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IEEE POWER ENGINEERING SOCIETY
ENERGY DEVELOPMENT AND POWER GENERATING COMMITTEE

PANEL SESSION: APPLICATION OF FUEL CELLS AND INFRASTRUCTURE DEVELOPMENT FOR THE HYDROGEN ECONOMY

IEEE 2004 General Meeting, Denver, 6-12 June 2004
Wednesday, June 9, 2004, Plaza Ballroom E, 9:00 a.m.

EXTENDED PANEL SESSION SUMMARIES

Sponsored by: International Practices for Energy Development and Power Generation Subcommittee

Chairs: Peter Meisen, President, Global Energy Network Institute, San Diego, USA, E-mail: Peter@GENI.org
Tom Hammons, Chair, International Practices for Energy Development and Power Generation, University of Glasgow, Scotland, UK; E-mail: T.Hammons@ieee.org

Track 2: Environmental Dimensions
Track 4: Sustainability and Global Change

This Panel Session was on Application of Fuel Cells and Infrastructure Development for the Hydrogen Economy. The panel reviewed various *Hydrogen Economy* infrastructure paradigms and associated Fuel Cell applications. The perspectives were provided by representatives from some of the most innovative Fuel Cell Companies that are active in commissioning stationary Fuel Cells at customer sites. The presentations first included discussion of an alternative hydrogen infrastructure to hydrogen tank delivery and handling. Then the customer perspectives were presented as a means of benchmarking the Fuel Cell applied to Premium Tower IT and Telecom needs. Finally, the U.S. DOE hydrogen code and standards program and associated activities was examined.

Authors and Titles of their Presentations were:

1) Gene Connelly, Relion Inc, Spokane, Washington, USA. "Hydrogen Infrastructure for Fueling Distributed Resources".

2) Eugene Hashimoto, Product Manager, and Scott Wilshire, Director of Market Engagement, Power Plug Inc., Latham, New York, USA. "Solutions for Critical Back-up Power and On-Site Hydrogen Generation".

3) Steven Esbach, Fuel Cell Energy, Inc., Danbury, Connecticut, USA. "Hydrogen Infrastructure and Fuel Cell Applications; Viewpoint and Experiences of FuelCell Energy, Inc.".
4) Richard D'Aquanni, Applied Resources Group Inc., Brookline, Massachusetts, USA. "Regulatory and Infrastructure Barriers to the Application of Fuel Cells".
5) James M. Ohi, National Renewable Energy Laboratory, Golden, CO, USA. "U.S. DOE Hydrogen Code and Standards Program".

Each Presenter spoke for approximately 20 minutes. Each presentation was discussed immediately following the respective presentation. There was a further opportunity for discussion of the presentations following the final presentation.

The Panel Session was organized by Richard T. D'Aquanni (Applied Resources Group, MA, USA), Jim McConnach (Climate Change Working Group, Canada) and Tom Hammons (University of Glasgow, UK).

Peter Meisen and Tom Hammons moderated it.

1). The first presentation was on Hydrogen Infrastructure for fueling distributed resources and was prepared by Gene Connelly, Manager Commercial and Industrial Sales, Relion Inc, Spokane, Washington, USA. It discussed how Relion Inc (formerly Avista Labs is utilizing existing H2 infrastructure to power its fuel cell systems. It also discussed the economies of the alternatives to cylinder delivery (reformers, metal hydride, and electrolyzer storage).

Eugene (Gene) Connelly joined Relion Inc, (formerly Avista Labs) in Spokane, Washington, in 1999. He is the Manager responsible for sales of Relion Inc.'s Fuel Cells in the commercial and industrial sectors. Prior to joining Avista Labs, Connelly served in a variety of business development and project management positions in the energy and environment industries. He has successfully developed and managed projects resulting in significant reductions in operating costs and consumption. The technologies he has implemented include cogeneration, waste to energy, and energy efficiency upgrades. Connelly received his M.S. Degree in Management from the State University of New York at Ft. Schuyler and a B.Sc Degree in Economics from Fordham University.

2). The second presentation concerned solutions for critical back-up power and on-site hydrogen generation and was prepared by Eugene Hashimoto, Product Manager, and Scott Wilshire, Director of Marketing Engagement, Plug Power Inc., Latham, New York, USA. It discussed various solutions for critical back-up power and on-site hydrogen generation. Customer case studies were presented and partner projects were highlighted. Eugene Hashimoto of Plug Power Inc. presented it.

Scott Wilshire joined Plug Power in March 1999 as Director of Large Residential Systems and was appointed Director of Marketing Engagement in November 2000. He is responsible for all customer interface and new business development as well as management of Plug Power's commercial launch, project training and documentation, and applications engineering. He has over 18 years of engineering experience in the power generation industry.

Prior to joining Plug Power, he spent two years with General Electric Nuclear Energy in the Nuclear Field Engineering Program and 13 years with Lockheed Martin in various engineering and senior management positions that culminated in his management of reactor servicing design for the USS Virginia class submarine program. He received a B.Sc degree in Marine Engineering/Nuclear Engineering from the United States Merchant Marine Academy, an M.Sc in Business Administration from Rensselaer Polytechnic Institute, and completed the U.S. Navy Nuclear Power Engineering School. Andy Skok, Director of Distributor Support, will present it.

3). The third presentation was on Hydrogen Infrastructure and Fuel Cell Applications and gave a viewpoint and the experiences of FuelCell Energy, Inc. Steven P. Eschbach, Director Investor Relations and Communications, FuelCell Energy, Inc., Danbury, Connecticut, USA prepared it. It discussed FuelCell Energy's high temperature fuel cell technologies, strategic partnerships and the emergence from a research and development company to one that is now offering commercial stationary base load fuel cell power plants to the commercial and industrial markets.

Andy Skok, Marketing Director for FuelCell Energy, presented it.

Steven P. Eschbach joined FuelCell Energy, Inc. in September 2001 as Director of Investor Relations and Communications. He came to FuelCell with a diversified financial and corporate communications background, most recently as the lead investor relation's consultant for Denver, Colorado-based. He has a B.Sc Degree in accounting from the University of Connecticut and a Master's Degree in Business Administration from the University of Hartford.

Andy Skok is Marketing Director for FuelCell Energy where he has over 25 years of experience in many different management positions. Areas of focus have included research and development, first of a kind demonstration projects, new product development, development of a world-class field service group, business development and marketing.

4). The penultimate contribution was entitled: Premium Power Fuel Cell Barriers to Utilization, a Customer's Perspective. Richard T. D'Aquanni, President, Applied Resources Group Inc., Brookline, Massachusetts, USA prepared it. It focused on the barriers that face a commercial customer that chooses to match a Fuel Cell Premium Power source to its Critical Load. Barriers were examined, together with recommended remedies that can be accelerated by Fuel Cell manufacturers and fuel suppliers.

Richard T. D'Aquanni (deceased) was founder and president of Applied Resources Group Inc., At Applied Resources Group Inc., he coordinated customer-focused engineering projects, due-diligence practices and benchmarking software. He had both undergraduate and postgraduate degrees in Electrical Engineering, and was a Registered Electrical Engineer in Massachusetts and a Control Systems Engineer in California.

5). The final presentation provided an overview of the U.S. Department of Energy's (DOE) Hydrogen, Fuel Cell, and Infrastructure Technologies program with focus on their work to develop a unified domestic program and agenda for hydrogen codes and standards. This program involves the DOE, key standards development and model code development, organizations, industry and industry associations, other federal agencies, and national laboratories. The presentation described the objectives, approach, and major elements of this collaborative effort. Recent accomplishments and on-going activities were also discussed. James M. Ohi, Senior Project Leader, National Renewable Energy Laboratory, Golden. Colorado, USA prepared it..

James M. Ohi joined the National Renewable Energy Laboratory (NREL) in 1978 (then the Solar Energy Research Institute) in Golden, Colorado. He has worked in technical, analytic, and management capacities for a number of technology development programs, including those for amorphous silicon photovoltaic materials, wind energy, energy-efficient buildings, advanced transportation systems, and bio-fuels. His current work is focused on hydrogen fuel infrastructure development, particularly safety and codes and standards, and on renewable hydrogen-fuel cells. He provides technical and programmatic support to the DOE Office of Hydrogen.

He holds a B.S. in chemistry and a M.A. in English from the University of California, Los Angeles, and a PhD from the Graduate School of International Studies, University of Denver, with emphasis on environmental science and policy.

The final EXTENDED PANEL SESSION SUMMARIES follow

SUMMARIES:

Rec'd 13 May, 2004

1. HYDROGEN INFRASTRUCTURE FOR FUELING DISTRIBUTED RESOURCES

Gene Connelly, Relion Inc, (formerly Avista Labs), Spokane, Washington, USA (Paper 0685)

Summary

Gene Connelly will discuss how Avista is utilizing the existing H2 infrastructure to power its fuel cell systems. The distribution of cylinder H2 is widespread and at a price that allows us to compete today in our core market of backing up critical loads in the telecom, utility and the computer server market. Gene will also discuss the economics of the alternatives (reformers, metal hydride, and electrolyser storage) to cylinder delivery.

The formation of a hydrogen economy where H2 is widely available through pipelines to serve distributed loads is a classic chicken and egg dilemma. Infrastructure investment and deployment will not occur without a reasonable market for the hydrogen. Conversely, the deployment of fuel cells is hampered by the lack of an H2 infrastructure to serve distributed resources. The commercialization of fuel cells in the 1- 10 kW range will hasten investment in the hydrogen economy. Hydrogen is sold in high-pressure steel or aluminum bottles, which come in many different sizes. Each kilowatt hour produced, requires 32 cubic feet of hydrogen The actual storage capacity is dependent on bottle volume and fill pressure. Hydrogen is provided by companies such as AirGas and Praxair in the following sizes and pressures.

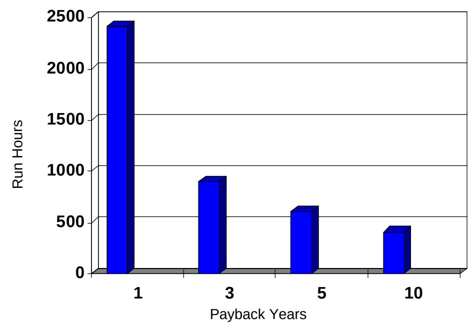
6" x 24"	33 cu-ft	29 lbs	1.0 kWh
6" x 37"	80 cu-ft	65 lbs	2.5 kWh
9" x 56"	197 cu-ft	125 lbs	6.1 kWh
9' x 66"	261 cu-ft	140 lbs	8.0 kWh

As Avista sells more units our price reduces over time and the technology can serve more applications and a larger market. Increased market penetration will increase demand for hydrogen and consequently the demand for reformers, storage technologies and distributed hydrogen systems. As demand increases hydrogen production will broaden and utilize wind, solar and biomas as base inputs.

A popular Avista Lab configuration to be discussed and consisting of an outdoor enclosure containing two Independence 1000 units and 6 bottles of hydrogen is illustrated in the two slides that follow:

The Value argument that Avista Labs uses regarding its Hydrogen infrastructure is illustrated in the chart.

Chart. Value Argument used by Avista Labs Regarding its Hydrogen Infrastructure



Where:

Unit Size (kW)	5	
Load Factor	50%	
Fuel cell efficiency	40%	
Reformer efficiency	80%	
NG cost $/MMBTU	$5.000	$0.047 per kWh
Hydrogen cost $/scf	$0.090	$2.100 per kWh
Interest/Discount Rate	6%	

Avista has evaluated other hydrogen storage technologies such as chemical and metal hydrides. The chemical hydrides such as sodium boro hydride available from Millennium Cell have good energy density, (similar to gasoline) and good safety characteristics as it will not explode or ignite until it has passed through the catalyst chamber. Metal hydrides store hydrogen in a metal powder at low pressure and also exhibit good safety characteristics. Currently the major impediment to these systems is the lack of a fueling infrastructure such is already in place with cylinder hydrogen.

Gene Connelly joined Avista Labs in Spokane, Washington, USA in 1999. He is the Manager responsible for the sales of the Avista's Fuel Cells in the commercial and industrial sectors.

Prior to joining Avista Labs, Connelly served in a variety of business development and project management positions in the energy and environmental industries. He has successfully developed and managed projects resulting in significant reductions in operating costs and energy consumption for his clients. The technologies he has implemented include cogeneration, waste to energy, and energy efficiency upgrades. These projects have served a wide variety of markets including industrial, commercial, and institutional facilities.

Connelly obtained his M.S. degree in management from the State University of New York at Ft. Schuyler and a Bachelor of Science degree in Economics from Fordham University. Connelly has also served as an Adjunct Professor of Economics at St. John's

Rec'd 21 May, 04

2. SOLUTIONS FOR CRITICAL BACK-UP POWER AND ON-SITE HYDROGEN GENERATION

Eugene Hashimoto, Product Manager, Plug Power Inc., Latham, New York, USA
Scott Wilshire, Director of Market Engagement, Plug Power Inc., Latham, New York, USA

Abstract

This presentation will discuss solutions for critical back-up power and on-site hydrogen generation. Customer case studies will be presented and partner projects will be highlighted.

Introduction

Plug Power has recognized and responded to the growing demand for alternative sources of critical backup power and hydrogen for industrial use in several industries. Premium power generation fuel cell systems have been delivered to the Telecommunications market, supplying rugged, reliable, emission-free backup power, and an on-site hydrogen generation system has been developed that will provide reliable and economical compressed hydrogen for industrial gas applications such as generator cooling and plasma spray welding.

Solution for Critical Backup Power

Unprecedented consumer demand for new telecom products, such as DSL and wireless broadband, has placed ever-higher demands on networks, while reliability and quality requirements remain high. These trends have forced telecom network planners to scramble to upgrade and optimize plant infrastructure, adding backup power, amid severe competitive cost constraints.

As traditional backup power technologies, like valve-regulated lead-acid batteries, fall short in the field, telecom operators are turning toward alternatives. Traditional technologies have long provided highly reliable power. Flooded lead-acid batteries typically achieve useful life spans of 20 years. Maintenance techniques for these and other widely used sources, such as engine-generator sets, are proven and easily implemented. Onsite personnel can monitor loads, equipment condition and provisioning requirements. Not withstanding the footprint and installation/replacement challenges, there is limited rationale for deploying new technology in such a critical environment—until outside plant expansion.

As telecoms deploy digital and fiber-network electronics and corresponding backup power sources in remote outdoor environments, the traditional solutions come up short. Valve-regulated lead-acid batteries, sensitive to temperature, are proving short-lived, too heavy for many practical outdoor applications (e.g. rooftop), and too laden with environmental issues. Engine-generator sets are maintenance dependent and produce combustion emissions and noise. With nearly half a million wireline and wireless sites scattered across the U.S. landscape, preventative maintenance is an escalating expense.

Over the last few years, researchers have made some advances in adapting the traditional technologies to the OSP environment. Even so, alternative technologies may take the upper hand in the race to serve telecoms in the new distributed landscape.

Several alternative batteries have generated extensive discussion throughout the industry. Notable among these is the lithium-ion battery; this option, however, is not without its hurdles.

Lithium-ion batteries have expected lifetimes of more than 10 years in extreme environments. They also offer substantial weight and space savings over both traditional lead-acid and nickel-cadmium storage systems. Other benefits include no ventilation requirements, better cycling characteristics, and more flexibility of form factor, all of which fulfill many OSP requirements.

Unfortunately, those distinct advantages come with significant disadvantages. Chief among them is cost: currently at 8-10 times the expense of valve-regulated lead-acid batteries, lithium-ion batteries require a higher initial capital outlay than many telecoms are prepared to make. As with other innovations, cost will come down as the technology matures—but telecoms are under pressure to come up with solutions now.

Another option, stationary fuel cells, circumvents battery technology. In the proton-exchange membrane (PEM) fuel cell, fuel atoms—hydrogen—are divided into protons and electrons. The electrons travel around the membrane, generating DC power; the protons pass through, combining with oxygen to produce heat and water with no combustion emissions.

Such a process makes fuel cells particularly adaptable to the OSP environment even as they carry the strengths of the new batteries. Plug Power's new line of backup fuel cell systems, GenCore®, is designed for reliable operation from –40C to 46C. Preventative maintenance is anticipated only every three years. The system provides immediate—and, as necessary, extended—response to power interruptions. The lightweight and small footprint makes it suitable for rooftop locations. The clean process produces zero emissions and little noise.

PEM fuel cells, moreover, have addressed many of the limitations of battery technology. Initial unit cost runs roughly half to one-third that of lithium batteries. While still more expensive than valve-regulated lead-acid batteries, fuel cells carry a lower life cycle cost, with lower maintenance needs and longer life.

The technology has drawn widespread support within key federal and state agencies, from the Department of Defense to the National Institute for Standards and Technology. Just as important, companies like Plug Power have been designing fuel cells specifically for stationary applications.

Several challenges remain to be worked out. Chief among them is the logistics of fuel supply, i.e. refilling of tanks via drop-off fueling and the corresponding concerns surrounding the siting of hydrogen. Plug Power and other companies have already undertaken field projects with telecom operators to resolve these issues.

All these technologies will continue to undergo development, driving down costs while expanding features. Researchers hope to turn the lithium battery into a significant commercial product within five years. Fuel cells are already in the field providing insights into application-specific needs and system design. Clearly, the potential is great for a near term "win-win" situation, the situation that everyone strives for; reliable service for customers – and lower cost for the companies that serve them.

On-Site Hydrogen Generation

In the realm of industrial gas use, hydrogen has long been widely used in applications such as generator cooling, and metal fabrication. Hydrogen has typically been produced in large (MMcf) steam methane reforming plants and distributed in low volumes via compressed steel cylinders and in larger volume via tube trailers.

Recently industrial gas suppliers and users have become the beneficiaries of the emerging "Hydrogen Economy" taking advantage of new technologies that offer the potential for cheaper and cleaner ways of producing hydrogen. Currently gaseous hydrogen users in typical gas applications pay in the range of $2-16/100scf. Embedded in this cost is the expense of transporting the gas e.g. to deliver 3 pounds of hydrogen, approximately 150 pounds of steel is required. Packaged gas is also tightly linked to the volume purchased and the purity of gas required. Low volume (<100,00scf/month) end-user utilities typically use gas stored in high-pressure steel cylinders, while medium volume users are typically serviced with high-pressure tube trailers.

Significant development has focused on commercializing electrolysis—both PEM and KOH—where de-ionized water can be readily converted into hydrogen-on-demand with oxygen as the sole by-product. Hydrogen generated in this fashion promises a 50% discount over rates offered to low-volume consumers.

Plug Power's GenSite™ uses auto thermal reforming (ATR) technology—a technology that has been embedded in over 380 of the Company's fuel cell systems, which have operated for more than one million hours. These natural gas reformers show the potential to produce hydrogen at ⅓ to ¼ the price of electrolysis, and up to ½ the price of hydrogen received by tube trailers.

Aside from the cost benefits of on-site hydrogen generation, there are many advantages in eliminating the need for transport—both for the end-user and the gas supplier. For the end-user, maintaining a hydrogen supply at the point of need increases the reliability of supply. For the gas supplier, on-site generation offers increased sales and new business outside their present distribution range. For both, a unit such as GenSite™ will provide an easy-to-install gas supply alternative.

Rec'd May 18, 04

3. HYDROGEN INFRASTRUCTURE AND FUEL CELL APPLICATIONS; VIEWPOINT AND EXPERIENCES OF FUELCELL ENERGY

Steven Eschbach, Director—Investor Relations and Communications, Fuel Cell Energy, Inc., Danbury, Connecticut, USA. (Paper 0811)

Abstract: This presentation will discuss FuelCell Energy's high temperature fuel cell technologies, target applications, markets, installations, strategic partnerships and the emergence from a research and development company to one that is now offering commercial stationary, base load fuel cell power plants to the commercial and industrial markets.

Keywords: High temperature fuel cells; base load fuel cell power plants.

Summary

FuelCell Energy, Inc., based in Danbury, Connecticut, is a world leader in the development and manufacture of high temperature hydrogen fuel cells for clean electric power generation. The Company's patented Direct FuelCell® (DFC®) technology combines high efficiency, low emissions, simplicity and economical cost for stationary power generation. FuelCell Energy's products, ranging in size for 250 Kilowatts (kW) to 2 Megawatts (MW), are designed for a wide range of customers, including hospitals, universities, hotels, utilities, wastewater treatment plants, office buildings, data centers, and manufacturing and industrial facilities. The Company is also developing next generation high temperature fuel cell systems, such as a diesel fueled marine Ship Service Fuel Cell, a combined-cycle DFC/Turbine® power plant and solid oxide fuel cells for applications up to 100 kW.

The unique feature of the Company's high temperature fuel cell systems is that they can generate hydrogen internally from a variety of fuels such as natural gas, propane, coalmine methane, synthesis gas from coal and digester gas from municipal and industrial wastewater treatment facilities. To date, FuelCell Energy has 30 DFC power plants at commercial and industrial applications worldwide, with more than 33 million kilowatt hours generated at customer sites.

Andy Skok will discuss the Company's high temperature fuel cell technologies, target applications, markets, installations, strategic partnerships and the emergence from a research and development company to one that is now offering commercial stationary, base load fuel cell power plants to the commercial and industrial markets. Photographs of the illustration of a multi-unit utility application follow:

Figure 1.

Figure 2

Figure 3

Steven P. Eschbach joined FuelCell Energy, Inc. in September 2001 as Director of Investor Relations and Communications. He came to FuelCell with a diversified financial and corporate communications background, most recently as the lead investor relation's consultant for Denver, Colorado-based. He has a B.Sc Degree in accounting from the

University of Connecticut and a Master's Degree in Business Administration from the University of Hartford.

Andy Skok ia Marketing Director for FuelCell Energy where he has over 25 years of experience in many different management positions. Areas of focus have included research and development, first of a kind demonstration projects, new product development, development of a world-class field service group, business development and marketing.

Mr. Skok has first-hand experience with power plant operability, reliability, instrumentation, operator training and customer interfacing. He directed field construction and operations of the world's first full-size 1.8 MW carbonate fuel cell power plant in Santa Clara, CA. In this role, he supervised all power plant site activities, including permitting, construction, process testing, electrical interconnection with the local utility, power plant testing, and interaction with sponsors, visitors and other agencies. He also led the design, fabrication, quality testing, design verification, start up and testing of the company's first DFC300 power plant. After the successful introduction of this early product, he played a major role in the design improvements presently being incorporated into the current production units.

Mr. Skok's responsibilities include technical support and training to the Company's original equipment manufacturing distributors, certification of fuel cell products, and technical support for the Company's New Product Introduction (NPI) process. This NPI process includes collecting market feedback, addressing customer issues, as well as managing the NPI process for FuelCell Energy's new products.

Mr. Skok received his undergraduate degree in Materials Engineering from Wilkes University and attended the Yale University's Chemical Engineering Graduate School. He has published numerous technical articles, is Chairman of the International Standards Committee IEC TC 105 working group on Fuel Cell Installation, and actively participates on over 12 other national and international Codes and Standards committees. He is one of the original IEEE 1547 participants. Company's DFC 300 and DFC 1500 power plants are shown below, respectively. An

Rec'd Jan 27 2004

4. PREMIUM POWER FUEL CELL BARRIERS TO UTILIZATION, A CUSTOMER'S PERSPECTIVE

Richard T. D'Aquanni, President, Applied Resources Group Inc., Brookline, Massachusetts, USA (Paper 0815)

Abstract: *This paper focuses on the barriers that face a commercial customer that chooses to match a Fuel Cell Premium Power source to its Critical Load. The barriers are presented along with recommended remedies that can be accelerated by the Fuel Cell manufactures and fuel suppliers.*
Keywords: *Distributed Generation, DG, Fuel Cell, Cogeneration, Hydrogen Economy, Premium Power supplier, Critical Loads.*

I. Introduction

This paper presents examples of barriers that need to be addressed if future Fuel Cell sales to commercial customers are to be realized. It addresses regulatory and infrastructure barriers to the application of Fuel Cells from a customers perspective. The barriers were apparent in two projects conducted by the author for the Cambridge Savings Bank (CSB) headquartered in Cambridge MA. The first project included the identification and specification of CSB's critical loads, the latter accomplished through detailed kW and power quality/reliability (PQ/PR) monitoring. Premium power solutions were identified and two vendors selected, Plug Power and Avista Labs, both providers of commercially available PEM technology to the marketplace.

II. Regulatory Barriers

The first barrier to be discussed is the inability to get permission to interconnect with the local electric utility. This barrier prevented Cambridge Savings Bank (CSB) from interconnecting a 5 kW Plug Power Fuel Cell to the NSTAR network despite it's proven safety, i.e. demonstrated through its compliance with requirements that exist in other states where rules have been passed, e.g. California.

It is worth noting that a branch office of the CSB was able to connect a 2 kW solar PV system to the overhead distribution network of the same utility. The major difference between the two was that the PV system is shut down on a grid outage, whereas the Plug Power unit was to operate as a co generator when the grid was available and as a back-up power source isolated from the grid when the grid failed. While the PV installation is approximately 2 kW_p and the Fuel Cell was 5 kW, the fraction of base load was significantly greater for the branch office PV than it was for the Fuel Cell which was to be located at CSB's Harvard Square headquarters.

While Plug Power and others participated in the regulatory discussions aimed at establishing an interconnection standard in Massachusetts, NSTAR was successful in deferring to a later date any discussion related to its network. With Fuel Cells and other DG eroding the revenue of electric utilities they understandingly resist any FC/DG initiative that does not, similar to demand side management (DSM), give them a return on their investments. In fact as long as the electric utility's revenue continues, however inappropriate to be based on kWh sales, then they will resist DG interconnection.

III. Infrastructure Barriers

From an environmental perspective, the Fuel Cell that either reforms natural gas or that relies on hydrogen derived from a non renewable resource must operate as a co generator in order to produce less CO2 than conventionally dispatched generation. Cogeneration, while not easily facilitated and hence considered a barrier to many, will reduce the CO2 per equivalent MWh generated. The barriers to co generate include the difficulty in finding an appropriately sized and high load factor thermal host and the difficulty in illustrating attractive economics after the host electric utility institutes a back-up power tariff. In addition, the recent high price of natural gas, the most popular co generator fuel, adds an additional burden on a co generator that fails to place a value on avoiding damage.

Another barrier is the misconception that Fuel Cells should be sized to a facility's base load. The facility's critical load is often a fraction of a facility's 7 x 24 base MWh load. With rare exception, a facility's base load is comprised of segmented loads that together will dilute the high value placed on maintaining a critical load. Communicating this fact along with the ease and low cost associated with the deployment of sub-metering and simultaneous monitoring of critical loads for PQ events will help accelerate cost-effective Premium Power Fuel Cell applications.

A third industry infrastructure barrier is the high cost of purchasing and operating a Fuel Cell without the complementary guarantee that it will resolve the customer's Premium Power problem. While initial costs are expected to decrease as Fuel Cell manufacturing processes are automated and as volume sales increase, the manufactures were reminded that a sale to CSB would be more likely if a Premium Power service contract complemented the sale of a Fuel Cell.

Related to Premium Power applications, the assumption that the Fuel Cell's simple design will result in a highly reliable product needs to be reinforced with a performance guarantee by the manufacturer. This becomes clear if the manufacturer realizes that a customer is paying a high price to address a critical load. ARG facilitated such an arrangement between CSB and forward thinking Plug Power.

IV. Performance Based Payments

A performance based fuel plan (PBP) to pay for the installation and maintenance of the fuel cell was a win-win for the customer as well as the Fuel Cell company. ARG accomplished this by simulating a Fuel Cell solution over a five-year period where the Bank's operational budget included a component that reflects PQ/PR damages that were expected from abnormal utility events [1].

The Philosophy behind this PBP was that, in theory if not in practice, the simplicity of the operating Fuel Cell that employs electrochemical processes and a single mechanical fan is very reliable. Hence, in addition to the possibility of being a zero emission generator running on hydrogen, it would approach premium 6 x 9's reliable power.

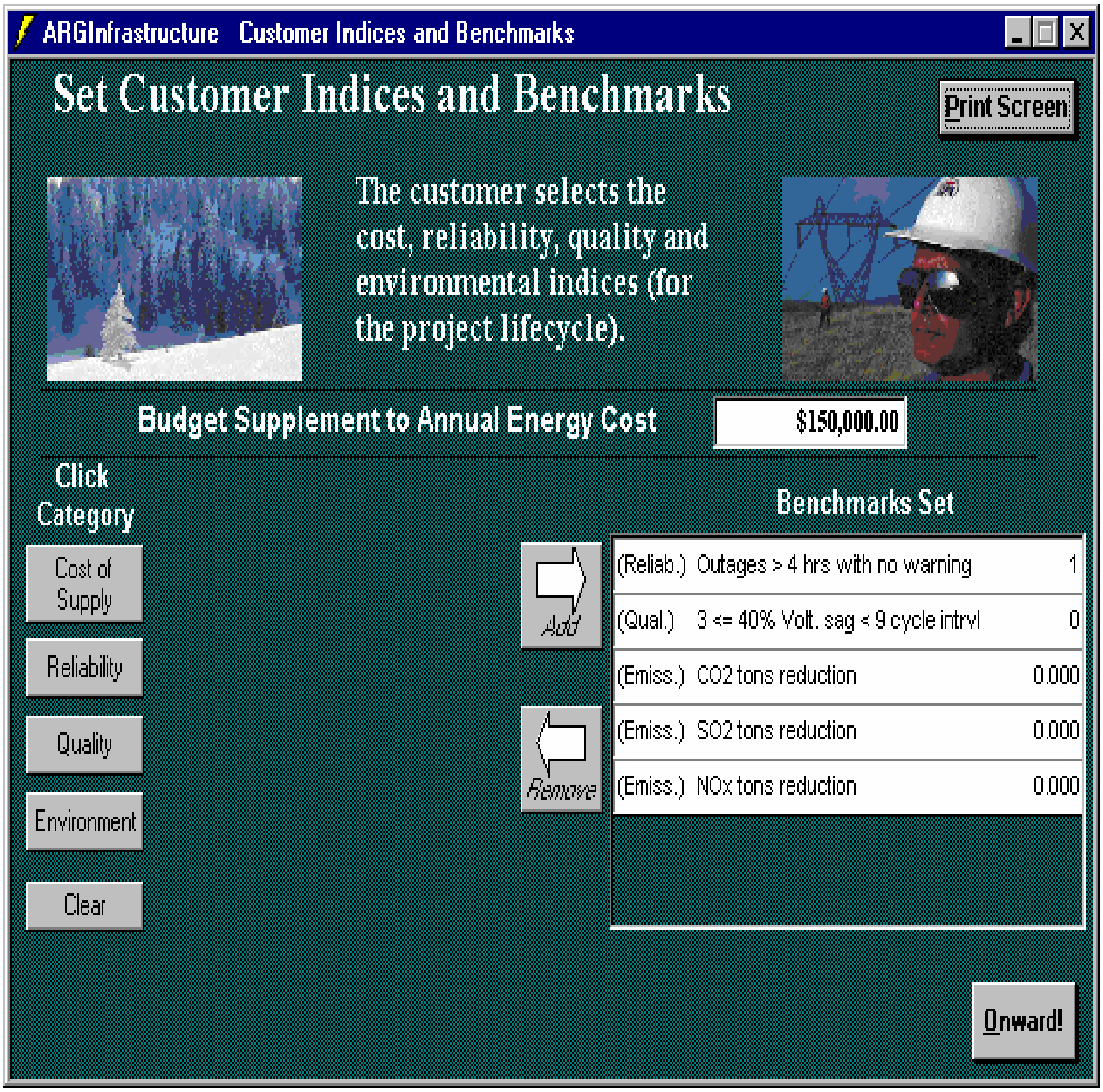
From the perspective of the customer that could not afford a single 4-hour outage, expected from a 3 x 9's grid reliability (99.9543%) the fuel cell back up is attractive even at a high price. In fact, assuming a fuel cell with a 90 % availability where 3.4 % is due to forced outages and 6.6 % due to anticipated or planned outages the combined reliability results in only 9.84 minutes of outages annually.

As described mathematically in the Appendix, the availability calculations assume: 1. good communication with the host utility will avoid scheduling planned maintenance during period of likely grid outages and 2. on-line communication and alarming from the fuel cell will allow for anticipation of some outages, e.g. a failing stack, and along with a good maintenance team, convert a forced outage to a planned outage resulting in significantly less damage.

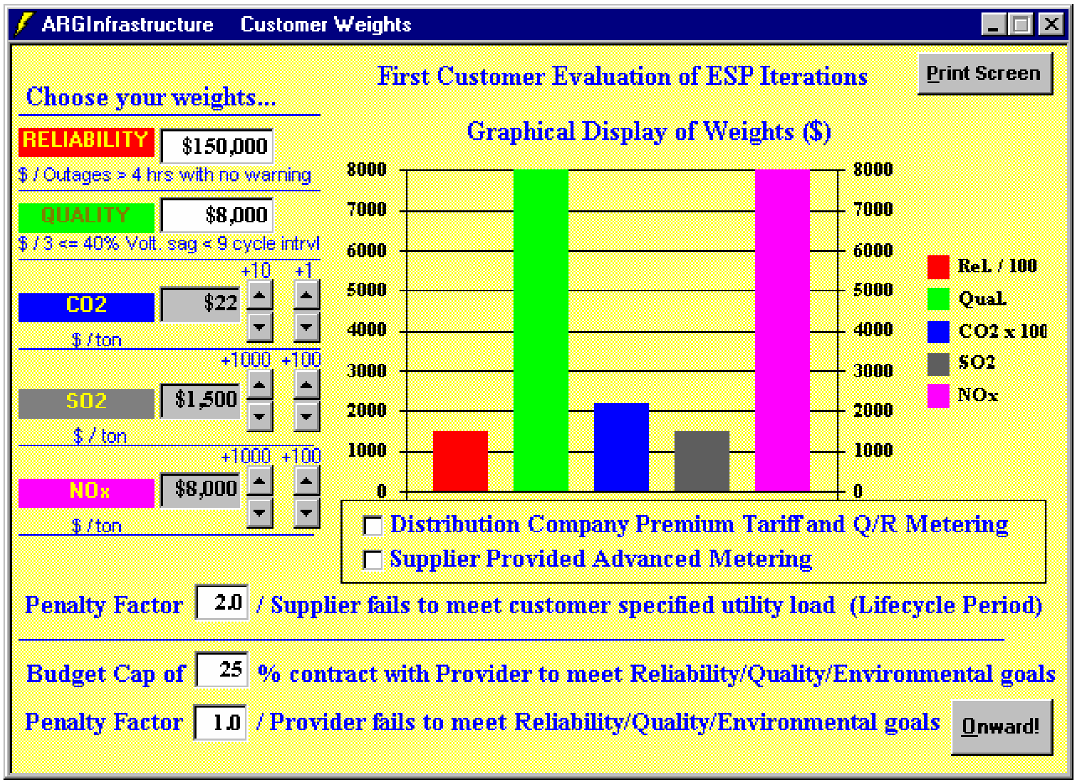
Specifying a payment for service plan over a 5-year period results in a win-win scenario allowing the Fuel Cell provider to do what it takes to maintain a guaranteed level of service to CSB.

Using a pre-set budget, the Fuel Cell provider commits to avoiding the damage at an annual cost that is less than the damage cost, thus helping the customer keep within its budgeted Total Cost of Operation. This is illustrated in the screens that follow.

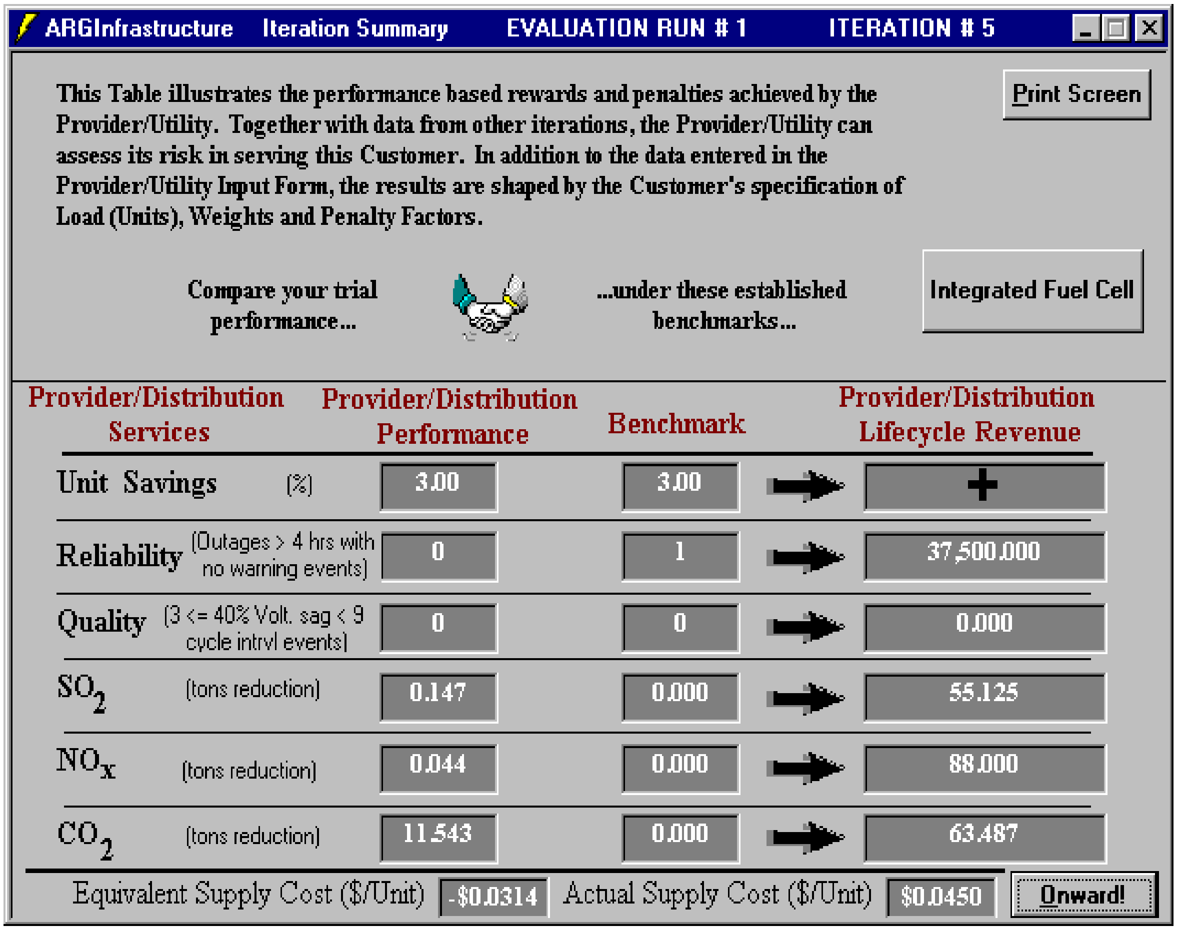
This first screen illustrates the cost, environmental and reliability and quality metrics and benchmarks that CSB experienced prior to deploying a Fuel Cell in the cogeneration/back-up mode.



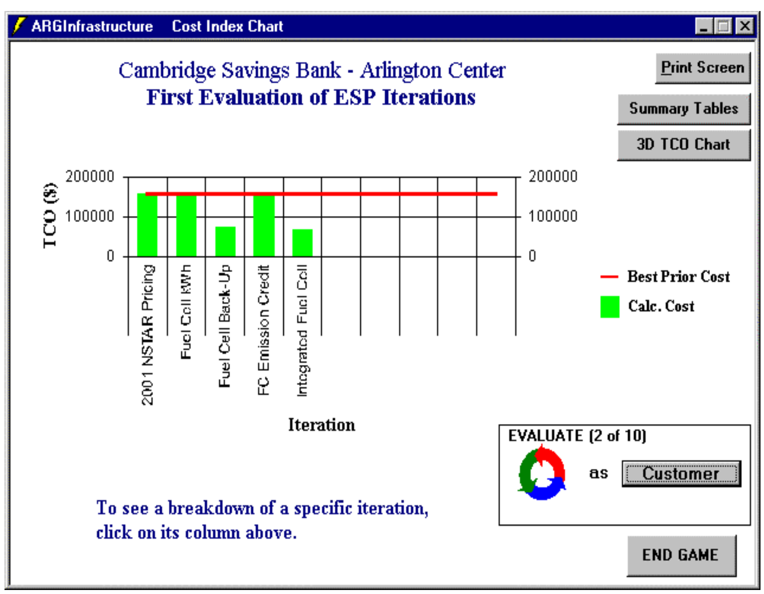
This next screen illustrates the values assigned to achieving environmental and damage avoidance goals:



The monetary value to CSB consistent with preliminary Plug Power agreements follows:



The Total Cost of Operation (TCO) to CSB at their Harvard Square headquarters is summarized as follows:



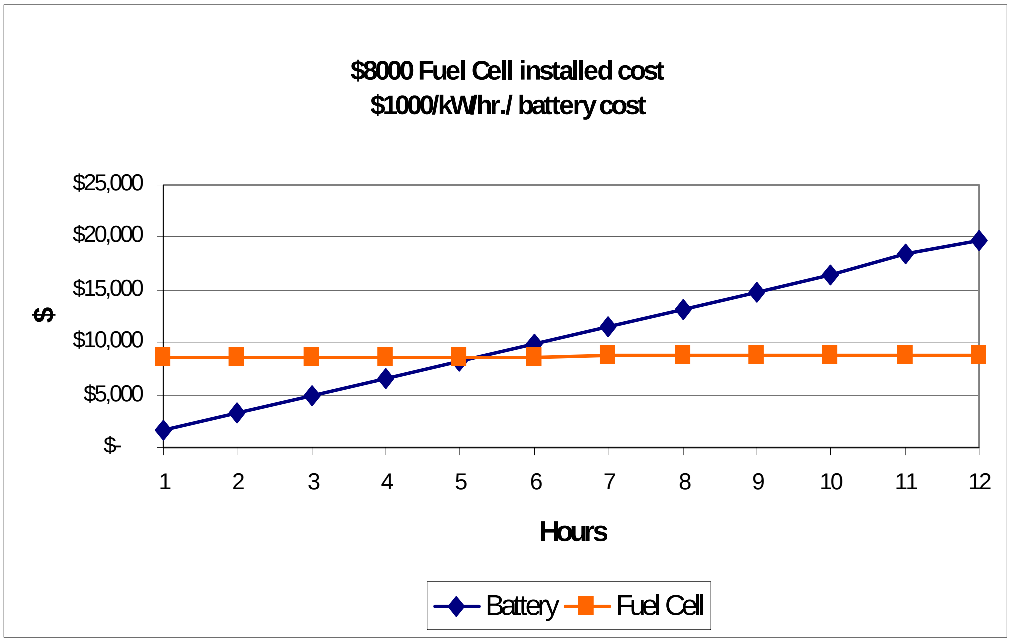
V. Follow up Project

Following the utility interconnection showstopper, CSB decided to continue by asking ARG to analyze the application of a Fuel Cell as a back-up power source. Unlike the co generator turned back-up generator project this Fuel Cell application dedicated its power to charge the existing batteries and avoid any back feeding of power into the utility grid following a utility outage. The batteries backed up by the Fuel Cell for an extended period of time would thus serve the critical Telecom/IT load.

VI. Hydrogen Fuel Barrier

At the time of this writing ARG is working with Avista Labs and Air Gas as we attempt to facilitate a 1 kW Fuel Cell with hydrogen fuel at the CSB. The 1 kW Avista Labs Independence unit is shown below:

This 1 kW unit will ultimately replace UPS batteries that are now in place in the Telecom/IT room. See the chart provided by Avista Labs below for the economic justification:



Rather than using a reformer to convert natural gas to hydrogen within a Fuel Cell, the Avista depends on the availability and delivery of hydrogen fuel tanks. While distributed widely, the sitting, handling and refilling of H2 cylinders at a commercial establishment in an urban setting present challenges consisting of educating and working with compliance officials including building departments, fire marshals and others.

From an availability perspective, Avista Lab's PEM fuel cell has hot-swappable membranes (so can deal with faulty or degraded membranes simply), can use industrial grade hydrogen (no reformers and not pure hydrogen), and low pressure 4 psi.

References

[1] CSB Premium Power Planning Study by Applied Resources Group Inc, February 13, 2003

Rich D'Aquanni is a founder and president of 22-year-old Applied Resources Group Inc (ARG). At ARG, Rich coordinates customer focused engineering projects, due-diligence practices and benchmarking software.

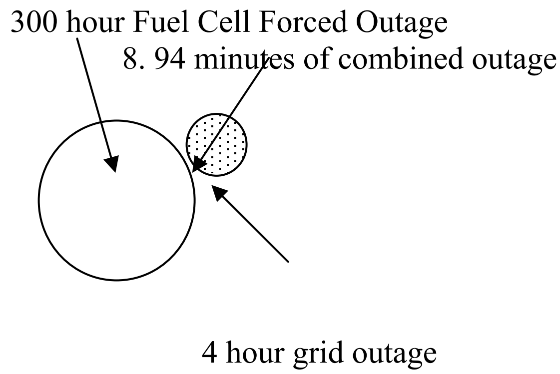
Mr. D'Aquanni has undergraduate and graduate degrees in electrical engineering and is a Registered Electrical Engineer in Massachusetts and a Control Systems Engineer in California. He is a senior member of the IEEE and contributor to P1595, the Draft International to Quantify GHG Emission Credits.

In addition to working with customers to contain utility costs he has been involved in numerous renewable energy generation projects. These include due diligence of biomass in Massachusetts and wind farm and solar PV feasibility studies in Morocco with recent projects in CT, RI, MA, NH and Iowa.

His Fuel Cell consulting clients include Wyeth, Harvard Medical School, The Energy Counsel of RI manufacturers and VESTAR, a CINERGY Company in addition to CSB.

Appendix

Value of adding a 90 % Availability Fuel Cell generator to a 99.9543 % Available Grid results in a 99.9983 % combined availability. This is graphically illustrated for one year below:



Note that the calculation is based on deducting the 574 hours allocated planned outage of the 8760 annual hours. Note that the planned outages are independent of grid outages. This assumes that planned outages can be coordinated to avoid periods of severe weather or grid stress or periods where grid O&M is occurring. Note that 576 hours are assumed to be planned vs. 300 hours assigned to forced due to the transfer of forced to planned outages by utilizing the fuel cells' real-time monitoring systems to anticipate forced outages before they occur.

The calculation is as follows: Combined Grid/Fuel Cell Available = 100% x (1-300x4/[(8760-576) x 8760]). The conversion to outage minutes before and after Fuel Cell back up is as follows: The duration of the outage in minutes the customer should expect if solely dependent on the grid = [1-99.9543/100] * 8760 hours/year * 60 minutes/hr resulting in 240 minutes. Duration of outage in minutes the customer should expect when dependent on the grid and the Fuel Cell = [1-99.9983/100] * 8760 hours/year * 60 minutes/hr or 8.94 minutes.

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5. U.S. DOE HYDROGEN CODE AND STANDARDS PROGRAM

James M. Ohi, PhD, Senior Project Leader, National Renewable Energy Laboratory, Golden, CO (paper 1319)

Abstract: The presentation will provide an overview of the U.S. Department of Energy's (DOE) Hydrogen, Fuel Cell, and Infrastructure Technologies program with a focus on DOE's work to develop a unified domestic program and agenda for hydrogen codes and standards. This program involves the DOE, key standards development and model code development organizations, industry and industry associations, other federal agencies, and national laboratories. The paper will describe the objectives, approach, and major elements of this collaborative effort. Recent accomplishments and on-going activities will also be discussed.

Keywords: Hydrogen; Fuel Cells; Infrastructure technologies; Codes and Standards.

Summary

Jim Ohi will provide an overview of the U.S. Department of Energy's (DOE) Hydrogen, Fuel Cell, and Infrastructure Technologies program with a focus on DOE's work to develop a unified domestic program and agenda for hydrogen codes and standards. This program involves the DOE, key standards development and model code development organizations, industry and industry associations, other federal agencies, and national laboratories. The paper will describe the objectives, approach, and major elements of this collaborative effort. Recent accomplishments and on-going activities will also be discussed.

In addition, the DOE and its national laboratories are defining a comprehensive research and development (R&D) plan to obtain the data and conduct the analysis and testing needed to establish a scientific and technical basis for hydrogen standards, codes, and regulations. Major areas of the R&D Plan will be described and key results to date will be presented.

The first element of this Plan defines unintended hydrogen release scenarios, the situational contexts needed to determine R&D priorities. Defining such scenarios was the subject of a workshop held in December 2003, and the results of the workshop will be presented. The scenarios will address the potential of combustible mixture formation as a function of factors such as release rates and quantities, release location, and environmental conditions. Releases in unconfined spaces, confined spaces (e.g., buildings and tunnels), and partially confined spaces (e.g., fueling stations, storage and distribution terminals) will be discussed. Potential release scenarios in normal environments, such as those under established operating conditions and controllable leaks from equipment, and piping, will be assessed. Releases in abnormal environments involving catastrophic releases due to equipment failure, accidents, fire, earthquake, and other natural disasters will also be discussed. The paper will also address scenarios in hostile environments involving catastrophic releases from sabotage and terrorist attacks.

Other sections of the paper will address R&D concerning fundamental properties of hydrogen—the critical physical and chemical properties that affect combustible cloud formation, ignition, combustion, and flame behavior and propagation. The paper will also discuss R&D needed to address fire and explosion damage potential.

A key part of the R&D Plan is to develop a Material Properties and Compatibility Handbook. A workshop to address this subject was held in December 2003, and the paper will describe the results of the workshop. The paper will also outline testing needs and requirements for key components and systems, including on-board and bulk gaseous and liquid hydrogen storage containers as well as transportable containers for mobile refueling systems. The paper will also discuss R&D planned for hydrogen safety sensors, including detection methods, applications, and requirements.

James M. Ohi: Jim Ohi joined the National Renewable Energy Laboratory (NREL) in 1978 (then the Solar Energy Research Institute) in Golden, Colorado, and has worked in technical, analytic, and management capacities for a number of technology development programs, including those for amorphous silicon photovoltaic materials, wind energy, energy-efficient buildings, advanced transportation systems, and bio-fuels. His current work is focused on hydrogen fuel infrastructure development, particularly safety and codes and standards, and on renewable hydrogen-fuel cell systems. He provides technical and programmatic support to the DOE Office of Hydrogen, Fuel Cells, and Infrastructure Technologies. He has also served as a team leader for advanced fuel cell R&D at NREL and as a principal investigator for NREL on renewable energy technology deployment to mitigate global climate change. He works with federal agencies, state and local governments, and non-governmental organizations on the development, testing, and deployment of renewable and sustainable energy systems. Before joining NREL, he worked for the Governor of Colorado’s Land Use Commission on energy and environmental regulation, and for county and city agencies in Colorado and California on environmental and land-use planning and regulation.

He holds a B.S. in Chemistry and an M.A. in English from the University of California, Los Angeles, and a Ph.D. from the Graduate School of International Studies, University of Denver, with an emphasis on environmental science and policy.

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