regulated up or down by the grid operator. In return for this control, the grid operator will pay the electrolyzer owner regardless of whether or not the grid operator takes control of the electrolyzer. This added revenue decreases the cost of hydrogen produced which further enables the introduction of hydrogen vehicles.
11	Ultimately supplying H2 with Green sources vs hydrocarbons will benefit all
12	electric vehicles
13	H2 from renewable energy is a very favorable technology.
14	Small incentive for stationary power and H2 generation, but you have to stop making the connection between H2 and power gen except in the very long term and in niche applications!
15	in the case of wind and solar-- subsidies for these specific installations can open the door for high efficiency, reversible, fuel cell/electrolyzers-- SOFCEL-- to be implemented; thereby opneing the door for excess hydrogen to be produced, enabling the hydrogen economy.
16	Sopme of the alternate energy systems depend on available wind, or waves, and makeing H2 can be done when the power is available, this may be less costly than storeing the power for release to the grid, on demand.
17	If they are promoted and implemented in the education system properly it should definetly be an incentive.
18	LEED credit is helpful and should be pursued.

32. What specifically can government agencies, such as DOE, do to create markets?	
	Response Count
	25
answered question	**25**
skipped question	**58**

Respondent	Answers to Question 32
1	Offer a loan guarantee program that is relevant to the broadest possible market rather than the most narrow interests; i.e loan guarantees for $2,000,000 to 10,000,000 programs which constitute the vast majority of projects and will have the greates impact on market transformation. For small business like ours try wotking wiht the SBA to administer the smaller loan sizes and don't make the loan packages so unbearabley difficult to process. DOE has no business acumen in these matters and should contract the whole program out to credit professionals...
2	As I noted above, the DoD may be able to do more for commercialization in all apps from soldier power to truck APU to mobile gen sets to stealth drones to submarine or even rail power. The DoE needs to create public/private partnerships with incentives and provide massive education from secondary schools through University and graduate programs to the general public.
3	Remove burdens do not create them - develop and standardize codes and standards
4	An help for several customer to test this new technology. These help will allow to have a feed back and could make publicity and informations about back up power system for example.
5	invest in clean technology for their own departments, municipalities and governmentd should lead in purchasing clean systems in their buildings
6	Encourage power utilities to add H2 electrolysis as a load on demand in order to stablize frequencies and cyclical-varying wind and PV.
7	I do not believe DOE or any government agency can create markets. All DOE can do is help create avenues to develop the technologies and reduce system costs to a point where they can compete.
8	This requires more thought than be put in this box.
9	Become users themselves at federal facilities.
10	Provide clear leadership. Mandate action.
11	See answer 29
12	MARKET IS UNLIMITED, BUT THERE IS NO PRODUCT. I WISH DOE WILL TAKE A CLOSER LOOK TO MAGNITUDE OF THIS INNOVATION. Altek's technology provides consumers a unique product that currently has no contender on the market.
13	DOE can take their facilities off the grid and purchase distributed power from firms they have funded development with.
14	provide economic incentives such as tax breaks to encourage smaller businesses to invest in the technology.
15	Initiate rebate programs.
	Become a user of the technology.
16	target specific sectors, create working example, then educate to all the benefits
17	Act as first buyer
18	Fund full programs for demonstrations without onerous cost sharing requirements for cash strapped early stage companies.
19	Buy fuel cells for government applications and sites
20	Gov't should NOT be in business to create a market. Supply side economic stimulation is fine, but the market will only "accept" fule cells when the pain of not changing is greater than the pain of staying with conventional power generation. Gov't should protect trade and infrastructure, but let capitalism govern the role out of fuel cells.
21	true stage gate process that forces investment and best- of teamings; subsidies; be the first customer
22	Continue to offer hydrogen training to local fire marshals and building officials, taking the mystique of hydrogen away.
23	Grants and progrqams specifically to a target are best, for example funding hydrogen storage development.
24	See question 27.
25	Purchase of systems is the most powerful incentive right now. DOE should be buying systems to support their installations nationwide. FAA should be buying systems to support their installations nationwide. The same goes for the CIA, the FBI, and the Federal prison system. Federally funded hospitals should also be using these systems in combined heat and power applications to lower carbon emissions.

33. How much, if any, and what type of support did you receive to offset the cost of purchasing and/or operations and management?		
		Response Count
		24
	answered question	**24**
	skipped question	59

Respondent	**Answers to Question 33**
1	Lot's of support from the navy contracts management, lot's of support and funding from the CA SGIP program.
2	The Danish program recieves government support as well as industry support.
3	None so far - we may partner with our county to create some economies of scale
4	Research funding
5	43%
6	It was a 50% 50% match grant
7	DOE matching funds were used to cover some of the costs of these activities
8	The installation we significantly supported by the Canadian Government.
9	None.
10	Our program was an industrial consortium were costs were shared among a number of participants.
11	None
12	NONE.
13	As an OEM, we received none. Our customer received or is in the process of receiving money to help pay for their investments in the technology.
14	none
15	$750K from NYSERDA
16	We received a grant of 30 keuro from the city of Arnhem. Total cost of facility was about 90keuro.
17	None.
18	Support from DOE, Dutch government and Westinghouse was received.
19	Don't know.
20	US DOE SECA program funding includes 20 to 50% cost share by the private industrial participant--results in 50% to 80% funding by US DOE
21	None.
22	Lots, from several branches of the Canadian govt.
23	None received.
24	There was a $1,000 per kW tax credit.

34. Did the support affect your decision to install a fuel cell?

	Response Percent	Response Count
Yes	72.7%	16
No	27.3%	6
Comments		8
answered question		22
skipped question		61

Respondent	Answers to Question 34
1	Would not have happened without CA SGIP
2	Michael Szerckhep [sic] would do this on his own.
3	We did not get any monetary support but we got lost of encouragement
4	Would not been possible without it
5	We are a fuel cell development company with limited resources. We probably would not have done this project without DOE
6	The project cost was the ultimate determining factor.
7	we did not receive any and we still tested it
8	NA

35. Was the installation of the fuel cell in response to government regulations?

	Response Percent	Response Count
Governmental Regulations	4.8%	1
Corporate Initiative	81.0%	17
Other	23.8%	5
Comments		7
answered question		21
skipped question		62

Respondent	Answers to Question 35
1	Response to a Navy RFP
2	Government and Corporate joint initiative, like the EU's JTI.
3	we needed backup power and did not have the cash to afford the installaiotn of a standard generator.
4	in response to our customers
5	Product Development Strategy.
6	Interest in the fuel cell business
7	NA

36. Please provide any additional input you might have regarding early market development strategies for stationary power generation.	
	Response Count
	16
answered question	16
skipped question	67

Respondent	Answers to Question 36
1	The US government is the largest property owner in the world. LOGAN has tried for a dozen years to sell just one large scale fuel cell project to GSA for any number of federal buildings, and with no success to date. We have invested thousands of man hours over the years providing site / engineering evaluations, product evaluations, performance studies, and ecdonomic reports to GSA.
	Now we read that FEMP has awarded IDIQ contracts worth $80MM to 15 elite ESPC companies to pursue alternative energy strategies at fed gov sites. LOGAN is a DOE aproved ESPC contractor with 15 years experience in providing fuel cell solutions to DOD and commercial customers. We have installed over 130 fuel cells across the US and in Europe aggregating > 10MW capacities at installations ranging from 5kW to 750kW since 1995. Why wasn't LOGAN invited to participate in a small piece of that offering. DOE and FEMP need to take a deeper look at the hundreds of small business across the US that have significant investment and experience in developing alternative energy solutions. The elite ESCOs have been playing it safe, in my observation, over the past 15 years growing into very large and profitable companies simply by changing out ballast, updating HVAC controls and automating / updating mature technologies; but not adding anything to the development of alternatives. So those of us who have carried the water all these years are having a hard time trying to figure out how we will be included now that the party is about to begin...!!
	If DOE really wants market transformation to take place rapidly, look to the small companies who have labored to commercialize the stationary products you want to adopt. We have the skill sets, the applications knowledge base and years of experience to do excellent work, and we are all lean and hungry...
2	See my presentations. Note: I have answered the initial programs as surrogate for the 'Danish mCHP demonstration program' initial installation.
3	- several site " tests" will chose, and the customers could have an help to test this system.
	- more resctriction about diesel generator
	- an Hydrogen price less expensive
4	Apologies that this has been a mobile application rather than stationary, perhaps nevertheless useful.
5	stationary power is a great place to start fuel cell applications.
	It is price insensitive.
	the operation environment is controlled.
6	Historically most new energy technologies require effective use of all side streams and waste streams to be efficient enough to enter markets. As with biofuels producing not only fuel, but fertilizers and feedstocks as additional revenue streams. For fuel cells multiple outputs (power, heat, cool, hydrogen) would be a analogous theme.
7	Promote CHP as the most cost effective type of distributed generation.
8	See answer to question 29
9	Altek's ground-breaking technology will make a significant impact to the environment and economy, new business developments and lifestyle for millions of people around the world. While not widely thought of as a fuel, aluminum is high in energy, plentiful, fully recyclable and safe to transport and store. In addition in this chemical process, reaction of aluminum with water creates aluminum hydroxide, a valuable byproduct which is also used for water purification.
10	we implemented mobile fuel cells in forklifts, not stationary power generation.
11	hydrogen can be used as energy storage for intermittent power sources, especially in remote, island, or resort communities, where these communities are not connected to the main grid. The hydrogen can be converted into electricity using an H2ICE genset and/or a fuel cell system.
12	Need policy that facilitates distribution utilities (gas and electric) to favor new technology.
13	Come up with a better name than fuel cells. To Joe Plumber the name doesn't make sense and is hard to understand.
14	My current favorites for stationary is solid oxide, on coal gas, with heat recovery to a rankine cycle system.
	The initial cost is high,but the systems are efficient and clean
15	Left for another discussion.
16	The most important thing right now is to get the government agencies to purchase fuel cell systems to meet their needs.

37. Your contact information is not required unless you would like to receive the results of the study. We greatly appreciate your time to complete our survey.

	Response Percent	Response Count
Name:	**100.0%**	**31**
Company:	96.8%	30
Address:	93.5%	29
Address 2:	22.6%	7
City/Town:	93.5%	29
State:	77.4%	24
ZIP/Postal Code:	93.5%	29
Country:	90.3%	28
Email Address:	96.8%	30
Phone Number:	80.6%	25
	answered question	**31**
	skipped question	**52**

BIBLIOGRAPHY

[1] Department of Energy, 2009, "Department of Energy – Hydrogen," Department of Energy website, http://www.energy.gov/energysources/hydrogen.htm/.

[2] D.P. Gregory, J.B. Pangborn, 1976, "Hydrogen Energy," Annual Review of Energy 1, 279-310.

[3] C.E. Thomas, (1997), "Direct-Hydrogen-Fueled Proton-Exchange-Membrane Fuel Cell system for Transportation Applications: Vehicle Safety Report," DOE/CE/50389-502.

[4] J.M. Ogden, 1999, "Prospects for Building a Hydrogen Energy Infrastructure," Annual Review of Energy and the Environment 24, 227-279.

[5] D.B. Myers, G.D. Ariff, B.D. James, J.S. Lettow, C.E.S. Thomas, and R.C. Kuhn, 2002, "Cost and Performance Comparison of Stationary Hydrogen Fueling Appliances", NREL/CP-610-32405.

[6] J.M. Ogden, R.H. Williams, E.D. Larson, 2004, "Societal Lifecycle Costs of Cars with Alternative Fuels/Engines," Energy Policy 32(1), 7-27.

[7] K. Adamson, 2008, "Fuel Cell Today Market Survey: Large Stationary Applications", Fuel Cell Today, August 2008.

[8] D. Brdar, C. Bentley, M. Farooque, P. Oei, and T. Rauseo, 2006, "Stationary Fuel Cell Power Plants Status", Fuel Cells Seminar.

[9] S. Nishikawa, 2006, "Current Status of the Large-Scale Stationary Fuel Cell Demonstration Project in Japan", Fuel Cell Seminar.

[10] P. Garibaldi, 2005, "Italian H2 Parks and Projects: Towards as Inter-Regional 'Lighthouse' Action Plan", IPHE SC Meeting, Paris.

[11] M. Tulloch, 2006, "Hebridean Hydrogen Park: Business Plan 2006-2008", Energy Innovation Zone.

[12] Frontiers Magazine, 2002, "Fuel of the Future", British Petroleum Website. http://www.bp.com/liveassets/bp_internet/globalbp/STAGING/global_assets/downloads/F/Frontiers_magazine_issue_4_Fuel_of_the_future.pdf, August 2002.

[13] M. Mintz, S. Folga, J. Molburg, and J. Gillette, 2003, "Hydrogen Distribution Infrastructure", Hydrogen in Materials and Vacuum Systems, G.R. Myneni and S. Chattaopadhyay (Editors), American Institute of Physics.

[14] J.J. Winebrake, and B.P. Creswick, 2003, "The Future of Hydrogen Fueling Systems for Transportation: An Application of Perspective-Based Scenario Analysis Using the Analytic Hierarchy Process", Technological Forecasting and Social Change 70, 359-384.

[15] B. Cook, 2007, "Fuel Cell Industry: Longer-Term Potential, But High Relative Costs Limit Near-Term Opportunity", North America Equity Research, 30 November 2007.

[16] A. Cruden, T. Houghton, S. Gair, M. Duerr, G.D. Agnew, E.M. Stewart, A. Lutz, 2008, "Fuel Cells as Distributed Generation", Proc. IMechE 222.

[17] M. Ricci, P. Bellaby, R Flynn, 2008, "What do we know about public perceptions and acceptance of hydrogen? A critical review and new case study evidence", International Journal of Hydrogen Energy, Volume 33, Pages 5868-5880.

[18] EG&G Technical Services, Inc., 2004, "Fuel Cell Handbok (Seventh Edition), Department of Energy website, http://www.netl.doe.gov/technologies/coalpower/fuelcells/seca/pubs/FCHandbook7.pdf/.

[19] HLG Members, 2003, "Hydrogen Energy and Fuel Cells – A vision for our future", European Commissions Website, http://ec.europa.eu/research/energy/pdf/hlg_vision_report_en.pdf.

[20] F. Mueller, F. Jabbari, J. Brouwer, 2009, "On the intrinsic transient capability and limitations of solid oxide fuel cell systems", Journal of Power Sources, Volume 187, Issue 2, February 2009, Pages 452-460.

[21] A. Elgowainy, L. Gaines, M. Wang, 2009,"Fuel-cycle analysis of early market applications of fuel cells: Forklift propulsion systems and distributed power generation", International Journal of Hydrogen Energy, Volume 34, April 2009, Pages 3557-3570.

[22] E. Varkaraki, N. Lymberopoulos, E. Zoulias, D. Guichardot, G. Poli, 2007, "Hydrogen-based uninterruptible power supply", International Journal of Hydrogen Energy, Volume 32, Issues 10-11, July-August 2007, Pages 1589-1596.

[23] R.J. Braun , S.A. Klein and D.T. Reindl, 2006, "Evaluation of system configurations for solid oxide fuel cell-based micro-combined heat and power generators in residential applications", Journal of Power Sources, Volume 158, Issue 2, 25 August 2006, Pages 1290-1305.

[24] I. Zabalza, A Aranda, M.D. Gracia, 2006, "Feasibility analysis of fuel cells for combined heat and power systems in the tertiary sector", International Journal of Hydrogen Energy, Volume 32, Issues 10-11, July-August 2007, Pages 1396-1403.

[25] K. Mahadevan, K. Judd, H. Stone, J. Zewatsky, A. Thomas, H. Mahy, and D. Paul, 2007, "Identification and Characterization of Near-Term Direct Hydrogen Proton Exchange Membrane Fuel Cell Markets", Market Research Study by Battelle for DOE Contract No. DE-FC36-03GO13110.

[26] D.P. Kaundinya, P. Balachandraa, and N.H. Ravindranatha, 2009,"Grid-connected Versus Stand-alone Energy Systems for Decentralized Power—A Review of Literature", Renewable and Sustainable Energy Reviews, Volume 13, Issue 8, Pages 2041-205.

[27] E. Bompard, R. Napolia, B. Wan, G. Orsello, 2008, "Economics evaluation of a 5kW SOFC power system for residential use", International Journal of Hydrogen Energy, Volume 33, April 2008, Pages 3243-3247.

[28] D. C. Young, G. A. Mill, R. Wall, 2007, ”Feasibility of renewable energy storage using hydrogen in remote communities in Bhutan”, International Journal of Hydrogen Energy, Volume 32, Issue 8, June 2007, Pages 997-1009.

[29] C.E. Thomas, 2009, *“*Fuel cell and battery electric vehicles compared”, International Journal of Hydrogen Energy, June 2009. International Journal of Hydrogen Energy, Volume 34, April 2009, Pages 4243-4255.

[30] P. Agnolucci, 2007, “Economics and market prospects of portable fuel cells”, International Journal of Hydrogen Energy, Volume 32, May 2007, 4319-4328.

[31] C. Cottrell and S.E. Grasman, 2009, “A Preliminary Study on Lessons Learned from Stationary and Portable Fuel Cell Applications”, 2009 Industrial Engineering Research Conference, May 2009.

[32] C. Cottrell, S.E. Grasman, M. Thomas, K. Martin, J. Sheffield, 2009, “Best Practices for Stationary and Portable Fuel Cell Markets”, 2009 HYSYDAYS Conference, October 2009.

[33] F.R. Dwyer, J.F Tanner, Jr., 2009, “Business Marketing: Connecting Strategy, Relationships, and Learning”, McGraw-Hill4th Edition, Pages 174-

VITA

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