

# FUEL CELLS: BRIEFING PAPERS FOR STATE POLICYMAKERS



August 2011

## ABOUT THESE BRIEFING PAPERS

In 2010–2011, Clean Energy States Alliance produced a series of briefing papers for state policymakers on various topics related to stationary fuel cells and hydrogen. This booklet collects those briefing papers together in one volume:

- Fuel Cell Technology: An Overview
- Advancing Fuel Cells through State Policies
- Hydrogen Production and Storage
- Fuel Cells for Supermarkets
- Fuel Cells and Critical Power Applications

These materials were produced as part of a larger education and outreach initiative by Clean Energy States Alliance (CESA) to inform and engage state policymakers about the benefits of fuel cells and model state policies to support them.

The briefing papers are available individually with larger graphics on the CESA website. For further information on CESA's hydrogen and fuel cell activities, and to download the individual reports, please visit [www.cleanenergystates.org/projects/hydrogen-and-fuel-cells](http://www.cleanenergystates.org/projects/hydrogen-and-fuel-cells).

## ACKNOWLEDGEMENTS

Many people assisted with these briefing papers by providing information or review. We want to thank Lewis Milford and Jessica Morey (Clean Energy Group); Maria Blais and Anne Margolis (Clean Energy States Alliance); Carole Read and Gregory Kleen (US Department of Energy); Dustin Lilya and Pete Pearson (Albertsons, SuperValu); Rizaldo Aldas (California Energy Commission); Joel Rinebold (Connecticut Center for Advanced Technology); Selya Price, John Murphy, and Rick M. Ross (Connecticut Clean Energy Investment and Finance Authority); Donna Ferenz (FuelCell Energy); Kerry-Ann Adamson (Fuel Cell Today); Kathy Haq (National Fuel Cell Research Center); L. Scott Larsen, Paula Rosenberg, and Dana Levy (NYSERDA); Frank Blake and Benny Smith (Price Chopper); Timothy Lipman (University of California at Berkeley); Michael Glynn and Homer Purcell (UTC Power); David J. Allar (Wegmans), and Kathy Loftus and Lindsay Lehfeld (Whole Foods Market). We also want to thank DG Communications for designing and producing the individual briefing papers and this booklet.

This four-part series was begun by Charlie Kubert (1959-2010), who wrote three of the reports and laid the ground work for a fourth. Charlie was a valuable member of the CESA team, and we would like to honor his contributions to this project.

## FINANCIAL SUPPORT

Funding for this report was generously provided by the US Department of Energy's Hydrogen Education State Partnership Project with supplemental support from Clean Energy States Alliance.

# Contents

- 1 Fuel Cell Technology: An Overview**
- 6 Advancing Fuel Cells through State Policies**
- 11 Hydrogen Production and Storage**
- 14 Fuel Cells for Supermarkets**
- 18 Fuel Cells and Critical Power Applications**

## DISCLAIMER

Clean Energy States Alliance does not assume any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process that is referred to in this report. References in this report to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not constitute or imply endorsement, recommendation or favoring neither by the United States Government or any agency thereof, nor of the individual members of Clean Energy States Alliance. The views and opinions expressed in this series of reports do not necessarily state or reflect those of the United States Government or any agency thereof, nor the individual members of the Clean Energy States Alliance.

Work on these briefing papers was conducted under US DOE Grant DE-FC3608GO18111 A000, Office of Energy Efficiency and Renewable Energy Fuel Cell Technologies Program.



# FUEL CELL TECHNOLOGY

## A Clean, Reliable Source of Stationary Power

Charles Kubert • May 2010 (updated August 2011)

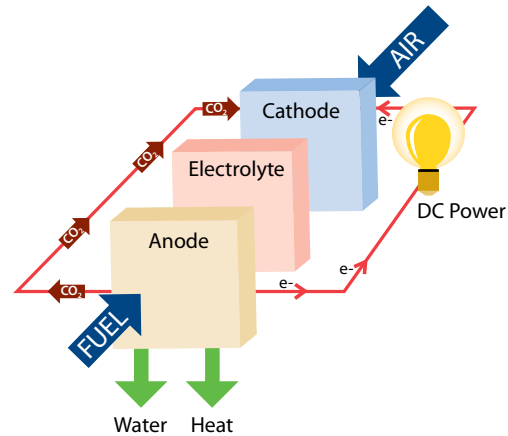
### Introduction

For many years, the focus of the emerging “hydrogen economy” has been on the use of hydrogen fuel cells for vehicles. While federal and state government and automakers still continue to invest in and promote policies to create the “hydrogen highway,” private businesses and government agencies are increasingly deploying fuel cells for stationary power applications. Stationary fuel cells are a technology that is commercially available, reliable, suitable to a wide variety of applications, declining in costs, and with federal and state support, becoming more affordable.

### Technical Background

A fuel cell is a device that converts the chemical energy of a fuel (usually hydrogen derived from natural gas or biogas) and an oxidant (air or oxygen) into electricity. In principle, a fuel cell operates like a battery. Unlike a battery, however, a fuel cell does not run down or require recharging (although cell stacks may need periodic replacing). It will produce electricity and heat as long as fuel and an oxidant are supplied. The fuel cell itself has no moving parts—making it a quiet and reliable source of power (see Figure 1). A fuel cell stack is a chemical power generator “sandwich” that consists of three parts: an anode, a cathode, and an electrolytic material in the middle. There are several

Figure 1:  
How a Molten Carbonate Fuel Cell Works



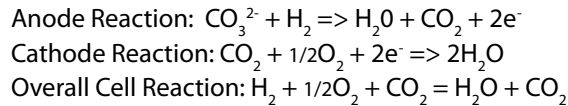
kinds of fuels cells, and each works slightly differently. In general terms, at the anode, hydrogen atoms enter and their electrons are separated so that the hydrogen ions (protons) pass through the electrolyte, while the negatively charged electrons pass through an external electrical circuit as direct current (DC) that can power useful devices. Whether the hydrogen ions combine with the oxygen at the cathode or at the anode, together hydrogen and oxygen form water that is drained from the cell. The chemical reactions for a molten carbonate fuel cell are as follows:

Table 1: Comparison of Fuel Cell Operating Characteristics

Fuel Cell Type	Operating Temp. (F)	System Size	Electrical Efficiency	CHP Efficiency*	Applications	Key Advantages
PEM	122–212	<250 kW (typically 5–10 kW)	25–35%	70–90% (low grade heat)	Backup Power	Low temperature, quick startup
Phosphoric Acid	302–392	50 kW–1 MW (typically 250 kW module)	>40%	>85%	Distributed Generation	Tolerance to hydrogen impurities
Molten Carbonate	1112–1292	50 kW–1 MW (typically 250 kW module)	45–47%	>80%	Distributed Generation	High efficiency, fuel and electrolyte flexibility
Solid Oxide	1202–1832	<1 kW–3 MW	35–43%	<90%	Utility-scale; large distributed generation	High efficiency, use of solid electrolyte

\*Assumes use of by-product heat

Source: U.S. Department of Energy Hydrogen Program



The major types of fuel cells—*proton exchange membrane* (PEM), *phosphoric acid*, and *solid oxide*—utilize different materials and processes and have different operating characteristics:

- PEM fuel cells are well-suited for back-up power applications at sites such as communication towers and equipment since they ramp up quickly and operate at low temperatures.
- Phosphoric acid fuel cells were a first-generation technology commercialized in the early 1980s. Their advantages for use as baseload power include high operating efficiency, particularly when waste heat is re-used, simple construction, low electrolyte volatility, and long-term operating stability.
- Molten carbonate fuel cells operate at higher temperatures and are also designed to be used as a baseload, 24/7 power source. Molten carbonate fuel cells convert gas into hydrogen within the fuel cell itself, avoiding the need for on-site storage of hydrogen or an external reformer.

- Solid oxide fuel cells are emerging as the latest fuel cell technology. Advantages of solid oxide fuel cells include an ability to reform gas within the fuel cell, the use of low-cost solid ceramic materials instead of a liquid electrolyte containing precious metals or corrosive material, and very high operating efficiency.

In addition to electric power, some stationary fuel cells also produce, as a by-product, heat that can be used for water, space, or process heating. The by-product heat can also be used to provide cooling through absorption or adsorption cooling systems technology to drive a refrigeration cycle. By capturing the waste heat from the fuel cell system, the overall thermal efficiency of the system can be very high under the right conditions. The already high 40–50% electrical efficiency that fuel cell systems offer can reach 90% in thermal efficiency, with the utilization of by-product heat.

Fuel cells can be scaled to provide power to anything from a portable electronic device such as a cell phone or a computer to large commercial, industrial and institutional facilities and even utility-scale projects. Because they are modular, multiple units can operate parallel to one another.

## Applications

Fuel cells can be deployed in any setting where a reliable source of baseload, on-site power is desired and, ideally, where by-product heat can be effectively utilized. They are also well-suited as alternatives to batteries or diesel generators for strictly back-up power applications, particularly in remote areas (such as cellular phone towers), and at critical facilities in urban areas with air quality issues.

## Current Fuel Cell Market

There are currently several hundred large fuel cell installations in the United States. In 2010, the U.S. market grew by more than 50%. Globally, 30 to 50 megawatts (MW) of fuel cell capacity are being installed annually with a projected 213 MW of new installed capacity in 2013. Projects are getting larger, with the average stationary fuel cell installation growing to about 1 MW, up from 250 kW in 2005.

## Costs

Costs for stationary fuel cell installations have dropped from about \$600,000 per kW in the 1970s (when fuel cells were developed for NASA) to about \$4,500 per kW today for the most widely deployed technologies. This is higher than the capital costs for fossil-fuel based distributed generation such as diesel generators and gas turbines. But it is lower than the capital costs of other distributed clean energy technologies such as solar photovoltaics. The U.S. Department of Energy's goal is to reduce this cost to about \$400 per installed kW by 2020 for solid oxide



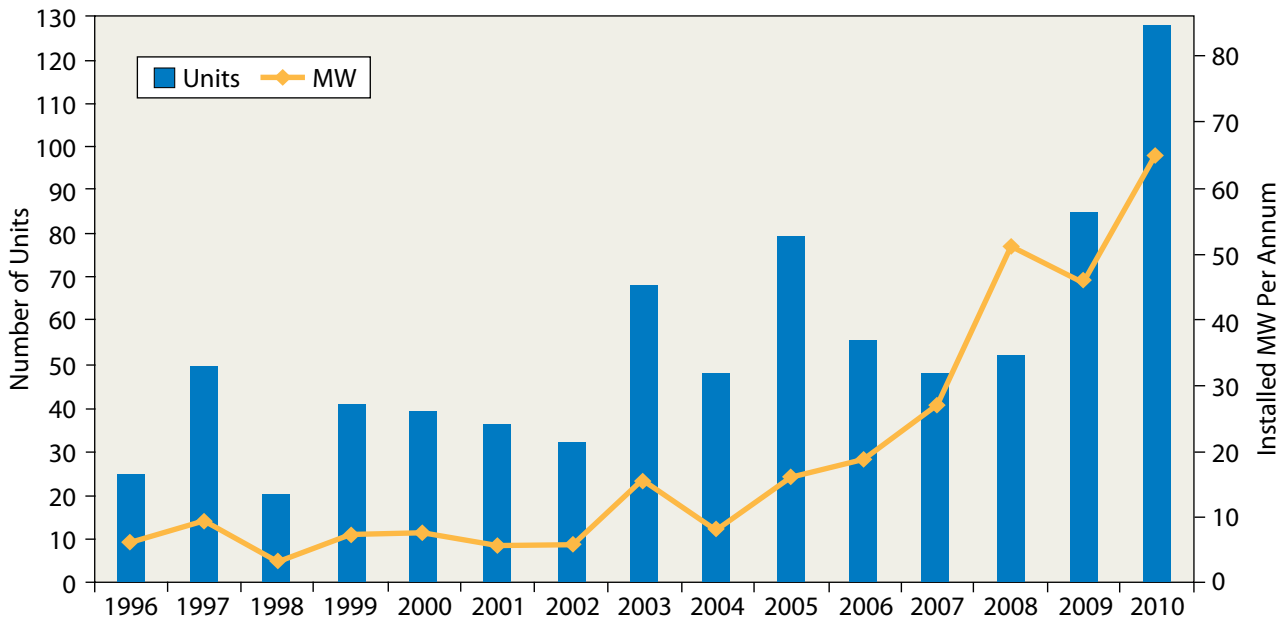
© FUELCELL ENERGY

### California State University, Northridge

CSUN installed a 1 MW stationary fuel cell power plant system from FuelCell Energy®. The system reforms hydrogen from natural gas to power the fuel cell and has successfully reduced the university's energy costs, improved power security through reduced reliance on the grid, created a state-of-the-art educational tool, and reduced their carbon footprint. Approximately 18% of the university's baseload power requirement is met by the fuel cells. The university further benefits from the fuel cells by utilizing by-product heat to provide 22 billion BTUs of thermal energy per year used to heat water for the campus, and by channeling residual CO<sub>2</sub> into an adjacent greenhouse where research on carbon dioxide plant enrichment is taking place.



Figure 2: Annual Number of Large Fuel Cell Units and MW Installed



Source: Fuel Cell Today, 2008 Large Stationary Survey; Pike Research, Research Report Stationary Fuel Cells (2011); DOE, 2010 Fuel Cell Technologies Market Report

fuel cell technology. It has formed the Solid State Energy Conversion Alliance (SECA), a government-industry partnership to achieve that goal. Like renewable energy technologies, fuel cells are eligible for the 30% federal Investment Tax Credit and for direct financial subsidies, in some states, lowering their capital costs considerably.

Because fuel cells can operate as a continuous, baseload source of power (unlike solar or wind which are intermittent), these capital costs can be spread out over far more kilowatt-hours (kWh) produced, especially when the by-product heat is captured and re-used. UTC Power projects that its PureCell® 400 kW unit will be able to produce power at 16¢/kWh (with 50% heat utilization), and at 14¢/kWh (with 100% heat utilization), before any federal or state subsidies. The capital costs of fuel cells can also be transferred through third-party ownership, in which a manufacturer or financial intermediary owns the system, realizes the tax benefits and sells energy to the host facility under a fixed price contract.

Table 2: Comparative Capital Costs for Distributed Generation Technologies

Technology	Cost (\$/kW)
Diesel Generator	\$800–\$1,500
Reciprocating Gas Engine	\$1,800–\$2,000
<b>Stationary Fuel Cells (1–200 kW)</b>	<b>\$2,500–\$4,500</b>
Wind Turbine (50 kW–100 kW)	\$1,500–\$5,000
Solar Photovoltaics (1–100 kW)	\$6,000–\$8,000

## Benefits of Fuel Cells

Stationary fuel cells have considerable benefits both to the facility where they are installed and to the public at large. These benefits will multiply as the costs of fuel cells continue to decline relative to grid power and the number of installations increases.

### User Benefits

#### Reliability

Fuel cells are well suited for primary power applications, providing both an extremely reliable and high-quality source of on-site power. This reliability makes them ideal for public safety facilities such as emergency dispatch centers, police and fire stations and hospitals. For private facilities such as computer server farms, data centers and laboratories where even momentary losses of power or voltage changes can disrupt computers and sensitive equipment, fuel cells deliver the sustained power quality needed, with grid power acting as a backup. Even non-critical facilities such as office buildings, retail stores and hotels can benefit from a grid-independent source of power that can also displace other fuels for heating, cooling and refrigeration.

#### Siting

While fuel cells have some local siting challenges, in general they are easy to site relative to other distributed generation technologies because they can operate emission-free, are quiet and compact. In some states such as California, they are completely exempt from



## United States Postal Service, San Francisco CA

The 680,000 square foot facility is a major postal service hub, processing 7.5 million pieces of mail per day. With the assistance of a third-party energy service provider, the facility installed a 250 kW fuel cell to provide a portion of both its power and space heating needs. The fuel cell complements a 285 kW, roof-mounted solar photovoltaic system that provides maximum output during periods of peak demand. The facility received financial support from both the California Self-Generation Incentive Program (SGIP) which provides incentives of \$2,500 per kW for natural-gas fuel cells, as well as the U.S. Department of Defense Climate Change Fuel Cell Program.

permitting requirements. Fuel cell technologies that directly utilize natural gas (or biogas) avoid any local concerns over on-site hydrogen storage.

### Remote Operation

Fuel cells can be operated and monitored remotely. This is important for fuel cells installed as backup power in remote locations such as telecommunications towers.

### Baseload Clean Energy

Many businesses and public facilities are installing solar photovoltaics as a way of providing on-site clean energy. Fuel cells' high efficiency and ability to produce constant power makes them a good complement to solar.

### Energy Cost Hedge

The installation of fuel cells can insulate businesses from unpredictable and rising electricity costs. While fuel cells still require hydrogen or natural gas as an input, these costs might rise less quickly than electricity, particularly in the event of state, regional, or federal carbon legislation.

## Public Benefits

### Environmental

Stationary fuel cells result in dramatically reduced on-site air pollution relative to back-up diesel generators. They can also result in reduced emissions relative to grid power depending on the source of generation that is displaced. This is due to the use of natural gas or biogas as the source of hydrogen, the high conversion efficiency of fuel cells, and the absence of particulate emissions. Fuel cells are driven by electrochemistry, not combustion. As a result, fuel cells emit only trace amounts of NOx. Because fuel cells are intolerant of sulfur, the fuels used have to be desulfurized, and thus fuel cells emit no SOx. If the direct fuel input is hydrogen, then only water vapor is generated in the exhaust. Because of the high electrical efficiency of fuel cells, the amount of CO<sub>2</sub> emitted per kWh of electricity generated is lower than from conventional fossil-fuel generation. Avoided emissions are further increased when the facility is configured to utilize the waste heat from the fuel cell. Table 3 compares the emissions profile of a fuel cell versus other forms of distributed and central power generation.

### Avoided Generation and Transmission Costs

Like other distributed generation technologies, fuel cells displace utility purchases of wholesale electricity on the margin and during peak demand periods. The cumulative effect of fuel cells with other distributed generation resources can also defer the need to build both additional generation and distribution system upgrades.

### Public Safety and Security

When power blackouts occur, the need to maintain critical public facilities and services ranging from police and fire dispatch to hospitals to water pumping and wastewater treatment is essential. Fuel cells provide a reliable way to ensure that these facilities stay up and running.

Table 3: Comparative Emissions Profiles of Fuel Cells vs. Distributed and Central Generation

Generation Technology	NOx (lbs/MWh)	SO2 (lbs/MWh)	Particulate Matter (lbs/MWh)	CO2 (Tons/MWh)
Fuel Cells	0.01	0.001	None	0.49*
Diesel Generators	5.9-17.1	0.3-0.5	0.74-3.0	0.75-0.9
Combined Cycle Natural Gas	0.11	0.022	0.067	0.50
Pulverized Coal	0.69	1.41	0.28	0.97

\*Assumes internal conversion of natural gas to hydrogen within the fuel cell. CO<sub>2</sub>-equivalent emissions would be reduced or eliminated if biogas or a renewable source of hydrogen were used.

Source: National Fuel Cell Research Center



FUELCELL ENERGY



### Sierra Nevada Brewing Co, Chico, CA

The Sierra Brewing Company wanted to find a reliable and affordable way to power its state-of-the-art brewing facility that was also environmentally-friendly. Its solution was a combined heat and power, 1 MW fuel cell power plant that provides nearly all of the brewery's

baseload power needs and the by-product heat and steam are used in the brewing process as well as other heating needs. This system not only lowers the overall energy cost at the plant, but also eliminates air pollutant emissions. When the fuel cells generate more power than is needed, Sierra Nevada sends the excess electricity into the grid and receives net-metering credit.

### Dublin San Ramon Services District Regional Waste Water Treatment Facility, Pleasanton, CA

Two 300 kW fuel cells were installed at the DSRSD regional wastewater treatment plant. This fuel cell system was designed to use the biogas generated by the wastewater treatment process as their renewable fuel



FUELCELL ENERGY

source. The fuel cells also generate heat that is used to pre-heat waste sludge, optimizing the anaerobic digestion process. The fuel cell helps reduce the demand on the local power grid by providing as much as 50% of the facility's required power. Because the facility is utilizing biogas, it was eligible for a larger \$4,500/kW incentive from California's SGIP.

## Conclusions

Fuel cells are coming into widespread commercial use for stationary applications, and their combination of reliability, efficiency, and low environmental impact make them an outstanding distributed generation technology for a range of applications. As the technology improves and costs decline, more businesses and public institutions should turn to fuel cells as a source of both primary and backup power.

However, as with other clean energy technologies, states play an important role in accelerating their adoption through both public policy and financial support.

## Sheraton New York Hotel

As part of a major renovation, the 1,750-room Sheraton New York Hotel installed a 250 kW fuel cell. This was the first hotel in New York to do so. The unit provides 10% of the electrical load of the hotel and, due to the hotel's large and constant hot water needs, effectively utilizes the system's waste heat to supplement natural gas in its boilers. The system received financial support from NYSERDA, New York State's energy research and development administration, which also manages its clean energy fund.

## Coming Soon: Fuel Cells for Your Home

While fuel cells in the United States are today targeted towards commercial use, in Europe and Japan, they are beginning to be manufactured and sold for the residential market. In Japan, residential fuel cells, about the size of a refrigerator, are being sold for \$30,000 (\$15,000 after government subsidy). More than 10,000 units were sold there in 2009 and 2010. Analysts expect the cost to drop to about \$5,000 within five years and one in four homes in Japan to have them by 2050. Beyond reducing dependency on the electric grid, converting natural gas into electricity (with the waste heat being used for space and hot water heating) would save homeowners a considerable amount in energy costs and also reduce the net carbon emissions of a home. Although the Japanese fuel cells are not likely a good match for the energy load of most American homes, ClearEdge Power, an Oregon-based company, has introduced a unit designed for the American market.

Policies such as including fuel cells as eligible resources in state renewable portfolio standards, encouraging or requiring the use of fuel cells in critical public facilities, and adopting uniform siting guidelines are important steps. In addition, providing financial incentives through state clean energy funds can help businesses overcome the first cost hurdles of installing fuel cells. These policy recommendations are reviewed in greater depth in an accompanying briefing paper, "Advancing Stationary Fuel Cells through State Policies."



# ADVANCING STATIONARY FUEL CELLS THROUGH STATE POLICIES

Charles Kubert • May 2010 (updated August 2011)

## Introduction

Over the past decade, states and municipalities have increasingly shaped public and regulatory policy to support renewable energy generation, from residential, roof-mounted, solar photovoltaic systems to large, commercial wind farms. They have done so for a number of reasons: in-state economic development, displacing emissions from conventional energy sources, diversifying the state's energy portfolio, and providing a long-term hedge against uncertain and volatile energy prices.

Stationary fuel cells share many of the characteristics of renewable energy generation. Fuel cells provide clean, quiet, efficient, and reliable distributed generation for a variety of applications: from critical facilities such as airports, emergency dispatch centers, hospitals, and telecommunications towers to office buildings, retail stores, and industrial facilities. Unlike many renewable energy technologies, fuel cells are not an intermittent source of power and can provide consistent, reliable power.

Yet, despite these advantages, most states have yet to give fuel cells the level of support they have provided to other clean energy technologies. This briefing paper identifies those policies that states have or can adopt to support fuel cells. These policies are broken down into three areas: 1) those that support the deployment of fuel cells, 2) those that remove state and local barriers to fuel cell installations, and 3) those that promote the development of an in-state fuel cell manufacturing sector.

### Policies to Support Fuel Cell Installations Hydrogen "Road Maps"

Many state energy or economic development offices have developed strategic plans to grow hydrogen and fuel cell industries and markets within their states. While a number of these have focused on hydrogen-powered fuel cells for transportation applications, other state plans are centered on the development of a fuel cell manufacturing industry and the deployment of fuel cells in stationary applications. These plans help to provide policymakers with a vision of how fuel cells can play a role in their state's economy and energy portfolio. For an example of a state hydrogen and fuel cell roadmap, see

the Connecticut Center for Advanced Technology website at <http://energy.ccat.us/energy/fuelplan.php>.

### Renewable Portfolio Standards

Twenty-nine states now have renewable portfolio standards (RPS), which have been the most important state-level policy driver for renewable energy development. These RPS policies primarily support large-scale projects such as wind energy. Few RPS laws include fuel cells as an eligible resource unless the hydrogen used in them is produced from a renewable resource such as biogas (almost all hydrogen produced in the United States currently is reformed from natural gas). By including fuel cells that utilize natural gas as an eligible resource, these technologies would qualify for the state RPS. If included in a distributed generation technology set-aside, as states have done with solar photovoltaics, fuel cells could receive some market-based financial support as well. Currently, only seven states (CT, DE, ME, MN, NY, OH, and PA) include all fuel cells, regardless of the fuel source, as RPS-eligible. An alternative approach would be to require utilities to install a certain amount of fuel cell generation capacity (either utility- or customer-sited) by a certain date and to allow cost recovery of these installations.

### Tax Incentives

Many states provide sales tax and property tax exemptions for renewable energy technologies. These exemptions should be extended to fuel cells to assist this clean energy technology to gain marketshare. This would complement the 30% federal investment tax credit (extended through 2016), for which fuel cells are eligible.

### State Purchasing Leadership

States can take the lead in acquiring fuel cells to replace diesel generators for back-up power in both new and existing facilities. Fuel cells could also be deployed as a primary source of power in new, high-profile public buildings such as at universities, administrative buildings, or airports. The long ownership cycle of these buildings, together with low financing costs, allows states to spread out the cost of these installations over many years.





## Critical Facilities

States can encourage the use of fuel cells as primary and/or back-up power in new telecommunications towers, hospitals, and emergency service facilities. They could do so directly by specifying that fuel cells be used, or indirectly by increasing the performance standards for back-up power (e.g., lower emissions, greater operating efficiency or more reliable performance), which would lead to the selection of fuel cells as the ideal generation source. While it is difficult to calculate “payback” on emergency and back-up power installations, the long investment time horizons and the public purpose of these facilities should allow states and municipalities to support the higher up-front costs of fuel cells for backup power. For more information on the application of fuel cells for critical facilities, please see the companion briefing on *Stationary Fuel Cells and Critical Power Applications*.

## State Clean Energy Funds

Eighteen states have ratepayer-supported clean energy funds that collectively have provided billions of dollars in support to renewable energy projects over the past decade. With the exception of California, Connecticut, New York and Ohio, state funds are not yet targeting fuel cells as an area of support. Direct grant assistance would encourage both private and public sector facilities to acquire fuel cells. These installations would, in turn, raise visibility of the technology and encourage further installations. States could consider establishing performance-based incentives rather than lump-sum grants at time of project completion. In addition, states will want to consider whether to only support projects using fuel cells for base-load power, or to also support back-up power applications.

These state clean energy funds have been the most active in supporting fuel cell installations at both private and public facilities.



### NYSERDA

The New York State Energy Research and Development Authority (NYSERDA) is the administrator of the State’s Renewable Portfolio Standard Customer Sited Tier Fuel Cell Program. The program has

a total of \$21.6 million in available funding (\$3.6 million per year) through 2015. The program is divided into two categories; the Large Fuel Cell Program for systems larger than 25kW and the Small Fuel Cell Program for smaller systems. Through this program and similar predecessor programs, NYSERDA has approved funding to install 33 large stationary fuel cells and 24 small stationary fuel cells.

Under the Large Fuel Cell Program, NYSERDA offers two types of financial incentives, with a maximum of

\$1 million per project site. Projects can apply for capacity incentives based on the manufacturers’ nameplate rating of the fuel cell, with an upper limit of \$200,000 per project site. Projects at sites of Essential Public Services, such as police stations and hospitals, or where the fuel cell system will be an integral part of a documented and verifiable “facility of refuge”, may receive up to an additional \$100,000. Performance-based incentives are paid to facilities that operate with an annual capacity factor of at least 50%. They are paid based on performance during the first three operating years subsequent to commissioning and are capped at \$300,000 per year.

Under the Small Fuel Cell Program, performance incentives are available of up to \$50,000 per project site. They are paid to those facilities operating with an annual capacity factor of at least 50%. Like the performance incentives for large systems, they are based on the first three years of operation but are capped at \$20,000 per year.



## CLEAN ENERGY

FINANCE AND INVESTMENT AUTHORITY

### Clean Energy Finance and Investment Authority

The Clean Energy Finance and Investment Authority (CEFIA), formerly the Connecticut Clean Energy Fund, has been a national leader in the support of fuel cell installations. CEFIA’s On-site Renewable Distributed Generation Program has provided grants totaling approximately \$23 million to 18 fuel cell projects representing installed capacity of 7.5 MW. There are an additional 3.4 MW of pending projects supported by \$8 million in grants from the Federal Government through the American Recovery and Reinvestment Act.

Connecticut’s Project 150 is an initiative to increase the amount of in-state renewable energy generation by requiring utilities to enter into long-term contracts for 150 MW of Class I renewable energy generation (fuel cells are Class I in Connecticut). Seven fuel cell projects were awarded contracts under Project 150. Although CEFIA is not directly funding these projects, it played an important role in evaluating project proposals.

CEFIA’s New Technology Programs support development and commercialization of emerging clean energy technologies, including fuel cell and hydrogen generation technologies. The Operational Demonstration Program has provided funds for a number of projects to demonstrate commercial viability of new methods of hydrogen and electricity production using fuel cell technology. These projects were supported by nearly \$1.1 million in seed funding which has leveraged approximately \$36 million in federal support. The program will continue to provide \$2 million annually to fund a mini-



### Pepperidge Farm, Bloomfield, Connecticut

Pepperidge Farm, the cookie and cracker manufacturer, installed a 250kW fuel cell in its Bloomfield, CT bakery



FUELCELL ENERGY

in 2006. This was followed by the installation of a much larger 1.2 MW fuel cell in 2008. Together, the two fuel cells will provide 70% of the electricity needed by the plant while utilizing waste heat in the plant's boilers. The fuel cells have an electrical conversion efficiency of 47% and an overall system efficiency of 70% through reusing the waste heat. Both installations were supported by significant grants from the Connecticut Clean Energy Fund, consistent with that state's commitment to supporting its fuel cell manufacturing industry.

imum of four projects. Additionally, CEFIA has created a new early-stage technology funding program, the Alpha Program, providing more than \$800,000 annually to support a minimum of four projects.

CEFIA has also begun a Fuel Cell Performance Monitoring Program at five sites with the economic and operating data to be used to establish the value proposition for fuel cells.

### California

The California Public Utilities Commission's ratepayer-funded Self-Generation Incentive Program provides support for commercial-scale installations of a variety of distributed generation technologies. The program has funded 67 fuel cell projects totaling 30 MW in capacity. The program provides support levels of \$2.50/watt for fuel cells using non-renewable resources and \$4.50/watt for those using gas from renewable sources such as biogas from wastewater treatment facilities. <http://www.cpuc.ca.gov/PUC/energy/DistGen/sgip/>

These direct incentives are complemented by the work of the California Stationary Fuel Cell Collaborative ([www.casfcc.org](http://www.casfcc.org)), which promotes the use of fuel cells for distributed generation and other specialized applications within California. Under the guidance of the Collaborative, private industry and public agencies work together to:

- Advance programs and activities that accelerate the deployment of fuel cells
- Advance public policy supportive of stationary fuel cells, including addressing siting barriers, encouraging state procurement of fuel cells for use in public building and maintaining financial incentives for fuel cell installations
- Initiate public demonstrations of fuel cells
- Conduct key studies to further existing knowledge

about fuel cell capabilities, performance and the impact of fuel cells for distributed generation, backup power and specialty vehicles and

- Raise public awareness about and acceptance of stationary fuel cell technologies

### Removing Installation Barriers

In addition to providing appropriate incentives, state and local governments need to address and remove barriers that may restrict the installation of fuel cells.

### Interconnection and standby charges

Interconnection is the process by which any distributed generation (both renewable and non-renewable) is connected to the local electric distribution grid. For many years, utilities put up roadblocks that made interconnection difficult. These included costly impact studies, insurance requirements, and delays. Most state regulatory commissions have addressed the interconnection problems that have held back all forms of distributed generation. However, the effectiveness of interconnection rules varies by state, and there is room for improvement in many states. For a review of state interconnection standards, see the annual "Connecting to the Grid" report, [http://www.irecusa.org/wp-content/uploads/2009/10/Connecting\\_to\\_the\\_Grid\\_Guide\\_6th\\_edition-1.pdf](http://www.irecusa.org/wp-content/uploads/2009/10/Connecting_to_the_Grid_Guide_6th_edition-1.pdf). For model interconnection rules, see <http://irecusa.org/wp-content/uploads/2010/01/IREC-Interconnection-Procedures-2010final.pdf>.

### Hydrogen Transportation and Storage

State and local fire marshals as well as the public are concerned about the movement and storage of hydrogen, even though hydrogen is a commonly used industrial gas stored at tens of thousands of industrial facilities. Both the International Code Council (ICC) and the National Fire Prevention Association (NFPA) have developed a set of codes and standards pertaining to hydrogen transport, storage, and distribution. In addition, NFPA is developing a new comprehensive set of hydrogen standards which was released in 2010, and the International Mechanical Code and International Fuel Gas Code also address hydrogen. These codes cover storage tank specifications, setbacks and enclosures, signage and other factors. State policymakers should ensure that their state fire and building codes are consistent with these international and national standards and formalize this consistency through legislation if necessary. Since many of the larger fuel cell technologies produce hydrogen on-site within the fuel cell itself, this code adoption is primarily relevant to on-site storage of hydrogen for PEM fuel cells used for back-up power and materials handling equipment. See: <http://www.nfpa.org>; see also CESA's companion briefing guide on Hydrogen Production and Storage.



## Project Zoning, Siting and Permitting

Siting approval and permitting for fuel cell projects is the domain of local governments. Like any energy project, local discretion can move a project forward or stall it. State policymakers should review local zoning and permitting codes regarding hydrogen storage and fuel cells and, to the extent possible, attempt to develop a consistent set of standards used by local governments. For more information on permitting, see [http://www.hydrogen.energy.gov/permitting/permitting\\_process.cfm](http://www.hydrogen.energy.gov/permitting/permitting_process.cfm).

## Fuel Cell Industry Support

Several states have invested considerable resources in building fuel cell manufacturing clusters. Connecticut, Ohio, South Carolina and Hawaii have all worked hard to make their states leaders in a growing fuel cell industry. While the industry is not yet large enough to support manufacturers in every state, the activities in these states provide collaborative models for stimulating industry growth.

### Connecticut

The Connecticut Hydrogen-Fuel Cell Coalition ([www.chfcc.org](http://www.chfcc.org)), administered by the Connecticut Center for Advanced Technology (CCAT), is comprised of representatives from Connecticut's fuel cell and hydrogen industry, labor, academia, government, and other stakeholders. CCAT and the Connecticut Hydrogen-Fuel Cell Coalition work to enhance economic growth through the development, manufacture, and deployment of fuel cell and hydrogen technologies and associated fueling systems in Connecticut.

Connecticut companies now lead the world in the development of alkaline, molten carbonate, and phosphoric acid fuel cells and are among the leaders in proton exchange membrane and solid oxide fuel cell development. Connecticut companies in hydrogen generation are leaders in both alkaline and proton exchange membrane electrolysis systems and in converting natural gas or petroleum products to hydrogen through reforming

processes. Connecticut is home to UTC Power, FuelCell Energy and Proton Energy Systems, among others.

One of the key strengths of Connecticut's program is that it has combined the industry development focus of the Fuel Cell Coalition with additional support for project deployment through the Connecticut Clean Energy Investment and Finance Authority (CEFIA). CEFIA's financial support of commercial fuel cell installations not only helps the industry to build an in-state market but also provides outstanding fuel cell demonstrations which can be used to promote the technology and the industry throughout the country.

As a result of these efforts, employment in the fuel cell industry has grown dramatically in Connecticut, with an estimated 2,000 working in the industry supply chain, representing over 70% of all renewable energy jobs in the state.

### Ohio

For the past decade, the State of Ohio has focused on building a fuel cell research and manufacturing cluster and industry supply chain. These efforts have been financially supported by the Ohio Third Frontier Program ([www.ohiothirdfrontier.com](http://www.ohiothirdfrontier.com)), a state economic development program funded through tax-exempt bonds that provides financial support to move companies and products from R&D through commercialization. The program focuses on industry clusters where the state has competitive strengths, including advanced materials and fuel cells.

The Third Frontier Program has been enhanced by the work of the Ohio Fuel Cell Coalition ([www.fuelcellcorridor.com](http://www.fuelcellcorridor.com)), a group of industry, academic and government institutions working collectively to strengthen the state's fuel cell industry and become a global leader in fuel cell technology. Its primary objectives are to:

- Build upon existing industry and academic strengths in the state to advance the integration of a coordinated, robust fuel cell supply chain.
- Promote public awareness of fuel cells as both a source of clean energy and a source of economic growth for the state.
- Expand networking and information-sharing among those engaged in the industry
- Identify and encourage federal funding that can leverage state resources in the development of a fuel cell industry in the state.

### South Carolina

South Carolina has developed one of the most integrated and well-funded hydrogen fuel cell industry development initiatives in the country ([www.schydrogen.org](http://www.schydrogen.org)). These



**Gills Onions of Oxnard, CA, with its Advanced Energy Recovery System, converts 100% of the onion waste at its processing facility (about 1.5 million pounds of onion waste per week) into**

**clean, virtually emissions-free, heat, electric power, and high-value cattle feed by using an anaerobic digester to produce methane gas from the onion waste to power two (2) 300 kW fuel cells, which provide Gills Onions with up to 100% of baseload electricity requirements. For installing the system, Gills Onions is eligible to receive \$2.7 million from Southern California Gas Co. as part of the state's Self-Generation Incentive Program, which encourages self-contained generation by businesses.**



initiatives include:

- **Industry Partnerships:** There are many partnerships between institutes and large corporations. For example, Toyota Motor Corporation has invested approximately \$1 million in the Center for Hydrogen Research in Aiken.
- **Hydrogen Infrastructure Development Fund:** This \$15 million public fund is available to private companies that work with USC, Clemson, S.C. State University and the Savannah River National Laboratory. South Carolina taxpayers who contribute to the Fund receive a 25% credit against their state income tax. Fund contributions will be granted to promote the development and deployment of hydrogen production, storage, distribution, and dispensing infrastructure.
- **Local Investments in Hydrogen Research:** South Carolina's local communities have also shown strong support for hydrogen and fuel cells. In 2005, Aiken County fully funded the construction of the Center for Hydrogen Research, a \$10 million state-of-the-art facility designed to facilitate cooperative research among the Savannah River National Lab, universities, and industry.
- **USC Columbia Fuel Cell Collaborative:** The University of South Carolina, the City of Columbia, the South Carolina Research Authority (SCRA), and EngenuitySC joined together to form the USC Columbia Fuel Cell Collaborative in 2005. The collaborative has three principal goals: to position the Columbia, SC, region as a leader in fuel cell innovation; to become world-class innovators for the hydrogen and fuel cell economy; and to recruit and retain fuel cell scientists, entrepreneurs, and innovators to help make South Carolina a pre-eminent location for the hydrogen and fuel cell economy.

## Hawaii

Hawaii, as a state with high-cost energy, has always been seeking ways to increase its share of clean, locally sourced

energy. Its long-running hydrogen program is an example of this. The program has centered on three areas: research, investment, and deployment.

- **Research:** In 1974, spurred by the OPEC oil embargo, the Hawaiian legislature established the Hawaii Natural Energy Institute (HNEI) at the University of Hawaii with the mandate to transition the state off of oil. Since that time, hydrogen has been supported as a key technology in this effort. In September 1985, HNEI was awarded a contract from the Department of Energy to establish the Hawaii Hydrogen from Renewable Resources Program. HNEI has also created the Hawaiian Fuel Cell Test Facility (HFCTF), with a public/private consortium of the Office of Naval Research, UTC Fuel Cells, and the Hawaiian Electric Company, the state's largest electric utility.
- **Investment:** In 2006, the Hawaiian legislature appropriated \$10 million for a hydrogen investment fund. This fund was created to develop a world-class renewable hydrogen program in Hawaii and has the goal of leveraging over \$100 million in additional capital. The fund is managed by a private venture capital firm with assistance from HNEI, which is responsible for developing an overall state hydrogen program development plan, the technical evaluation of proposed investments, hydrogen infrastructure project management, and attracting cost-share projects to the state.
- **Deployment:** The first cost-sharing grant from the state investment fund was awarded to the Hawaii Hydrogen Power Park at Hawaii Volcanoes National Park (HAVO). The project includes hydrogen production from renewable electricity, compression, storage, delivery, and dispensing to hydrogen vehicles. Separately, HAVO was awarded \$2 million from the National Park Service to purchase two hydrogen fueled shuttle buses.

## Conclusions

Despite being a proven technology with significant performance and environmental benefits, stationary fuel cells have yet to achieve the visibility or market acceptance that other clean energy technologies have. Proactive state policies that are targeted directly at fuel cells can play an important role both in increasing stationary fuel cell installations and in growing the fuel cell manufacturing industry. While direct financial support for fuel cell projects is an important element of these policies, there are a myriad of other actions that states can take to both raise awareness of and to remove barriers to fuel cell installations. Policymakers should develop comprehensive legislation that addresses all of the factors that can encourage or hinder fuel cell markets in their states.



### Fuel Cells for Combined Heat and Power

**At South Windsor High School in CT, a UTC PC25 fuel cell generates 200 kW of electricity. Not only does that clean energy significantly reduce the high school's demand upon the power grid, but the school**

**further benefits by capturing the more than 900,000 BTUs of heat that the fuel cell generates hourly. That by-product heat is used for space heating and to preheat boiler return water.**

**This project was funded with support from the Connecticut Clean Energy Fund.**



# HYDROGEN PRODUCTION AND STORAGE

Charles Kubert and Warren Leon • May 2011

## Introduction

When policymakers consider the expanded use of hydrogen in either vehicles or stationary applications using fuel cells, they sometimes express concern about how the hydrogen will be produced, transported, and stored. This briefing paper provides background information on hydrogen production and storage, and shows that there is already considerable experience with hydrogen. It also looks at ways to produce hydrogen from renewable resources both in the near-term and long-term. The paper's focus is on the production and storage methods needed for stationary fuel cell deployment rather than on the larger infrastructure required to support using hydrogen extensively in vehicles.

As an introduction, although hydrogen is the most common element in the universe, it cannot be mined or extracted in its elemental form. It instead needs to be separated from other compounds (such as water or hydrocarbon fuels). This conversion process requires energy, but the hydrogen produced can still be a cleaner and more reliable source of stored energy than either fossil fuels or grid electricity.

Currently, hydrogen is widely used as a commodity chemical, with approximately 10–11 million metric tonnes produced in the US each year. If it were used directly as a fuel, that amount would be enough to power about 30 million cars or 5–8 million homes.

Hydrogen production falls into four general categories. According to the US Energy Information Administration, about 25% of the total is produced and used on-site at oil refineries, generally for “hydro-treating” crude oil as part of the oil refining process to improve the hydrogen-to-carbon ratio of the fuel. Production for ammonia for fertilizer accounts for 21%. Merchant production for sale to diverse parties for such purposes as treating metals and “hydrogenation” in food processing accounts for another 15%. Finally, about 36% of total US production is a by-product of another process, most frequently catalytic reforming at oil refineries or production of chlorine and caustic soda.

### Hydrogen Production Methods

Hydrogen is produced today primarily through *steam methane reformation* (SMR), in which natural gas or another

methane source is reacted with steam in the presence of a catalyst to produce hydrogen and carbon dioxide. The current cost of producing and transporting hydrogen through SMR as a dedicated process (rather than as a by-product) is \$2–\$5 per delivered kilogram.

Hydrogen can also be produced by *electrolysis*, in which water is split into hydrogen and oxygen atoms in an electrolyzer, using only electricity. This process currently costs about twice as much as SMR, although it could be more competitive in places where the cost of the electricity for electrolysis is particularly low. Electrolysis may be used as a means of storing energy. For example, the electricity produced by wind turbines during off-peak periods could produce hydrogen, which could then be stored and used to generate electricity at a later time in an on-site fuel cell system or to provide hydrogen for other applications.

Additional emerging hydrogen production methods include *gasification* or *pyrolysis* (gasification in the absence of oxygen) of coal, low-value oil refinery products or biomass, and direct solar photochemical processes. The US Department of Energy is placing particular research emphasis on hydrogen production methods that have low overall emissions of greenhouse gases per unit of usable energy (i.e., those utilizing renewable non-carbon resources).

### Hydrogen Delivery and Storage

For some stationary fuel cell applications, transportation of hydrogen is not an issue, because the hydrogen is produced on-site. That is the case with molten carbonate fuel



#### Hydrogen Production by Alkaline Electrolysis

These electrolyzers are manufactured by Hydrogen Technologies AS and each is two megawatts.



cells, some phosphoric acid fuel cells, and solid oxide fuel cell technologies. They all directly convert natural gas or biogas into hydrogen internally within the fuel cell itself.

However, smaller stationary fuel cells, such as those using proton-exchange-membrane (PEM) technology (e.g., those used in forklifts and telecommunications towers) and some phosphoric acid fuel cells, often rely on hydrogen produced off-site and delivered in tanks to be stored on-site.

Some code officials and policymakers, as well as the general public, remain concerned about the flammable nature of hydrogen. In reality, through 40 years of industrial use, well-developed codes and standards governing hydrogen's transport, storage, and use have evolved to ensure safety. Like gasoline and natural gas, hydrogen is flammable. But also like gasoline and natural gas, it can be managed safely when the codes are followed and its properties are understood.

Hydrogen is often delivered in 22-foot or 44-foot steel tube trailers and can be stored on-site in the trailer vessels or transferred to code-certified pressure vessels. When needed in larger quantities or when transporting hydrogen over long distances and/or to multiple sites, it is often delivered as a liquid in a cryogenic tanker. After transport, the liquid can be transferred directly to an insulated storage vessel where it is later vaporized for use as a gas, or it can be vaporized from the tanker and used to fill on-site gaseous storage vessels. Hydrogen is also transported by pipeline, typically as a low-pressure gas. Several small hydrogen pipeline networks exist in the United States, usually near petrochemical production facilities, such as those along the Texas Gulf Coast and in Louisiana and California.

The applicable codes that states should follow are the ASME Boiler and Pressure Vessel Code, Section VIII ([http://campaign.asme.org/bpvc10/Pressure\\_Vessels.cfm](http://campaign.asme.org/bpvc10/Pressure_Vessels.cfm)) for stationary uses and 49 Code of Federal Regulations ([www.access.gpo.gov/nara/cfr/waisidx\\_99/49cfr172\\_99.htm](http://www.access.gpo.gov/nara/cfr/waisidx_99/49cfr172_99.htm)), which covers the transport of hazardous materials.

These codes specify that hydrogen cylinders and storage tanks should be stored outside at a safe distance from structures, ventilation intakes, and vehicle routes. When it is necessary to locate storage inside, the provisions in National Fire Prevention Association (NFPA) Compressed Gases and Cryogenic Fluids Code ([www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=55](http://www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=55)) should be followed. Although codes and standards provide valuable guidelines, local officials have the final authority for permitting hydrogen storage and power generation facilities in a given jurisdiction.

## Production of Renewable Hydrogen

Although stationary fuel cells can be highly efficient (with a combined efficiency of up to 80% when waste heat is utilized), they presently still rely primarily on non-renewable fuels such as natural gas. In the longer term, it is envisioned that cleaner and more sustainable sources of hydrogen will be employed. In fact, a number of states are facilitating this goal by offering financial incentives for fuel cell installations that employ hydrogen derived from renewable resources.

There are four key technology platforms for the production of hydrogen from renewable resources:

1. **On-site Use of Biogas:** Methane biogas is produced as a by-product of wastewater treatment, the decomposition of landfills, and anaerobic digestion of manure or food processing waste. This biogas is often used to fuel conventional reciprocating engines, but can also be used to generate power and process heat directly in an on-site fuel cell. Several wastewater treatment plants, wineries, breweries, and a food processing facility in California have installed fuel cells to utilize their on-site biogas, and California's Self-Generation Incentive Program provides enhanced incentives for fuel cells using on-site biogas. For an example, see the sidebar on Sierra Nevada Brewery.
2. **On-site Solar or Wind:** Solar panels or wind turbines installed at commercial/industrial sites to produce electricity can be used to produce hydrogen through electrolysis. AC Transit (a San Francisco Bay Area transit agency that operates a fleet of fuel cell buses) and Honda (see sidebar) are implementing demonstration projects for this.
3. **Industrial-scale Solar, Wind, Geothermal, or Hydropower:** Electrolysis-based hydrogen production facilities can also be co-located with large-scale renewable energy sites and the hydrogen then shipped to various markets. This could be a more cost-effective means of storing energy than batteries or other options. For an example, see sidebar on Hawaii.



### Compressed Hydrogen Gas Tube Trailer

This hydrogen tube trailer with 10 tubes carries 140,000 cubic feet of hydrogen at 2,800 pounds per square inch. It is



4. **Grid Power:** Twenty-nine states currently have renewable energy portfolio standards that require utilities in the states to generate or procure an increasing share of their electricity from renewable sources. As these portfolio requirements are tightened, renewable energy will occupy an ever larger share of the country's overall energy mix. As a result, hydrogen produced from a national grid that is increasingly enriched with renewable sources, will itself become increasingly renewable-based.

It is expected that the costs of renewable energy and the processes used to convert these sources to hydrogen will decline over time. However given the current high costs for these technologies and the low cost of natural gas, steam reformation of natural gas will continue to be the low-cost source for hydrogen for the foreseeable future, whether produced on-site or off-site.

## Conclusions

Although large-scale commercialization of hydrogen vehicles will require a significant ramp-up in hydrogen production and development of an extensive delivery infrastructure, the technologies and safety standards are already in place to handle hydrogen production, distribution, and storage for stationary fuel cells and early-market material handling applications, such as forklift trucks. Most larger-scale stationary fuel cell installations produce hydrogen directly from natural gas within the fuel cell stack, eliminating the need to transport and store hydrogen. Those fuel cell applications that require on-site storage of hydrogen need relatively small amounts, which can be safely stored in approved containers.

State policymakers can confidently move forward in supporting stationary fuel cell technologies without fear of jeopardizing public safety. Even though hydrogen produced from natural gas is a relatively low-carbon carrier of energy, in the long-term, hydrogen production for both transportation and stationary power uses should move towards renewable sources of energy such as wind, solar, and biomass to produce the hydrogen. Renewable sources are already used at some production sites, for example producing hydrogen from biogas obtained from wastewater treatment. However various cost and technical challenges remain in producing larger quantities of hydrogen at central locations from renewable sources such as solar, wind, and hydropower. State policymakers should encourage research and demonstration projects that address those challenges.

## Honda's Solar Photovoltaic Hydrogen Electrolysis Station

In 2010, Honda Motor Company in Torrance, California opened a new, more compact and efficient solar-hydrogen refueling station. Solar PV panels produce electricity for hydrogen production through electrolysis. The system uses a 48-panel, 6-kilowatt solar PV system. It is designed to demonstrate what could ultimately be appropriate at the household level.

The most noteworthy feature of the prototype is the use of a new type of electrolyzer that eliminates the need for a compressor. This is expected to improve system efficiency by about 25% compared to a previous Honda prototype, while also reducing the size and cost of other key components.

The station has a modest capacity and flow rate, producing about 0.5 kg of hydrogen over 8-hours. The company projects this would be sufficient for an individual with a consistent commute to drive 10,000 miles per year. An interesting feature of the station is that it is designed to take advantage of net metering and potential future smart-grid developments by exporting electrical power to the grid during the day and then using a similar amount of energy at night during off-peak times when the cost of electricity is typically lower.

### Electrolysis Using Solar Electricity

This solar-powered hydrogen refueling station was developed by Honda to demonstrate what might ultimately be used at the household level.



SOURCE: HONDA MOTOR COMPANY

## Using Hydrogen for Grid Management in Hawaii

The Hawaii Natural Energy Institute of the University of Hawaii is implementing a project to demonstrate how electrolyzers can be used to take the surplus production from renewable energy facilities and convert it to hydrogen. This approach is especially appropriate to Hawaii, which has excellent renewable resources, variability in generation from those resources, and a significant difference between base load and peak load. The electricity for the demonstration will be supplied by Puna Geothermal Venture and the hydrogen will be used by the County of Hawaii Mass Transit Agency for two shuttle buses. US DOE is Project Sponsor and the Naval Research Laboratory is Federal Technical Program Manager.



# FUEL CELLS FOR SUPERMARKETS

Warren Leon and Alexei Ponomarov • July 2011

## Introduction

**S**upermarkets are turning out to be an important early market for stationary fuel cells. State clean energy agencies that are interested in helping to bring fuel cell technology into widespread use would be well-served by explicitly supporting fuel cells for supermarkets as a key market niche.

### The Appeal of Fuel Cells for Supermarkets

In recent decades, supermarkets have grown larger and some have moved to 24-hour operation, 7 days a week. Stores have added large banks of freezers and refrigerated cases, as well as sections where prepared foods are cooked and kept warm. These changes have not only significantly increased the electrical, heating, and cooling loads of supermarkets, but have made them well-suited to take advantage of the electricity and heat provided by fuel cells.

Fuel cells provide a constant supply of electricity, which is just what these new supermarkets need. The heat produced by the fuel cells can be used for a variety of purposes, from heating water to running absorption chillers for cooling the stores. Using both outputs is key to the economics of a supermarket strategy for fuel cells, and also yields significant greenhouse gas emission reductions and other environmental benefits. The total efficiency of supermarkets' fuel cell systems can be quite high—often twice or more efficient as getting power from a central utility.

Because supermarket owners need to worry about the risk to the large inventory of cooled and frozen food during an interruption of power from the electric grid, they appreciate a fuel cell's ability to keep operating during a blackout. With a fuel cell, a supermarket can remain open at a time when the surrounding community is vulnerable and in need of supplies.

Recent trends in fuel cell financing have made them more business friendly. Manufacturers and system integrators increasingly offer lease arrangements that reduce the up-front cost of an installation. Longer initial warranties and the option of purchasing an extended warranty reduce the risk to the supermarket company.

### Reasons for State Agencies to Target Supermarkets

Fuel cells clearly have appeal for supermarkets, but why might state agencies want to give special attention to supermarkets? Most importantly, to commercialize a

new technology, it makes sense to concentrate on a few niche markets where it can gain traction and become self-sustaining, rather than trying to spread the technology thinly over a small number of random installations in diverse settings.

The early installations among supermarket chains have created growing visibility for fuel cell technology within the industry. This is starting to stimulate other supermarket companies to want to learn about fuel cells and consider emulating the early adopters.

Beyond the essential starting point that fuel cells are a good match for the energy needs of supermarkets, there are other reasons why this is a promising niche:

- Supermarket chains own multiple stores. As in the cases of Price Chopper and Whole Foods Market described below, a company that climbs the steep learning curve for the first installation can then take what it has learned and apply it to additional installations in other stores. Each new installation becomes easier and better adapted to the specific needs of the company.
- Because of their many customers, supermarkets can educate large numbers of people about fuel cells through information panels and educational materials in those stores that have fuel cells.
- Supermarket chains can use fuel-cell-powered forklifts and other materials handling equipment at their distribution centers, as well as stationary fuel cells at their stores.

Grants and other incentives from state agencies have been essential to make the initial fuel cell installations possible. Such support will continue to be important in the coming years. Through it, states can help to advance a promising clean energy technology, while helping important local businesses.

The rest of this briefing paper describes a few of the early uses of fuel cells at supermarkets. In addition to these examples, other supermarket companies have used fuel cells, including Central Grocers, H.E. Butt Grocery Company, Safeway, Star Market, Stop & Shop, and Wal-Mart.

### Albertsons Implements a Model Installation

A 50,000 square-foot Albertsons supermarket that opened in San Diego, California in 2010 is being powered by a PureCell 400-kilowatt fuel cell system from UTC Power. The





system was leased from UTC, reducing Albertsons' up-front costs and risks.

The fuel cell provides about 90% of the electricity that the store needs. Albertsons is also using almost all of the heat produced by the system for heating and cooling. In the case of a power outage, the fuel cell can generate enough energy on-site to power the building. Because of the use of the heat, the total efficiency of the system is about 60% (nearly twice as high as relying on the electric grid) and the store's annual carbon footprint is reduced by 478 metric tons of CO<sub>2</sub>. In addition, the PureCell system is designed to operate in water-balance, saving millions of gallons of water annually when compared to traditional power generation.

Pete Pearson, Director of Sustainability and National Accounts for SuperValu, Albertsons' parent company, explains that the company weighed its energy options as part of the planning process for the new store. "At the very beginning of the project, we thought of implementing a system that would provide clean energy for our facility. We considered solar installations but a fuel cell seemed to be the perfect solution. We wanted to help the environment, reduce our carbon footprint, and gain operational efficiency. We performed a thorough engineering and financial analysis before proceeding with implementation. And now the system is in place and is working just fine and as expected."

Federal and state financial incentives were necessary to make the project financially feasible. Especially important was a grant from California's Self-Generation Incentive Program through San Diego Gas & Electric.

Albertsons also needed to learn about and give special attention to the interconnection process, especially because of the company's desire for the fuel cell to be available as

independent power during a electric grid power outage. "Particularities of the interconnection with the grid in San Diego area were unknown to us," comments Pearson. "But we communicated with San Diego Gas & Electric; they provided us with the requirements to safely disconnect from the grid."

As advice for other companies that may want to consider installing a fuel cell, Pearson points out that "you have to have adequate gas and electrical connections that could run in parallel with the fuel cell. Furthermore, fuel cells are not 'one size fits all'. You have to work closely with the vendor and the utility company and, of course, get the financial piece settled first." Because a fuel cell is still a relatively new technology, the company "has to make sure there is proper service and support provided from the vendor's side. We negotiated a clause with UTC to assure that we have availability of parts and service contractors in case of malfunction of the fuel cell. UTC Power has a remote control system which can track the operation of the fuel cell and dispatch service technicians within 24 hours to repair it."

It has been important to Albertsons to let shoppers know that the store is powered by the fuel cell. The store therefore features abundant signage about it and the company will highlight the fuel cell in the store's upcoming one-year anniversary celebration.

### **Price Chopper: One Fuel Cell Leads to Another**

Price Chopper's experience shows how an initial successful fuel cell installation can lead to additional installations. The supermarket chain, which is based in Schenectady, New York and has 128 stores in six Northeast states, started by installing a fuel cell in its Colonie, New York store. It then moved on to install a fuel cell in its Glenville, New York location, and more recently installed a third system in Middletown, Connecticut.

Price Chopper started to investigate fuel cell projects because of concerns about the instability in electricity prices and the price spikes of 2007. Grants from the state of New York through the New York State Energy Research and Development Authority (NYSERDA) were essential to achieving an appropriate return on investment for the Colonie and Glenville projects. With grants of roughly \$800,000 for each project, the price of each fuel cell went down to between \$1 million and \$1.5 million. Significantly, Price Chopper's management projects a five-year payback period. "Without the grants, the projects would not have been approved," notes Benny Smith, Vice President of Facilities at Price Chopper.

The Colonie project was the first field-connected installation of UTC Power's new 400-kilowatt PureCell system. Price Chopper is leasing the fuel cell, which was installed in June 2009. It generates up to 70% of the store's



The fuel cell at an Albertsons supermarket in San Diego.



Price Chopper's first fuel cell installation in Colonie, New York.

required energy during the summer and the entire amount of electricity needed during the winter. The system also captures the heat produced by the fuel cell, which is used for hot water, refrigeration, air conditioning, snow melting, and floor heating.

A key benefit of the fuel cell is that it provides the store with an uninterrupted power supply. In case of a grid failure, the supermarket will continue to operate at full capacity independently of the electric grid.

Price Chopper is convinced that fuel cells are a perfect match for supermarkets. As Smith points out, "Supermarkets are a great facility to apply fuel cell technology because we are operating 24-7 year-round. It's not like an office building where you go home at five o'clock and the lights go off."

### Wegmans Switches Forklifts

Supermarket chains' distribution centers run 24 hours a day, 7 days a week. In these large indoor spaces, battery-powered forklifts are usually used for materials handling, because they do not produce any emissions. But battery-powered systems also have disadvantages and fuel cell technology has recently been proving itself to be a sound, practical alternative.

For one thing, battery charging, with up to three battery changes a day, can disrupt work flow, whereas fuel cell refueling proceeds quickly. In addition, fuel cells

ensure constant power delivery and performance. As Jennifer Gangi of Fuel Cells 2000 notes, they avoid "the reduction in voltage output that occurs as batteries discharge and the numerous interruptions in current input and output electric forklifts experience due to the frequent starting and stopping during use."<sup>1</sup>

In March 2010, Wegmans, a supermarket company with stores in six eastern states, purchased nine hydrogen-powered forklifts for its Retail Service Center at Highridge Business Park in Pottsville, Pennsylvania. The forklifts were manufactured by Plug Power, one of several suppliers of fuel-cell materials-handling equipment. A \$1 million grant from the Pennsylvania Energy Development Authority helped make the project possible.

The employees at Wegmans were not only trained on how to operate the new forklifts, but were also educated about hydrogen and fuel cells, as well as the financial and environmental reasons for adopting the new technology.

"The new equipment with the fuel cells was a huge hit," said David J. Allar, the Maintenance Manager at the Wegmans Center. "Employees are highly satisfied with the new forklifts. They don't need to wait for the battery to be charged or changed any more. Operators can refill the fuel cells with hydrogen at their convenience. Refueling takes several minutes and lasts for about two shifts." With the use of the fuel cells, Wegmans was able to avoid the addition of 60 lead-acid batteries, changing equipment, and more staff to maintain and change the batteries. Moreover, Wegmans determined that implementing forklifts with fuel cells in just the produce area of the Retail Service Center reduced the company's carbon emissions by an amount equivalent to removing 134 cars from the road.



One of the fuel-cell-powered forklifts being used at the Wegmans Retail Service Center.

1 Jennifer Gangi, "Fuel Cell-Powered Forklifts: Raising the Bar," *Industrial Utility Vehicle & Mobile Equipment Magazine* (May-June 2008). Available at [http://www.iuvmag.com/articles/2008\\_05-05.html](http://www.iuvmag.com/articles/2008_05-05.html)



Another important benefit of the hydrogen-powered forklifts is that, once installed, they do not require any special charging space. Rooms that were previously used to recharge the lead-acid batteries can now be used as additional space for product storage. According to Allar, just gaining this extra space was a large enough financial advantage to the company to almost pay for the fuel cells.

“The fuel cells have performed far beyond our expectations,” concludes Allar. “There was nothing that interrupted our operations in the least and the employees’ reception of the new technology was incredible.”

It is unsurprising that Wegmans has added to its fuel cell fleet and currently has 37 forklifts in operation. The company is now looking to expand its use of fuel cells to yard tractors and refrigerated trailers at the Retail Service Center.

### Whole Foods Thinks Holistically

Whole Foods is serious about “whole energy” as well. The company takes a systematic, holistic approach that seeks to reduce energy use at all stages in a store’s life-cycle, from store design and construction through engineering, procurement, relationships with suppliers, and maintenance. As part of the search for the best energy solutions, the company has experimented with fuel cells and installed them in four stores in California, Connecticut, and Massachusetts.

In San Jose, California, a UTC 400-kilowatt PureCell system installed in 2010 is generating more than 90% of the store’s needs. The heat produced by the fuel cell is being used for heating and cooling, as well as for refrigeration of the produce in the store. Because the system takes advantage of both the electricity and heat generated by the fuel cell, it is approximately 60 percent efficient. Whole Foods Market estimates that the installation reduces its carbon footprint by 370 metric tons of carbon dioxide each year. The California Energy Commission provided valuable support to make the installation possible.

Two stores in Connecticut have been equipped with UTC Power fuel cells. In Fairfield, another 400 kilowatt UTC Power fuel cell has been installed. The project received a grant of \$731,291 from the Connecticut Clean Energy Fund as part of that agency’s On-Site Renewable Distributed Generation Program.

A 46,000-sq-foot-store in Glastonbury, Connecticut was Whole Foods Market’s first fuel cell installation in 2008 and the first supermarket in the world to get most of its energy from a fuel cell. Like the other three installations, this one is configured to operate independently of the electric grid if necessary. A 200-kilowatt UTC Power fuel cell is able to provide enough energy for the store to operate without interruption in case of a grid failure.

The system provides half of the store’s electricity needs and all of the required hot water.

A fuel cell has also been put in place in Dedham, Massachusetts with help from a grant from the Massachusetts Renewable Energy Trust. The 400-kilowatt fuel cell generates most of the electricity for the store. “With the combined power generated from our fuel cell and solar panels, the Dedham store is essentially able to generate almost 100 percent of its power needs onsite with clean energy resources,” observes Kathy Loftus, Global Leader of Sustainable Engineering, Maintenance and Energy for Whole Foods Market. The clean energy systems help the company reduce its carbon footprint by 764 metric tons of CO<sub>2</sub> per year.

Whole Foods Market has also started to use fuel-cell-powered forklifts. Sixty-one forklifts are in operation at a distribution center in Landover, Maryland. Although the company had been aware of the labor-saving virtues of fuel-cell-powered forklifts, the equipment was not affordable until Genco Supply Chain Solutions received a \$6.1 million award from the US Department of Energy through the American Recovery and Reinvestment Act. Now, by introducing the new forklifts, Whole Foods has reduced the 4,000 hours in labor time that it took annually to recharge the batteries of the previous forklifts to only 250 hours.

But the company is not stopping there. As Loftus notes, “Whole Foods also hopes to retrofit one or two sites with 100-kilowatt, solid-oxide fuel cells from Bloom Energy of Sunnyvale, California, in the near future.”



A fuel cell being delivered and installed at the Whole Foods Market in Dedham, Massachusetts.



# STATIONARY FUEL CELLS AND CRITICAL POWER APPLICATIONS

Charles Kubert • May 2010

## Introduction

In recent years, events ranging from weather to natural disasters to human error have exposed the vulnerability of our electric grid. For many individuals and businesses, these power outages are often no more than a temporary inconvenience. But for critical facilities in both the public and private sector—telecommunications towers, hospitals, airports, emergency dispatch, banks and data centers, and even basic infrastructure such as water and sewage pumps, traffic signals, and refrigeration—even brief outages represent a risk to public safety and potentially significant societal and economic costs.

For decades, these types of critical facilities have relied on two types of back-up power: banks of valve-regulated lead-acid (VRLA) batteries and diesel generators. While both of these technologies are relatively low cost, each has shortcomings, particularly for facilities that need to plan for power outages measured in hours and days, not minutes.

VRLA battery systems are typically designed to only provide power for approximately 15 minutes at full power, enough time to complete an orderly shutdown of equipment. They can also assure a constant supply of power so that even temporary (under 1 minute) power outages or surges do not disrupt computer equipment. However, batteries are sensitive to extreme heat and cold, making them imperfect for outdoor applications in many locations, and they need to be replaced every few years due to declining performance.

Diesel generators (gensets) are today's primary source of backup power. However, they are inefficient, produce emissions from fuel combustion, and require periodic maintenance. Often, they are not suitable for urban locations, where the associated noise, fuel storage, and pollution are unwelcome. In some jurisdictions, such as the state of California, the use of diesel generators for back-up power purposes is subject to strict air quality regulations. In addition, in extreme disasters and prolonged power outages, diesel generators are reliant upon the delivery of fuel. Hurricane Katrina and the earthquake in Haiti are both reminders of that risk.

Fuel cells are a technology that both the public and private sectors are increasingly turning to for both primary and back-up power needs. Although the understanding

of the chemistry of fuel cells goes back more than a century, they are very much a 21st century technology.

The basic design and electrochemical principle behind fuel cells is straightforward. A fuel cell stack requires only hydrogen (or a similar energy carrier), oxygen, and an electrolytic solution. Hydrogen and ambient air flow into the fuel cell, which contains an anode and a cathode. At the anode, the hydrogen separates into a proton and an electron. The proton migrates to the cathode, where it reacts with the oxygen to form water. The electrons, which cannot pass through the membrane, flow from the cell to provide useful electrical power.

Fuel cells are quiet, have no moving parts, and produce no particulate emissions. They are virtually maintenance-free and can be both tested and operated remotely. Because they are modular, they can be configured for any size power needs, from a few kilowatts for a remote telecommunications tower to megawatt-scale for hospitals and airports. Hydrogen is safely stored on-site or produced within the fuel cell itself. (For more on fuel cell technologies, please see accompanying CESA briefing papers at [www.cleanenergystates.org/JointProjects/hydrogen.html](http://www.cleanenergystates.org/JointProjects/hydrogen.html).)

## Fuel Cell Application Platforms

There are two primary application platforms in the use of fuel cells for critical facilities. The first application uses fuel cells strictly as *standby* power in the event of grid failure. The second application utilizes fuel cells as a high-quality source of *primary* power for the facility that will also continue to provide uninterrupted power during an electrical outage.

### Standby Power

In a standby power application, the fuel cells, or a combination of fuel cells and batteries, provide direct current (DC) power to run the equipment or facility. The fuel cells have internal batteries that provide temporary "bridge" power until the fuel cell reaches peak power production and takes over the load. When grid power is restored, the fuel cells shut down. Fuel cells can be ramped up quickly and can operate indefinitely as long as there is a continuing source of hydrogen or other fuel. Proton Exchange Membrane (PEM) fuel cells are used for this application.



### Primary Power

As a source of primary power, fuel cells can provide consistent, distributed, high-quality power generation to a facility, regardless of disruptions to the electric grid. This model is a significant paradigm shift in thinking about critical power because the fuel cell provides reliable, base-load power generation and continues to operate even when the electric grid goes down. Because they are used continuously and systems can be configured to use by-product heat from the fuel cells, the capital costs of the fuel cells can be spread out over all facility operating hours. Fuel cells can also displace purchases of both electricity and natural gas.

### Cost/Benefit

Fuel cells do have higher up-front costs when compared to other forms of both standby and distributed generation. But these costs can be lower on a life-cycle basis because of the reduced replacement and maintenance needs. Further, the higher reliability of fuel cells means that the potential human, social, and economic costs of prolonged power outages can be greatly reduced. Finally, fuel cells owned by private companies are eligible for a 30% federal investment tax credit further lowering the cost differential with other forms of backup power.

## Applications of Fuel Cells in Critical Facilities

### Telecommunications

The telecommunications industry relies on a network of cell phone towers and field facilities to transmit phone calls and data. To operate effectively, each of these towers and field facilities requires a constant and highly reliable

electrical power supply. Currently, the primary source of backup power for communications towers is lead-acid batteries. However, batteries can provide power for only a limited duration. In addition, since many telecommunications towers are located in remote areas, maintaining these battery banks can be challenging. These towers are, therefore, an ideal application for fuel cells. The fuel cell and hydrogen tank can be securely stored behind a fence at the tower and can be operated automatically and remotely.

The State of Pennsylvania has installed a hybrid power solution microcell communications site in Clinton County. The site uses solar photovoltaics and a small wind turbine, with a PEM fuel cell manufactured by ReliOn providing backup power when the solar and wind generation are insufficient. The site supports first responder communications activities, making it critical that it be operational at all times.



RELION

### First Responder Stations & Call Centers

During the massive blackout in New York City in August 2003, the New York Central Park Police Station remained in operation because it is powered by an on-site fuel cell that is grid-independent. Other first-responder stations across the country are beginning to adopt this model—by using clean, distributed generation to power and heat their facilities. For example, New York just completed the largest fuel cell project in the nation at the Verizon 911 call center in Long Island, and the East Anaheim Police Department and Community Center in California has installed a fuel cell system to provide power for its operations.

Table 1: Relative Comparison of Characteristics of Backup and Distributed Power Systems

Technology	Initial Capital Cost (\$/kW)	Variable O&M (\$/kWh)	Maintenance Requirements	RunTime	Fuel Emissions	Lifespan
Battery	400–900 (Lead-Acid)	Depends on local electric rates	Low	Short	No direct emissions	Short
Diesel Genset	350–800	0.025	Medium	Long (if fuel available)	Significant	Long
Natural Gas Engine	450–1100	0.025	Medium	Long	Low	Long
Microturbine	950–1,700	0.014	Medium	Long	Low	Long
PEM Fuel Cell	7,000	0.01–0.05	Low	Long	Very low	Long
Molten Carbonate Fuel Cell	5,000	0.01–0.05	Low	Long	Very low	Long

Note: Fuel cell costs exclude batteries required for startup and/or backup.

Source: “New Performance Based Standards for Standby Power,” Clean Energy Group, 2007; “Economic Analysis of PEM Fuel Cell Systems,” Battelle Memorial Institute, 2005.



UTC POWER



This 200 kW fuel cell installation is located at the East Anaheim Police Department and Community Center. The fuel cells produce enough energy to power 250 typical homes in Anaheim and any excess power is then

fed back into the electric grid. It can also provide backup power to its dedicated loads in the event of a power outage.

### Air to Ground Communications

The Federal Aviation Administration (FAA) launched a program in September 2009 to deploy fuel cell backup power units ranging in size between 1 kW and 4 kW (51 kW total) at 26 sites across the FAA's three service centers: east, central, and west.

The FAA has been using fuel cells at its sites since 2003 to provide backup power to air-to-ground communication and repeater equipment. This new project will provide fuel cell backup power to radio transmit receive (RTR) and air traffic control sites that are not currently using traditional backup power systems. At these sites, if grid power goes out, the site goes down, causing a disruption in communication between pilots and ground control. The high reliability of fuel cells is expected to improve communications at these locations in an environmentally responsible manner.

### Hospitals

Hospitals are required by law to have a secure, resilient power supply to continue to operate critical equipment during power outages. For most hospitals, this has meant diesel generators. The Connecticut Clean Energy Fund sponsored a fuel cell installation at the Saint Francis Hospital in Hartford, CT. The St. Francis fuel cell operates in a combined heat and power application that produces up to 200 kW of baseload electricity and preheats boiler feed water with the heat recovered from the fuel cell. The fuel cell system also provides secure power in case of grid failure.

### Airports

Power blackouts at airports are infrequent but extremely disruptive and costly for air traffic control, airlines, airport security, and passengers. The power outage at Reagan National Airport on January 4, 2010 was not just a local problem; it represents a national energy reliability and

security problem. And it happens all too often at airports around the country, unnecessarily disrupting passengers, threatening airport security, and wasting money.

Although airports have redundant power supplies including back-up generators, these can and do fail. Several airports are testing fuel-cell operated ground handling equipment. Airports should also consider the replacement of diesel generators with fuel cells for back-up power. To amortize the costs of these systems, airports should consider the installation of fuel cells large enough to provide a source of primary power for the entire facility.

### Emergency Centers

According to the Department of Energy, under an extreme national disaster scenario, schools could provide a safe haven for 25 to 50 million citizens. Several state clean energy funds support on-site clean energy projects at schools that can serve as emergency shelters. If grid power is down, many of these facilities will have at least partial power to conduct emergency management operations and meet community needs. For example, South Windsor High School and Middleton High School in Connecticut are home to fuel cell systems that provide a portion of the schools' primary power under normal operations and provide grid-independent power which enable the schools to be used as emergency shelters.

### Wastewater Treatment

Wastewater treatment is critical public infrastructure that needs to keep operating in the event of power loss. In addition, the biogas produced in the treatment process provides a readily available renewable fuel to power a fuel cell system, while avoiding the flaring or release of methane. To reduce air pollution and reliance on the local power grid, the Regional Wastewater Treatment Facility in Tulare, California, decided to implement a reliable and clean, onsite, distributed power resource. Tulare is home to more than 50,000 residents and the wastewater facility treats nearly 9 million gallons of water per day. The facility installed an anaerobic digester to capture methane from the wastewater treatment process, which then is used by three stationary fuel cells to provide high-quality, clean baseload power, resulting in substantial cost savings to the facility. The fuel cells have successfully addressed emissions non-attainment restrictions in place throughout California's San Joaquin Valley. The fuel cells have successfully reduced the facility's emissions as well as its reliance on the local power grid.

### Policy Support for Fuel Cells in Critical Facilities

State and local governments can promote the use of fuel cells in critical facilities through a number of policies.



UTC POWER



### St. Francis Hospital

St. Francis Hospital is the first hospital in Connecticut powered, in part, by a fuel cell. The PC25 cell, manufactured and installed by Connecticut-based UTC Power, generates 200 kW of electricity. It eliminates part of the hospital's dependence on the power grid and will provide supplemental power in the event of a power disruption.

- Require that fuel cells be installed as primary or back-up power systems in all new public buildings and all critical use facilities (e.g., emergency dispatch centers, hospitals, water pumping, wastewater treatment). Leading by example, states and municipalities can jump-start fuel cell demand and provide visible demonstration projects. In addition, the long investment horizon for public entities allows them to finance and amortize system costs over decades, lowering the up-front financial hurdles.
- Specify performance requirements for back-up power (for example, emissions, reliability, operating time) that are more rigorous than those that lead to the selection of diesel generators as the default technology and that are best met by fuel cells.
- Provide state incentives and/or financing to support the installation of fuel cells for these critical facilities.
- Develop federal-state partnerships to fund installations and facilitate joint procurement.

### Conclusions

Reliable sources of standby and primary power are essential for the tens of thousands of facilities—from telecommunications towers to hospitals and data centers—for which even brief interruptions of power can have significant impact. Fuel cells are an ideal source of both primary and standby power for these applications. They are clean, quiet, reliable, and produce consistent, high-quality power. They are also cost-effective relative to other technologies on a life-cycle basis.

State policies should recognize the advantages of fuel cells for these critical facilities and encourage or require their installation as new facilities are built or renovated. This is not part of “worst case” disaster planning. Rather, snow and ice storms, transformer damage and human error can all result in power outages lasting from a few minutes to many days. Regardless of the cause, fuel cells should be part of the solution in protecting our communities’ critical infrastructure when the power goes out.

### Backup Power Requirements

State and local codes for emergency and back-up power requirements generally follow the National Fire Protection Association’s (NFPA) National Electrical Code (NEC). NEC Article 708, first included in 2008, covers Critical Operations Power Systems (“COPS”) and is the most comprehensive and stringent set of standards for back-up power established to date. NEC Article 708, developed in response to the 2003 power blackout in the Northeast and Hurricanes Katrina and Rita, covers any facility that, if incapacitated, would disrupt national security, the economy, public health and/or safety. Local jurisdictions have the authority to designate a facility as a COPS. Potential facilities include air traffic control centers; fire and security system monitoring; hazardous material handling facilities; communication centers and telephone exchanges; emergency evacuation centers; financial, banking, business data processing facilities; fuel supply pumping stations; hospitals; water and sewage treatment facilities; 911 centers; critical government facilities; police, fire and civil defense facilities including power for radio repeater operations; radio and TV stations; and transportation infrastructure.

NEC 708 specifies that these facilities or critical components of these facilities must be capable of restoring power within ten seconds and running for up to 72 hours (3 days) on back-up power. NEC 708 specifically designates generators, uninterruptible power supply or *fuel cell systems* with adequate fuel supply as meeting these requirements. For more information, refer to page 70-609 of the NEC 2008 Edition (available at [www.nfpa.org](http://www.nfpa.org)) or for an overview of Article 708, see <http://www.geindustrial.com/Newsletter/cops.pdf>.

FUELCELL ENERGY



### Tulare Regional Wastewater Treatment Plant

By utilizing digester gas as an onsite renewable energy source, Tulare received \$4 million in financial incentives from California’s Self-Generation Incentive Program (SGIP) and avoided paying \$600,000 in state Emission Reduction Credits that would have been required if it had used combustion equipment. This combined heat and power configuration uses three FuelCell Energy DFC 300™ Fuel Cells.



Clean Energy States Alliance (CESA) is a national nonprofit coalition of state clean energy funds and programs working together to develop and promote clean energy technologies and markets. CESA provides information sharing, technical assistance services and a collaborative network for its members by coordinating multi-state efforts, leveraging funding for projects and research, and assisting members with program development and evaluation.

Many states across the U.S. have established public benefit funds to support the deployment and commercialization of clean energy technologies. More than twenty states are actively participating in CESA membership activities. Through these clean energy funds, states are investing hundreds of millions of public dollars each year to stimulate the technology innovation process, moving wind, solar, biomass, and hydrogen technologies out of the laboratory and toward wider use and application in business, residential, agricultural, community and industrial settings. State clean energy funds are pioneering new investment models and demonstrating leadership to create practical clean energy solutions for the 21st century.

[www.cleanenergystates.org](http://www.cleanenergystates.org)



**Clean Energy States Alliance**

50 State Street, Suite 1  
Montpelier, VT 05602  
Phone 802.223.2554  
Fax 802.223.4967  
Email [cesa@cleanegroup.org](mailto:cesa@cleanegroup.org)  
Web [www.cleanenergystates.org](http://www.cleanenergystates.org)

© 2011 Clean Energy States Alliance