When the Grid Fails:

Fuel cells power critical infrastructure in disasters

The United States' power grid is 99.97% reliable, but when it fails, it is both painful and costly. Hurricanes, tornados, thunderstorms and other weather events—not to mention human error, animals and mechanical failure—can knock out power and communications infrastructure that cost Americans at least $150 billion in economic losses each year.[1]

ReliOn fuel cell powering cell site

Recognizing the vulnerabilities of grid dependency, organizations are looking at fuel cells as an attractive option for reliable backup power. After Superstorm Sandy slammed the Caribbean and the East Coast, fuel cells provided emergency backup power to at least 100 telecommunications towers in both the Bahamas and the Northeast United States. During Hurricane Irene in 2011, ReliOn fuel cells kicked on at 56 Sprint cell towers, and ClearEdge Power[2] fuel cells maintained power at both a storm shelter at South Windsor High School and a Whole Foods location in Connecticut.

Diesel generators and battery backup systems still provide the vast majority of emergency power despite their limitations. Diesel generators require regular maintenance (usually multiple service visits per year), must be located outdoors due to the toxic emissions and noise they produce, and are susceptible to mechanical failure because of their large number of moving parts. Batteries are a clean source of energy, but their power output is mass-dependent (i.e., high-capacity batteries are extremely large and heavy), they must be charged regularly, and they are prone to capacity and performance degradation.

A downed power line in a snowstorm

To address the challenges of intermittent disruptions of grid power with a clean, reliable, low-maintenance solution, companies—from telecommunications firms to banks and hospitals—are switching to fuel cell systems for a reliable source of zero-emission backup power.

[1] "The Smart Grid: An Introduction," Prepared for the U.S. Department of Energy by Litos Strategic Communication. http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/DOE_SG_Book_Single_Pages(1).pdf

[2] ClearEdge Power recently acquired UTC Power. All references to UTC Power, before and after the acquisition, reflect the most recent ownership.

Here is a look at how fuel cells are impacting backup power in several industries.

TELECOMMUNICATIONS

Today, more than a third of U.S. households rely solely on wireless communications devices, putting ever more pressure on mobile networks to function during emergencies. Storms can be particularly disruptive to critical communications systems used by first responders, 911 operators, emergency crews, and the general public. Superstorm Sandy knocked out 25 percent of cell sites in the 10-state area it affected, causing cell phone outages in more than 150 counties. After the summer 2012 "derecho" thunderstorm knocked out power all over the Washington, D.C. area, 2.3 million people lost access to 911 services for four days, partially due to backup diesel generator failures at Verizon facilities.[3]

In 2005, Hurricane Katrina had an even more devastating effect on phone networks in Louisiana and Mississippi, with over three million people losing phone service altogether. In the wake of that storm, the Federal Communications Commission mandated that all cell sites be equipped with at least eight hours of backup power, but telecom companies successfully challenged the rule in court.

Nevertheless, a number of large mobile service providers, including Metro PCS, AT&T, Sprint, and others have installed fuel cell systems at more than 3,000 cell towers nationwide.[4]

- MetroPCS has the largest network of fuel cell systems in the telecommunications industry, consisting of almost 2,000 10- and 15-kW fuel cells in California and more than 350 fuel cells in South Florida. After concluding that its South Florida fuel cell sites carried roughly half the yearly maintenance costs of its diesel sites,[5] the company purchased more than 21 MW worth of fuel cells

What is a fuel cell?

A fuel cell is a device that combines hydrogen and oxygen electrochemically, with no combustion, to produce electricity. The only byproducts are heat and water. A fuel cell has a structure similar to a battery, but a battery stores electricity, while a fuel cell generates electricity from fuel. The fuel cell does not run down or require recharging. It will produce energy in the form of electricity and heat as long as fuel is supplied.

Fuel cell advantages

- Reliability – can be configured to be grid independent
- Generates high quality power
- Fuel flexibility – can operate on conventional or renewable fuels
- Exceptionally low/zero emissions
- Scalable to fit any power need
- Cost savings via high electrical and overall efficiency
- Modularity/scalability/flexible installation
- Silent operation
- Rugged – can operate in extreme temperatures
- Minimal maintenance with few moving parts
- Can be used with or instead of batteries and diesel generators
- Can partner with solar/wind and other renewable technologies

[3] "Impact of the June 2012 Derecho on Communications Networks and Services," January 2013 FCC report http://apps.washingtonpost.com/g/documents/local/federal-communications-commission-report/238/

[4] Fuel Cells 2000 estimate based on internal research.

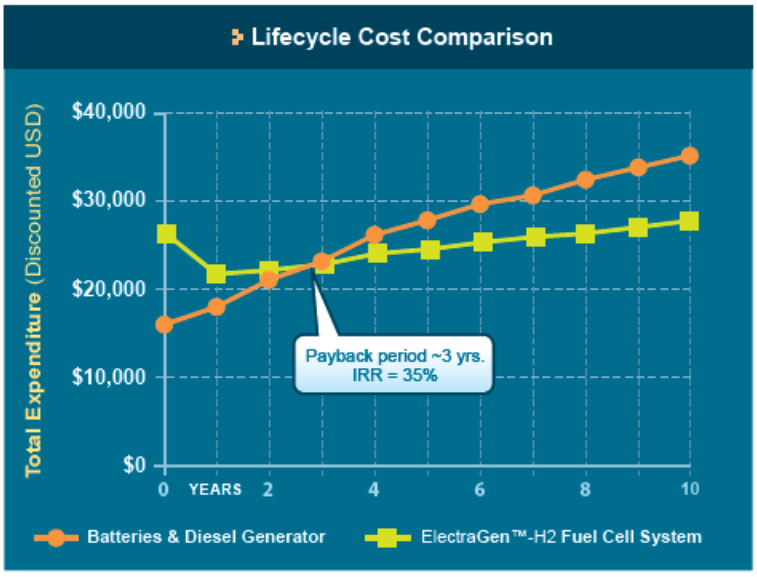
[5] "The Metro PCS South Florida Fuel Cell Project," November 2011 MetroPCS Presentation. http://www.fuelcellseminar.com/media/9383/plenary-%20tom%20browning.pdf

from Altergy Systems in early 2012 in what is believed to be the biggest U.S. fuel cell order ever.[6]

- AT&T acquired its first fuel cell in the 1990s and now has hundreds of backup units at cell sites across the country, installed during the past few years with funding assistance from the 2009 American Recovery and Reinvestment Act (ARRA) through the Department of Energy. AT&T is also installing 17 megawatts of fuel cell power at 28 sites in California and Connecticut, including some at its data centers.[7]
- Sprint also received ARRA money to install hundreds of fuel cells for backup power at telecommunications sites, and the company has said it would eventually like to replace all of its existing backup systems with fuel cells.
- Indonesian operator Telekom International and Singapore-based Cascadiant are building a 3G wireless network in East Timor with 100% renewable energy backup, using methanol fuel cells along with wind and solar power.

Fuel cells have already helped cell networks power through a difficult storm. When Superstorm Sandy knocked out power in the Bahamas, seventeen 5-kW Ballard Power Systems fuel cells on the islands of New Providence, Abaco, and Grand Bahama operated as designed for 700 hours and produced more than 1,200 kilowatt-hours (kWh) of electricity. The continuous power supply kept the cell network up and running for seven days, enabling critical communications amid the storm's destruction. In New York, 60 Altergy Systems fuel cells successfully backed up cell sites after Sandy knocked out utility power to 8.1 million customers.

After Hurricane Irene in 2011, fuel cell manufacturer ReliOn reported that 56 of its systems, owned by Sprint, provided backup power throughout the entire outage. Forty-five of those sites experienced grid power outages in excess of six hours during the storm, with fuel cells providing a total of 725 hours of continuous power. Average duration per site was 16 hours, with the maximum single outage duration being 50 hours. And after Winter Storm Alfred in October 2011, ReliOn fuel cells kept cell towers up and running in Connecticut, letting people stay in touch and access 911 services.



Ballard Power Systems

[6] http://www.altergy.com/announcements/largest_fuelcell_order_in_history.asp

[7] "The Business Case for Fuel Cells 2012," Breakthrough Technologies Institute. http://www.fuelcells.org/wp-content/uploads/2012/12/FC-Business-Case-2012.pdf

In addition to fuel cells' reliability, the economic argument for providers to use them for backup power is starting to come together. By replacing diesel backup power with fuel cells for a cellular network, Ballard Power Systems estimates that its ElectraGen-H2 fuel cell would pay for itself in three years through maintenance savings and tax credits.[8]

DATA CENTERS

Like wireless networks, data centers require an uninterrupted supply of high-quality electricity. A study by the Aberdeen Group[9] estimated that companies lose an average of $138,000 for every hour their data center is offline, and companies with more than 1,000 employees lose an average of $1.1 million per year.

Understanding the impact of power loss, the First National Bank of Omaha (FNBO) installed four fuel cells to back up its data center as far back as 1999, making it one of the longest-running fuel cell installations in the world. The bank's data center processes several million credit card, banking, and ATM transactions daily, requiring highly reliable power to keep the systems operational. Before the fuel cells were installed, grid power outages were impacting operations—during one outage, backup generators failed, costing the bank several million dollars in credit card transactions (the bank estimates the cost of one hour of downtime at $6 million). The fuel cells provide an unmatched 99.9999% availability, making the bank confident enough to forego building a second backup data center for $75 million. According to a report by PA consulting, in 2011 (the most recent year for which data is available), the average U.S. customer was without power for 112 minutes, suggesting that FNBO's fuel cell saved the bank almost $12 million in that year alone.

Apple's Maiden, NC data center

Apple and eBay have both invested heavily in fuel cell power to safeguard their data access:

- Apple's new iCloud data center in Maiden, North Carolina, receives 10 MW out of the 20 MW it requires from 24 Bloom Energy fuel cells. Some of the hydrogen powering the fuel cells comes from biogas produced by a landfill three miles away.
- By mid-2013, eBay's flagship data center in Utah, named Quicksilver, will use a 6 MW fuel cell installation as its primary power source. The company was able to recoup much of the higher initial cost of the fuel cells by simplifying the building design and eliminating the need for UPS and backup generators.

However, most data facilities still use diesel generators, which have frequently failed in emergencies. During Hurricane Sandy, a data center in the New York City's financial district flooded and took down a

[8] http://www.ballard.com/files/PDF/Backup_Power/BUP_EmrgncyEcon_EGen_091712-01.pdf
[9] http://www.thinkgig.com/do-you-know-the-cost-of-data-center-downtime-infographic

number of high-profile web sites, including Bloomberg News, the Huffington Post, Gawker, and BuzzFeed, as well as several Verizon data facilities. Amazon's EC2 cloud hosting service, which powers a number of heavily-trafficked sites including Netflix, Pinterest, and Instagram, suffered outages during the "derecho" thunderstorm that hit the Midwest and Mid-Atlantic in June 2012. Even though Amazon said all of its generators were less than two years old and had been tested and maintained weekly, a backup generator in Northern Virginia failed, causing widespread outages. And in 2007, San Francisco-based 365 Main experienced a highly-publicized generator failure that led to outages at several of its clients' web sites, including Craigslist, Technocrati, and LiveJournal.

GROCERY AND RETAIL STORES

Before big storms hit, people stock up on food, water, and other supplies, knowing they might not be able to reach a grocery store or that the store will close if it loses power. Grocery stores can suffer big losses in spoiled produce and perishables if grid power is lost for an extended time.

Fuel cells generate heat and water as byproducts and the excess heat can be used for space heating, hot water, or run through an absorption chiller for air conditioning or refrigeration, providing even more efficiency for stores that have to keep food cold or fresh. Several supermarket chains, including Whole Foods, Safeway, Stop & Shop, Albertson's, Star Market and Price Chopper, have invested in fuel cell backup systems at some of their new stores, hoping to mitigate the financial impact of losing power. Some stores are even able to operate completely independent from the grid. A Safeway store in Santa Cruz, California now receives 60-70% of its power from two 100-kW Bloom Energy fuel cells (the rest is provided by solar PV panels on its roof).

Perhaps the best example of the benefit of fuel cells to grocery stores came during Hurricane Irene, when a Whole Foods in Glastonbury, Connecticut, the first grocery store to install a fuel cell, was able to keep its coolers running during the storm's destruction with its 200 kW ClearEdge fuel cell. Whole Foods now has four stores nationwide powered by fuel cells.

The East Hartford, CT Cabela's

Other stores are following suit:

- Walmart says it is working toward having 100% renewable energy at its stores and facilities. It has already installed Bloom Energy fuel cells at 26 Walmart and Sam's Club locations in California. These fuel cells produce a total of 65 million kWh of electricity each year, providing 40-70% of a store's annual energy needs.
- Outdoor equipment retailer Cabela's has a store in East Hartford, Connecticut that receives two-thirds of its power from four fuel cells.
- A Staples distribution center in Ontario, California, has been backed up by a 300 kW Bloom Energy Server since 2008. The system produced over two million kWh and mitigated 2.5 million

pounds of carbon dioxide from being emitted in the first year alone. Fuel cell systems at distribution centers help keep business operations online and prevent supply chain disruptions.

HOSPITALS

Backup power is critical in hospitals, where patients' lives could be threatened if power is lost for life support, operating rooms, and medicine refrigeration. In states where hospitals are required to have at least 24 hours of backup power, many rely on diesel generators usually placed on the roof. Even with regular testing and maintenance, these generators have a spotty track record of providing emergency backup power. During the aftermath of Hurricane Katrina, generators failed or ran out of fuel at four hospitals, necessitating extraordinarily difficult evacuation efforts via boat and helicopter. At **Memorial Hospital**, 45 patients died after its generator failed. A report by the Urban Institute on hospitals' challenges during Katrina called the generator failures "one of the most striking and disappointing parts of the post-Katrina experience."[10]

During Hurricane Sandy, several hospitals were forced to evacuate patients due to malfunctioning backup generators.

- At New York University's **Langone Medical Center**, more than 300 patients had to be evacuated when flood water shorted out fuel pumps located in the basement, rendering both of its rooftop generators useless. Without power for elevators, many patients had to be carried down staircases.
- At **Bellevue Hospital Center**, also in Manhattan, National Guard troops carried fuel up 13 flights of stairs for hours to power rooftop generators, which also eventually failed. The power failure led to the evacuation of 725 patients, many of whom also had to be carried down stairways.
- A similar story unfolded in Stafford, Connecticut, during Hurricane Irene. A backup generator failed at **Johnson Memorial Medical Center**, and 43 patients had to be evacuated.
- Hospital generators have also failed outside of catastrophic weather events. In San Diego, generators at **Scripps Mercy Hospital** and **Sharp Memorial Hospital** failed during a massive regional power outage in September 2011, prompting evacuations.

One of the earliest fuel cell demonstration projects included a 200 kW fuel cell at **North Central Bronx Hospital**, located on the building's second-story rooftop that served as supplementary or backup power to the grid and diesel generators. That unit has since been decommissioned, but because of the success of that trial, several hospitals have turned to fuel cell backup power systems to help prevent this kind of situation while reducing energy costs.

[10] "After Katrina: Hospitals in Hurricane Katrina: Challenges facing custodial institutions in a disaster," Bradford H. Gray & Kathy Herbert, the Urban Institute, 2006
http://www.urban.org/UploadedPDF/411348_katrinahospitals.pdf

- **St. Francis Hospital** in Hartford, Connecticut, now has installed two fuel cells at two campuses: a 400 kW ClearEdge Power cell that backs up the operating room and is integrated with the building's air conditioning system, and a 400 kW system that provides half of a building's electrical needs. ClearEdge says the system is saving the hospital $10,000 in electricity costs annually.[11]
- Other hospitals with fuel cells either installed or planned include **Stamford Hospital** and **Waterbury Hospital** in Connecticut (4.8 MW and 2.4 MW systems from FuelCell Energy respectively) and **St. Helena Hospital** (400 kW ClearEdge Power system) and **Sutter Santa Rosa Hospital** (600 kW Bloom Energy system) in California.

ADDITIONAL APPLICATIONS

There are many other sites and services that need continuous, reliable power, especially during a storm.

Shelters: South Windsor High School in Connecticut, a designated emergency shelter, is equipped with a 200 kW ClearEdge PureCell fuel cell, which is usually tasked with decreasing the school's draw on grid power and heating air and water. During Winter Storm Alfred in 2011, the fuel cell kept South Windsor running for nine days as the facility provided shelter, food, and hot showers to 400-600 area residents.

Police/ fire stations: For more than a decade, the New York City Central Park Precinct has had a 200 kW ClearEdge Power fuel cell installed, enabling the station to be completely off the grid. The police station was the only building in the area to retain power during the massive blackout that hit the Northeast in 2003. The fuel cell system also saved the police station $200,000 in capital costs by avoiding the installation of power line extensions.[12]

Mobile power: Toyota is currently designing a fuel cell bus that could provide portable power to evacuation centers, shelters, and other vital facilities during emergencies. The bus will provide a maximum output of 9.8 kW for 50 hours—enough to power lights of an average school gym for five days. Toyota plans to test the bus over the next two years as part of the Toyota City Low-Carbon Verification Project. As a mobile power source, the bus could be deployed to areas suffering prolonged power loss to give people an opportunity to recharge critical devices while they wait for power to be restored.[13]

Gas stations: After Hurricane Sandy, finding an open gas station in New Jersey was a challenge, as the few gas stations with power had to serve millions trying to get fuel for their backup generators and cars. Fuel cell backup power at gas stations could prevent the long lines and gas rationing that typically follows hurricanes.

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[11] "Connecticut Hospital Uses Fuel Cell for Suite Power," Health Facilities Management. http://www.hfmmagazine.com/hfmmagazine/jsp/articledisplay.jsp?dcrpath=HFMMAGAZINE/PubsNewsArticleGen/data/Backup/0510HFM_Upfront_EnergyMgt&domain=HFMMAGAZINE

[12] "Phosphoric Acid Fuel Cell Technology," U.S. Department of Energy. http://www.fossil.energy.gov/programs/powersystems/fuelcells/fuelscells_phosacid.html

[13] "TMC Develops Fuel-cell-bus Power Supply System," August 2012 Toyota News Release. http://www2.toyota.co.jp/en/news/12/08/0831.html

Residential: In Japan, micro-CHP (combined heat and power) fuel cell systems have become increasingly popular since the 2011 tsunami. These fuel cells provide space heating, hot water, and additional power for homes. Panasonic has already sold more than 20,000 Ene-Farm micro-CHP units in Japan, and sales from all three companies selling Ene-Farm units are on pace to reach 40,000 systems this spring. The European consortium Ene.Field plans to install 1,000 residential micro-CHP units across Europe this year. Residential fuel cell backup power systems could help consumers become grid-independent in the future, as later generations of Ene-Farm units will be able to operate without any grid power whatsoever.

In the U.S., real estate developers are increasingly looking at fuel cells to power large, multi-unit apartment buildings and micro grid communities. Becker + Becker, an architectural firm, has two apartment buildings, one in New York (Octagon) and one in Connecticut (360 State Street), using fuel cells. Both systems were reported to be reliable during the recent spate of storms and the Octagon is now being configured for grid-independent operation.

Grid backup: Widespread blackouts can be extremely costly. The Northeast blackout of 2003, in which 45 million Americans in eight states lost power for up to two days, resulted in a $6 billion economic loss for the region.[14] Now, in the largest utility-scale fuel cell deployment in the country, Delmarva Power is installing 30 MW of Bloom Energy Servers in Delaware, enough to power 22,000 homes. The units will decrease carbon dioxide emissions by 50% compared to Delaware's electric grid, and provide the stability of what Delmarva President Gary Stockbridge called "a reliable round-the-clock baseload source in an otherwise intermittent portfolio."[15]

As global population and economic production grows, demand for power is beginning to outstrip existing grid capacity, leading to 15 percent longer outages and 43 percent higher electricity costs.[16] Fuel cells help reduce grid dependency and mitigate financial losses from power outages while keeping critical infrastructure up and running. No longer an environmentalist's pipe dream, fuel cells' reliability, scalability and wide range of fuel sources are saving money for companies in a variety of industries, and making dependable access to emissions-free power a reality.

To read more about fuel cells and the various applications and customers they serve, please go to http://www.fuelcells.org.

FUEL CELLS 2000
www.fuelcells.org

[14] http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/DOE_SG_Book_Single_Pages%281%29.pdf
[15] http://www.bloomenergy.com/customer-fuel-cell/delmarva-power-clean-energy/
[16] http://www.asme.org/kb/yellowbrix-article?topic=9fc44ce4-1ff3-4bc3-b6fd-89bab07e387f&storyid=183033092

Appendix: Storm power outages

Major hurricanes since 2003

Year	Name	Power outages
2003	Isabel	2,970,000
2004	Charley	2,000,000
2004	Frances	3,000,000
2004	Ivan	900,000
2004	Jeanne	2,600,000
2005	Dennis	285,000
2005	Emily	250,000
2005	Katrina	2,600,000
2005	Rita	1,000,000
2005	Wilma	6,000,000
2008	Gustav	1,500,000
2008	Ike	8,000,000
2010	Karl	54,000
2011	Irene	8,400,000
2012	Isaac	250,000
2012	Sandy	8,000,000
	Total	47,809,000

Major blizzards since 2007

Year	Storm	Power outages
2007	February 21-26 winter storm	250,000
2007	Valentine's Day blizzard	300,000
2007	April nor'easter	175,000
2007	Saskatchewan blizzard	115,000
2007	North American ice storm of '07	858,000
2008	January Western North American storm complex	2,000,000
2008	North American blizzard of '08	298,500
2008	December 16-19 blizzard	1,000,000
2009	January Central Plains & Midwest ice storm	2,000,000
2009	Christmas blizzard	200,000
2010	Late January Oklahoma winter storm	358,268
2010	February 5-6 blizzard	354,700
2010	February 9-10 blizzard	300,000
2010	February 25-27 blizzard	541,500
2010	March 2010 North American winter storm	1,000,000
2010	December 2010 North American blizzard	24,600
2011	January 25–27 North American blizzard	650,000
2011	Groundhog Day blizzard	161,000
2011	October 2011 nor'easter ("Alfred")	3,389,000
2012	November 2012 nor'easter ("Athena")	715,000
2012	December 17-22 Midwest blizzard	130,000
2012	December 25–28 North American blizzard	300,000
2013	February 2013 nor'easter ("Nemo")	700,000
	Total	15,820,568