# Final
# Project Closeout Report
# For

# Sprint Hydrogen Fuel Cell (HFC) Deployment Project

## Project # EE0000486

## at
## Sprint Telecommunications Sites in
## California, Gulf Coast and Eastern Seaboard
## Markets

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# Final Project Closeout Report for Sprint Hydrogen Fuel Cell (HFC) Deployment Project in California, Gulf Coast and Eastern Seaboard Markets

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## 1. EXECUTIVE SUMMARY

Sprint is one of the telecommunications industry leaders in the deployment of hydrogen fuel cell (HFC) systems to provide backup power for their mission critical wireless network facilities. With several hundred fuel cells commissioned in California, states in the gulf coast region, and along the upper eastern seaboard. A strong incentive for advancing the integration of fuel cells into the Sprint network came through the award of a Department of Energy (DOE) grant focused on Market Transformation activities for project (EE0000486). This grant was funded by the 2009 American Recovery and Reinvestment Act (ARRA). The funding provided by DOE ($7.295M) was allocated to support the installation of 260 new HFC systems, equipped with an on-site refillable Medium Pressure Hydrogen Storage Solution (MPHSS), as well as for the conversion of 21 low pressure hydrogen systems to the MPHSS, in hopes of reducing barriers to market acceptance:

- Eliminate Barriers to Siting and Permitting 72-Hours of Hydrogen Fuel.
- Eliminate Barriers to Re-Fueling Sites at the Required Level of Performance.
- Collect and Analyze Data Sample to Evaluate Economic and Operational Metrics.

## 2. BACKGROUND

The majority of cell sites have a battery bank as their primary means to provide backup power when the utility source is lost. Sprint's current standards seek battery reserve capacity between two and four hours, depending upon site specific characteristics. In special situations, eight hours may be sought. However, such sites are inherently more costly to deploy based upon physical space requirements, battery string/cabinet weight loads, structural integrity evaluation and associated improvement requirements, and other cost impacting issues. The battery type predominantly used is the valve regulated lead-acid (VRLA) chemistry. With a design life of approximately five years, their longevity is greatly impacted by a variety of factors: average temperature of operating environment, frequency and depth of battery discharge, maintenance routines, etc. Based upon the conditions under which these VRLA batteries operate, operational expenditures (OPEX) are high based upon more frequently required maintenance visits and/or early string replacement costs.

If a facility is defined "mission critical," a backup power solution capable of producing on-site power may be justified. The incumbent technology of a diesel generator system is tried and true. However, it comes with a variety of economic and environmental costs. Alternative backup power producing solutions are being investigated to cost effectively address these identified concerns.

| Economic | Environmental |
|---|---|
| Costly Periodic Maintenance requirements | Produce Greenhouse Gas Emissions (GHG) |
| Spill containment and remediation costs | Noisy (70 dbA or greater) |
| Fines for exceeding emissions' threshold limits | "Not-in-my backyard" Public perception |
| Little, if any, economic incentive available | National Code & Zoning regulation |

Although not a "cure all," HFCs offer a solid foundation upon which to build a viable solution for producing clean backup power for America's wireless networks.

Fuel cells are longer lasting and are more predictable than batteries and can operate for 10 years or more with undiminished power quality and capacity. When compared with generators, fuel cells are cleaner, quieter, reduce GHG emissions, and require less maintenance. They are environmentally friendly because they convert the chemical energy in hydrogen directly to electricity with pure water and heat as the only by-products. Other advantages of fuel cells as optimal backup power solution include:

- Higher operating efficiencies
- Scalable and modular operation
- Wide range of operating temperatures
- Indoor and outdoor use
- No moving parts
- Long life cycle

Over the past several years, large storms and sustained periods of power loss have helped to reaffirm the need for a fuel cell infrastructure to serve as a primary backup power component for cellular communications sites. Sprint's primary goal is to provide 72 hours of runtime for vital communication systems to support emergency responders, 911 call centers, and critically impacted customers. Hydrogen fuel cells, installed in 2011, were responsible for providing continuous and uninterrupted power to the Sprint network during Hurricane Irene. They also provided significant support during Super Storm Sandy and Winter Storm Alfred, events which crippled large areas of major metropolitan areas for several days.

## 3. INTRODUCTION

This is the final project closeout report for the Sprint HFC Deployment Project (EE0000486). The document was completed on April 15, 2015. These projects are located at 281 Sprint collocated telecommunications sites in the following states:

| State | New Sites | Retrofit Sites | No. of Systems |
|---|---|---|---|
| California | X | | 76 |
| Connecticut | X | | 29 |
| Louisiana | X | X | 10 (N), 9 (R) |
| New Jersey | X | | 30 |
| New York | X | | 65 |
| North Carolina | X | | 2 |
| Texas | X | X | 48 (N), 12 (R) |

These markets were strategically chosen as candidate locations due to the frequency and potential for a natural disaster to occur and grid power to be interrupted, as well as their proximity to hydrogen distribution facilities.

Although the United States electric utility grid is considered to be highly reliable, it can cost companies and individuals billions of dollars in loss annually during extended power outages. Hydrogen fuel cells are considered to be a premier technology for providing clean and reliable power for direct current (DC) applications. Other uses gaining popularity for fuel cell technologies can be found in the automotive, warehousing, utility and stationary storage industries. Hydrogen is stored in high pressure containers and used for powering cars, busses, and fork trucks for transporting people and products.

Over a decade ago, fuel cells were in the experimental and test phase. The development of fuel cells for use as a backup power system in the cellular communications market has matured significantly since then. These engines and storage tanks are now robust and proven in many industries, applications and environments. Fuel cells provide an environmentally friendly replacement for the traditional diesel, propane, and natural gas generator sets that have been favored in the telecommunications market.

The DOE has provided considerable amounts of time, financial resources and effort to help educate the public and commercialize fuel cell technology. One of the first industries to partner with the DOE is the telecommunications industry. With more than 250,000 cell tower sites in the United States alone, there is a huge potential for increasing the use of fuel cells to provide "green" backup power during natural disaster events like earthquakes, hurricanes, tornados, blizzards, ice storms and grid losses. Fuel cell power system are an attractive solution for implementation based upon their characteristics of zero emissions output and ease of operation while providing reliably efficient power.

## 4. ACQUISITION SERVICES

There are several different approaches in acquiring all the necessary information for installing a hydrogen fuel cell backup power system. The fuel cell power cabinet that houses the Proton Exchange Membrane (PEM) stack module is not typically a concern for property owners or jurisdiction regulators. The hydrogen storage cabinet is the critical system component that is regulated by multiple codes at the national and local levels for stored quantity and pressure. The most common and thorough permitting requirements involve a review process through the zoning, building, electrical, mechanical and fire departments. A well planned and organized process can lead to the successful deployment of fuel cell technology as a backup power system in any market. The phased approach to site selection, zoning, permitting and construction activities lends itself to milestone tracking and go/no go decision points.

HFC backup power generator systems are a fairly expensive power sources in comparison to the standard retail cost of a combustion engine generator set. Some of the initial unit price "capital expenditure" can be offset by maximizing market deployment resources to reduce construction cost in the mobilization of crews and equipment to site. Pursuing multiple sites in a provided market area radius can help control the deployment schedule and potentially accelerate the completion date. Staging a market segment with a set number of systems, a qualified contractor and a standardized design package will produce cost efficiencies in labor, materials, and speed to market. Speed to market is a critical component for these backup power projects, as their driving initiative is to be installed and operational ahead of the next prolonged power outage.

The primary element for a HFC system is the hydrogen gas. Although, hydrogen is one of the most abundant elements in the world, it is not necessarily the easiest to harvest, store, or have delivered in certain areas. A major issue with hydrogen fuel cells for telecommunications towers is the ability to deliver fuel to both remote and rural sites, as well as, compact site locations in congested metropolitan locations. There are several siting considerations that must be evaluated for the delivery of hydrogen gas by a certified supplier. Some of the basic concerns include the type and size of truck, open/available parking position for delivery and length of the fueling hose needed to reach a storage system. Another major concern for hydrogen fuel delivery is the proximity to overhead power lines. Hydrogen suppliers are very cautious about not parking hydrogen trucks or performing hydrogen fueling operations while underneath or in close proximity to high voltage lines. The advancement of hydrogen delivery vehicles to a four wheel drive box style truck or small tube trailer package has significantly increased fuel delivery flexibility.

*Phase 1*

Taking into consideration the vast combinations of site variables that may be encountered for the thousands of cellular towers in the United States, it is essential to perform and implement an upfront, or Phase 1 (Site Survey), procedure. This initial evaluation task can narrow a large list of potential candidate sites, down into a smaller and more manageable list of sites. This scrubbed list will identify sites with a higher potential for successful deployment. The main emphasis in this step is to quickly identify sites that are not viable for a fuel cell installation and eliminate them as potential candidate sites. Making this determination early in the process will reduce the initial capital expenditure for engineering services, equipment orders, and permitting fees that will be incurred in subsequent phases.

When siting an area or location for a fuel cell generator it is not only important to consider the optimal installation location, but to also investigate the surrounding areas and take into consideration how the owner's property and adjacent properties may be developed or utilized in the future. There are several national, state, and local jurisdictional codes that must be adhered to when deciding the final location of a fuel cell generator. Code compliance is not necessarily reflective of the type of fuel cell system being installed, but is typically influenced by the fuel type, quantity, and pressure at which the fuel is maintained during standard operating conditions. Below is a list of the most common site conditions that must be observed when evaluating the viability of a fuel cell generator.

- Buildings and structures on the same property
- Underground flammable or combustible liquid and gas storage tanks
- Ignition sources
- Overhead electrical utilities
- Public streets, walkways, and gathering areas
- Property lines that can be built upon
- Above ground flammable or combustible liquid, gas and material storage

Site assessment and selection are the most critical components to ensuring that a fuel cell candidate site can be successfully carried through the entire design, permitting, and construction process. The geographic considerations for a large rollout program will typically involve a combination of factors, such as population, weather patterns, and electrical grid performance. After these parameters are defined, cell towers can be located in metropolitan, rural, and remotely isolated locations. Existing documentation such as a property leases, construction drawings, and internet research can be a quick and efficient way to make an overall determination of existing conditions for a specific candidate site location before dispatching personnel to the field to perform a site walk investigation.

The physical site audit is where the prescreened information can be collected and validated about the existing conditions, equipment configurations and the overall viability for the installation of a fuel cell generator. During this process, one should first document the exact location of the project and any obstacles that may potentially affect the ability of a candidate site to be constructed, fueled, or maintained throughout the product life cycle. These considerations should include the use or storage of any alternative fuel types, generators, or other back-up power equipment and the main utility or power supply. Gathering as much information about the current operation and functionality of the equipment or facility, along with taking a real time measurement of the actual DC and alternating current (AC) power load will provide the framework for determining the type, size, and projected runtime of a fuel cell system deployment.

To ensure that the survey team gathers all the essential data while visiting the site, a useful tool called a "Site Survey" template should be used. As an example (see Appendix A), this may be an excel spreadsheet, with all the pertinent topics defined, which will be populated by the client representative while on site. The data gathered using this tool is brought back to the office and used during the final analysis and go/no-go decision making process. All factors discussed above are considered when making this decision. Only the candidate sites with the most comprehensive information and with the highest ratings from this process should be considered as viable candidates to move into the design, leasing, zoning and permitting processes.

*Phase 2*

Site acquisition services consist of the following processes:

- Leasing
- Design
- Zoning
- Permitting
- Notice to Proceed (NTP)

In order to condense the amount of time for the Phase 2 duration, it would be ideal to run the landowner and jurisdictional approvals in parallel. In this optimal scenario, both governing party's decisions are completed at the same time and the sites can be moved into the installation process without delay.

One way to save capital can be to run these two approvals in series and start with the landowner approval prior to engaging the authority having jurisdiction. This way, if a landowner does not allow installation or requests additional information or monetary compensation, there has been no capital funds “wasted” on the jurisdictional approval process. Any pushback, rejection, education or remediation of agreement terms will invoke schedule delays and, as a result, extend the time required to complete the Phase 2 (Site Acquisition) process.

The leasing portion of acquisition services is where the landowner’s consent and approval is obtained to install the backup power fuel cells system. There are multiple types of consent that may be required - the current lease language is used to determine the type of consent necessary for each site. The most common types of leasing consent are courtesy letters, consent letters and formal amendment applications. There are two distinctive classifications of landowners which play a part in determining the type of leasing required for a site: tower aggregators and private owners.

It is necessary to complete the preliminary site layout portion of the engineering design documents in order to begin the leasing process. These layout drawings are used to accurately communicate the proposed installation location to the tower aggregator or landowner. In regards to tower aggregators, a formal application is required no matter where the fuel cell system is being placed. For sites that are privately owned, if the proposed layout falls within the current lease limits, then the lease language will indicate if the lessor needs to be notified of the modification or if the lessor needs to consent to the modification. If the proposed layout falls outside the current lease limits then a lease amendment may be required for additional funding and entitlements. The leasing process is complete when a receipt of the courtesy letter delivery is received, the signed consent letter is received, or the amendment is approved during the formal application process.

An important characteristic element of this process is the potential need to educate the local authority having jurisdiction (AHJ) that hydrogen is a safe and viable fuel source when used in accordance with current codes and industry standards. The AHJ’s main safety concerns involve the storage quantity and pressure of the compressed hydrogen gas located on site. A secondary concern is for how it will react in an open environment in the event of an incidental release. Recently deployed systems store approximately 4,000 to 8,000 standard cubic feet (scf) of hydrogen in a single storage cabinet. The average storage pressure of these systems can be as much as 3,000 pounds per square inch (psi), with system operating pressure ranging from 5 psi to 100 psi. The gaseous hydrogen fuel used for a PEM fuel cell generator is a product with greater than 99 percent purity. Hydrogen gas is 14 times lighter than air, disperses quickly into the atmosphere and therefore, rapidly drops below flammable concentration limits. Compressed hydrogen is most readily available in the commercial industry in metal cylinders which are designed to be transferred to the site full and exchanged in the same manner as a gas grill propane tank. Hydrogen’s versatile fuel characteristics provide for a wide range of operating temperatures allowing it to be placed in many regional locations. Ensuring a safe operating environment is critical when designing a fuel cell system that stores, processes, and converts hydrogen gas into usable electricity. The site acquisition process involves challenges based on proposed equipment technology, land owner’s approval, lease agreement terms, and jurisdictional ordinances and code requirements.

This is where the jurisdictional education most often takes place.

Depending on the AHJ over a facility, there are three categories that most sites fall into for the zoning process. The first case is a no zoning approval required prior to filing for the building permit as the zoning review is performed simultaneously with the building permit review.

The second scenario requires an administrative process prior to filing for a building permit. This process typically consists of submitting a zoning package which includes an application, design plans, and a fee for compliance with local zoning ordinances. In this scenario, the zoning must be approved before submitting for the building permit.

The third category entails a formal public hearing approval process. This process requires an extensive application, legal representation, public hearing meetings with board officials and possibly a signed and sealed site survey. The public hearing may require attendance of the licensed engineer, an attorney and most often a licensed city planner.

During the zoning process, the jurisdictional reviewers have the right to enact local codes that require costly improvements to the site. This may include screening of the system, landscaping or access improvements. A major component for expediting the zoning, permitting and owner acceptance of fuel cell systems could include the creation of a governmental approval document supporting the use of fuel cell technology, acceptance of fuel storage devices and universal guidelines for siting. A document of this caliber would provide a high level of confidence and risk acceptance when being reviewed and permitted. By expediting the process and using pre-qualified underwriter laboratory (UL) listed equipment systems; the telecommunications industry could maximize the creation of a robust hydrogen powered infrastructure.

Building permits must be obtained prior to starting construction. They encompass electrical, plumbing, structural and fire approvals. In most jurisdictions this process starts with submitting signed and sealed plans along with a fee, application, equipment data sheets and engineering calculations. The permit approvals come with a list of inspections that are required during construction, including a final inspection. Through the permitting experience, knowledge is gained on the patterns and data requirement that are consistently requested, such as compressed gas warning placards and hazardous chemical warning signs placed on facility entry gates and the hydrogen storage cabinet. The AHJ's also prefers to see the maximum amount of gas stored on site stated directly in the construction documents. Some regions of the country will require a separate fire department review which requires its own submittal with a fee, review process, and approval.

Once the landowner and jurisdictional approvals are received, the site moves into the NTP procedure. This is the formal correspondence with the landowner to convey that all requirements have been met and requesting final approval to mobilize to the site for construction.

*Phase 3*

Once all proper permits have been pulled and the NTP has been received from the landowner the construction phase can begin. The construction process includes not only the site modifications, installation of the new equipment, fueling and commissioning, but also includes the quality control, safety inspections, construction oversight, commissioning, and any additional testing.

The construction phase starts with a Pre-Construction Meeting. The Pre-Construction meeting is between the Landowner and the Installation contractor to go over the planned construction and discuss any additional requirements that the owner may have. The installation may start with site modifications in order to provide the necessary room for the new equipment to be installed.

Site preparation modifications could range from removing existing vegetation to the installation of a new concrete pad or even installing additional steel beams on an existing platform to support the new equipment. The installation of the new equipment includes installing anchor bolts, electrical infrastructure and the fuel tubing.

The first item when installing the new fuel cell equipment is the anchor bolts, which can be done one of two ways, either cast in place or post installed. Once the anchor bolts are installed certain AHJs (California deployments, for example) require you to perform a pull test on every anchor bolt, proving anchors will hold the specified weight. The second item is the electrical infrastructure which includes three primary areas, power wiring, alarm wiring and grounding conductors.  The power wiring includes running new power cables to a new DC disconnect switch and then terminating the circuit on existing DC bus, typically found in the standard battery cabinet. The alarm wiring connection typically includes the use of Cat5 data cable for signal and control wiring from the new equipment back to the existing radio base station (RBS). These registered alarm signals are transmitted to the National Operations Center (NOC). The third component of installing the fuel cell system is the installation of the stainless steel fuel tubing between the Hydrogen Fuel Cell and the Hydrogen Storage Module (HSM). This includes routing metal tubing between the two cabinets and leaving an expansion loop in the line to allow for flexibility during climate change. The fuel tubing should be protected from falling debris from the cellular tower.

Once the site modifications are complete and the new equipment has been installed, the new equipment can be fueled. The fueling of the site is done by a hydrogen gas supplier and this activity has to be coordinated/scheduled prior to commissioning. The average delivery is 8,000 scf of Hydrogen stored at 2,600 psig. After the HSM is fueled, the commissioning activities can be scheduled with all representative parties. Typically this will include the contractor, equipment manufacturer and the client representative. The commissioning process includes verifying the alarm wiring is punched down inside the existing equipment and communications are read back to the NOC. The equipment is turned on and run through a full diagnostic program and test cycle to ensure that the equipment is functioning properly. A series of tests are performed to simulate power outage situations that the equipment is expected to encounter.

When the system is fully operational, the final inspections are performed. The final inspections include the inspection and acceptance by the owner representative, the inspection and sign off by the local AHJ and the inspection by the land owner. The inspection by the owner rep is typically verifying the installation has been performed per the drawings and specification agreed to by the owner. The inspection and sign off by the local AHJ is to verify that the installation has been performed in accordance with all applicable building codes.

This inspection is also when the local AHJ will approve the installation, sign off on the permits that have been pulled, indicating the installation is acceptable and provide a certificate of occupancy allowing the equipment to be utilized for normal operations. The inspection by the land owner is to verify that the equipment has been installed as agreed to by the land owner and the equipment owner.

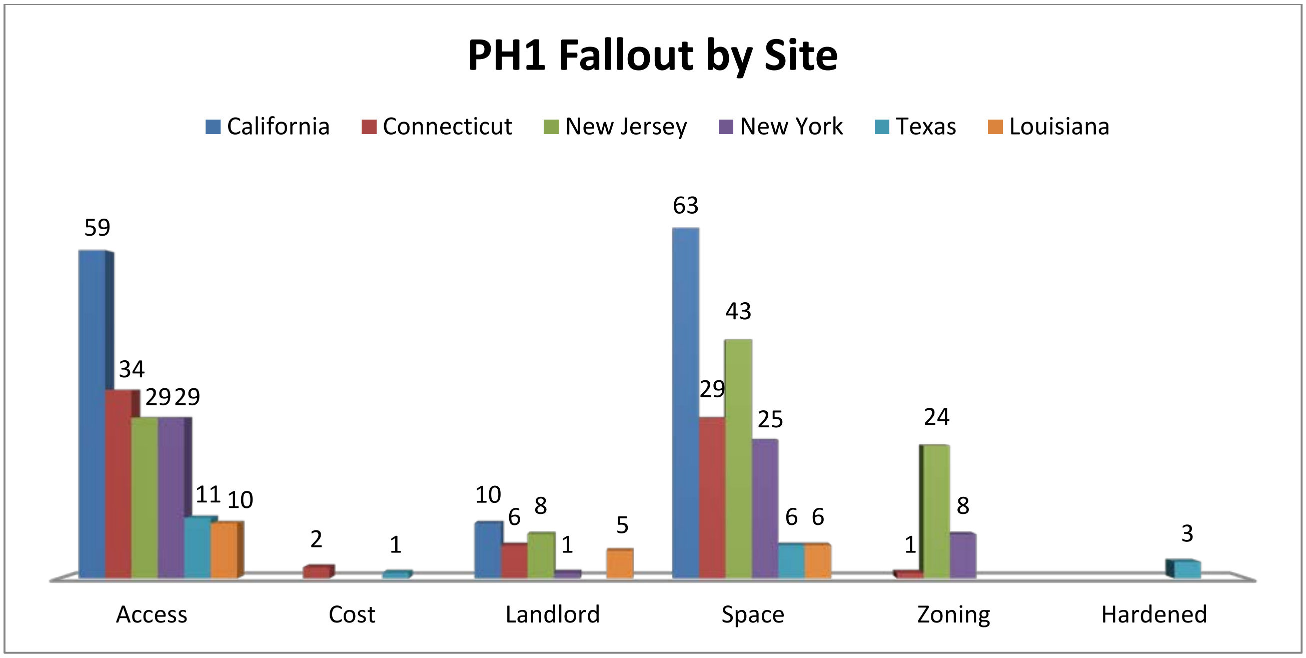
After all the inspections have been performed, the final task to be performed is the archiving of all the documentation for the installation. This documentation includes a commissioning report, As-Built Drawings, completion photos and building permit signoffs. The commissioning report would be from the equipment vendor showing time of commissioning and certifying equipment operated as designed. The As-Built Drawings are a record set of how the equipment was installed on the property and any deviation from the planned installation. The completion photos are taken as a snapshot in time to validate the physical condition of the site. The building permit signoffs would include all paper work supplied by the local AHJ inspector at the time of inspection. A copy of all the documentation that has been assembled should be turned over to the equipment owner, the land owner and a copy should be kept by the installing contractor.

## 5. CLOSEOUT STATUS

The Sprint HFC deployment project is status closed in terms of scope, budget and schedule. The project originally targeted 260 new site builds with 70 retrofit upgrade sites, for a total deployment of 330 sites. New builds are located in 7 states along the Western, Gulf, and Northeastern Coastal regions of the United States. The retrofit sites were all concentrated in the Gulf states of Texas and Louisiana. Retrofit sites were to upgrade the existing hydrogen storage and fuel cell power systems. The retrofit of the existing fuel cell systems was not as practical in the engineering design and system deployment as planned. Therefore, it was not possible to reach the targeted number of sites for the retrofit applications. Below is a table that contains the number of targeted project sites for full deployment, the number of sites investigated and the final as-built closeout numbers.

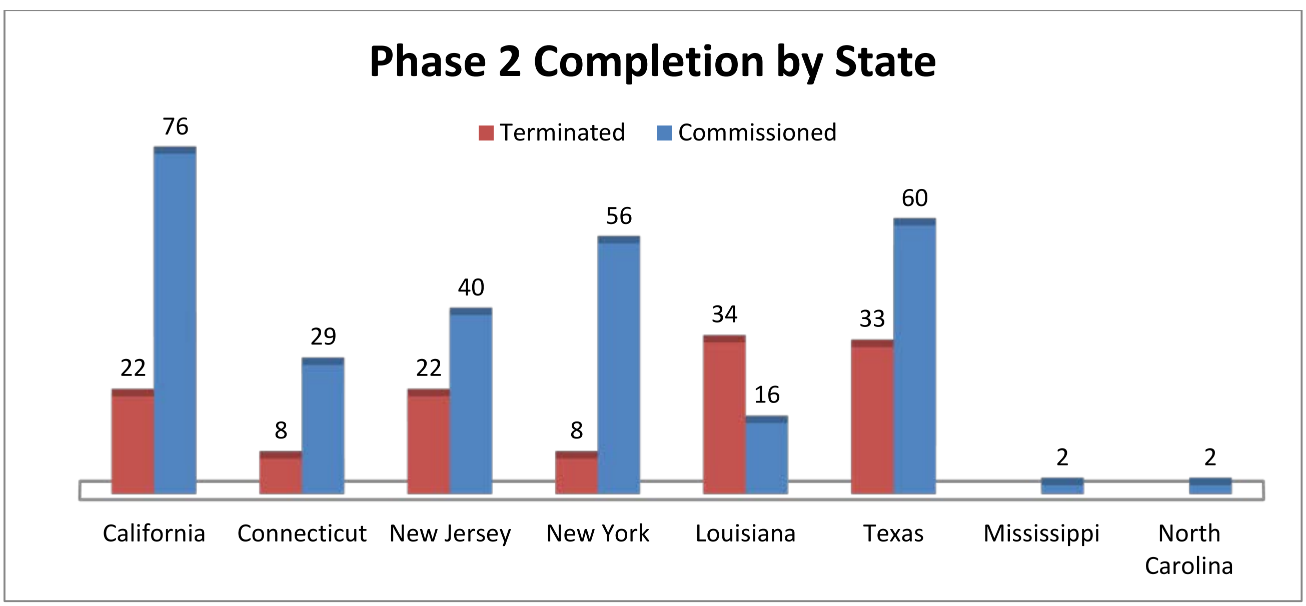
| Planned | Targeted Sites | Sites Investigated | Final Sites Built |
|---|---|---|---|
| New Sites | 260 | 780 | 260 |
| Retrofit Sites | 70 | 70 | 21 |

Unfortunately, investigating every site in a market was not feasible for the installation of an HFC. Several factors can negatively impact the viability of a site deployment. These constraints are identified in the initial evaluation process. This includes site access for fuel truck and delivery requirements, infrastructure upgrade cost, landowner approval, existing physical space limitations, zoning/permitting requirements and existing backup power systems. The site selection fallout table below illustrates the number of sites that were removed from the program per state for one of these categorical constraints. The largest fallout numbers that were encountered across all market segments were due to existing space limitations and the hydrogen fuel truck access and delivery requirements.




Initial Site Selection Fallout by State

Even candidate sites that make it through the initial site evaluation process are not all going to be potential viable candidates for a hydrogen fuel cell power system installation. The second phase process of permitting, zoning and owner approval can create risk to the deployment of these power systems. The site completion table below illustrates the number of sites that were terminated in the later stages of the project, as well as, the sites that were installed and fully commissioned per location.




Site Completion by State

Once the final inspection information, generator commissioning reports and handoff checklist acceptance forms for all the installations are received, the commissioning activities are considered complete. Every site where the HFC systems are deployed as part of the HFC Project has received a certificate of occupancy from the AHJ. All equipment that was procured has been installed, tagged and cataloged in the Sprint asset management system. Completed as-built drawings that reflect the final site conditions have been fully documented and uploaded into the Sprint database. All work contracted for this project is complete and all subcontractors have been fully paid for services rendered. Lean waivers have been received for all properties that were involved with the installation as part of the hydrogen fuel cell project.

## 6. LESSONS LEARNED

As a large scale hydrogen fuel cell deployment project expanding into several states and regional areas, there are several good work practices, innovative approaches and unexpected outcomes that should be noted as lessons learned from this project.

One major catalyst for influencing the AHJ's acceptance for these fuel cell and storage systems into the Sprint Network was a government issued National Environmental Policy Act (NEPA) permit. A NEPA permit establishes that a federal agency funding a project has taken into full consideration the impacts, both positive and negative onto the human and natural environment. This document was used as an educational tool when working with jurisdictional reviewers or property owners to establish a positive prospective on hydrogen gas fueled power systems. The NEPA permit provided guidelines to the beneficial use of the systems without degrading the environment, nor imposing risks to personal health and safety as a result of unintended consequences.

In some instances, the testing of technical safety systems installed in the unit where mandated as part of the final acceptance and permit closure process. The fuel cell system is designed and manufactured with hydrogen sensors to constantly monitor the amount of hydrogen gas being used in the system and the presence of a leak or associated gas buildup within the system. If a leak is present in the system and a buildup is measured at a higher than normal concentration ratio, the system will shut itself down and not be operational due to the abnormal or perceived dangerous environmental condition. Although not recommended without professional certification or experience, the performance of the system sensory components in the control system can be field verified using a small tank of pressurized hydrogen gas and releasing it into the fuel cell cabinet. The performance of this test helped gain the confidence of local fire marshal that the system could prevent the buildup of hydrogen gas into a hazardous condition.

The ability to fuel the HSM onsite using a fueling procedure called "bumping" from a delivery truck is an innovative approach to hydrogen fueling and a significant improvement to previous fueling processes. Although the capital cost of research and development for the hydrogen transportation vehicles and storage tank systems are high, they reduced operational costs and safety concerns.

These results quickly changed the hydrogen delivery standard away from a bottle swap or exchange process. Traditional hydrogen bottle systems where cumbersome, heavy, and provided safety concerns if not reconnected properly.

The previous fueling process provided several points of potential failure in the system, such as the storage vessel, transportation of the bottles and fueling technician interface. By installing a storage tank system with a single point of connection for refueling operations, a single telecommunications site could be fueled by one person in approximately 45 minutes. The bumping hydrogen fueling procedure is more in-line with the transportation methods and fueling techniques used in the more common propane system delivery.

The most significant lesson learned was training personnel to become educators and facilitators. Hydrogen gas as the main characteristic of the system unfortunately comes with a strongly negative connotation for being extremely dangerous. It is often times associated with the Hindenburg disaster and considered to be highly volatile, potentially explosive and capable of erupting into a ball of fire. The system integrator must be knowledgeable about all the aspects associated with the storage of hydrogen, the system usage and what byproducts are released from system operation. A major strategy for success on several occasions and in several markets was the scheduling of round table discussions with the local fire marshal, the AHJ permit reviewer, local inspectors and government officials. By facilitating open meetings to discuss the system technology, all parties involved were educated on the use of hydrogen as a safe product in comparison to other more popular or accepted fuel sources. This helped pave the way for acceptance in future market deployments of the hydrogen fuel cell system. These entities are crucial in the approval process and ultimately responsible for performing all reviews of the system, technology, fuel sources and making determinations on whether or not the system is safe and provides a benefit to the community.

## 7. CONCLUSION & FUTURE DIRECTION

The Sprint deployment of hydrogen fuel cells into the telecommunication industry for this DOE and ARRA sponsored initiative is complete. Upon reflection of the process and the project elements, there are several identifiable areas for improvement and future growth opportunities. Many of these opportunities reside in the continued education, documentation and practical use of fuel cell systems in real world applications for providing reliable and efficient power. The continued support by large government bodies for hydrogen fueling infrastructure growth and fuel cell technology advancements will be a major catalyst to market transformation.

A major detractor to improving market demand for increased hydrogen fueling infrastructure is in large part due to the current methods available for producing the product. Although hydrogen fuel cell systems are perceived to be clean and have no negative emissions output other that water, the production of hydrogen fuel itself is considered an environmentally dirty process. The process of extracting hydrogen from natural gas produces carbon monoxide and dioxide, while other electrical means require the burning of other fossil fuels. Currently, there is a very small national demand for hydrogen fuel which has adversely affected the number of locations where hydrogen is stored and readily available for consumption.

Future government involvement and funding with strategic corporate partnerships (telecom, automotive, manufacturing, and emergency response organizations) could help solve current hydrogen fueling shortfalls and provide infrastructure to stimulate the hydrogen market.

Fueling situations:

Initial commissioning fill

Normal hydrogen refueling (replenishment) activities

Disaster recovery planning, logistics, and successful multiple system refueling

Some of the major drawbacks to the deployment of hydrogen power system in the telecommunication industry revolve around the physical size, weight and limited power output of the total system.

Rooftop deployments constitute a large demographic of potential locations where hydrogen fuel cell technology can be improved. One major improvement would be the use of a high strength, low weight polycarbonate fuel tank system product. Such a tank system would need to be affordable (comparable to today's steel tank vessels), re-certifiable (in the field if at all possible), and capable of supporting two to three times the pressure currently stored on-site. This is important as when the radio equipment power requirements increase, the associated output power delivered by the HFC increases in the same footprint, so too must the amount of stored hydrogen increase with the allocated footprint. The use of light weight material that can be easily transported to site and installed on a large building rooftop without the use of heavy equipment and associated support tasks (road closure permits, night work pay differential, etc.) would help to dramatically reduce construction costs.

The ideal rooftop power system would be manufactured of modular components that can be assembled on site with the use of minimal human resources. An adverse constraint to this type of system may be the network equipment building system (NEBS), UL, or other certification agencies unwillingness to certify a manufactured product that is field assembled for power generation and hydrogen fuel storage.

A letter of recommendation from the DOE fully supporting the installation of hydrogen fuel cell technology as a clean backup power delivery system is the next opportunity for developing universal industry standards. A DOE sponsored document package detailing the following items would be extremely beneficial for gaining initial support when engaging the community and jurisdiction for approval.

- Construction Details
- System Codes & Standards
- Testing Procedures
- Fire Safety
- Clean power
- Environmental & Community Benefits

Having published documentation that carries a "stamp of approval" by a high level government agency such as the DOE has substantial credence for acceptability across the nation. These standard documents would pave the way for fuel cell educational reform and potentially provide for faster permitting and construction activities in environmentally impacted areas. Also, opening the door for broader distribution throughout to country and facilitating in the build out of hydrogen refueling infrastructure.

## 8. PHOTOS

The photo pages included in this section are examples of successfully deployed systems in three of the major market segments. They represent a variety of differing site conditions and constrains for the installation of hydrogen fuel cell power cabinets and high pressure storage unit technologies within the telecommunications industry.

- California Photo Sheet
- Gulf Coast Photo Sheet
- East Coast Photo Sheet

**DOE Rollout of 5Kw and 10Kw Hydrogen Fuel Cells**

# GULF COAST \ FUEL CELL DEPLOYMENT

**DOE Rollout of 5Kw and 10Kw Hydrogen Fuel Cells**

# EAST COAST \ FUEL CELL DEPLOYMENT

**DOE Rollout of 5Kw and 10Kw Hydrogen Fuel Cells**

## 9. REFERENCES / PUBLICATIONS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Davis, C. (2014). Hydrogen Fuel: The Chicken and Egg Problem. *The Triple Helix Online.*


## 10. ACRONYMS

AAA – American Automotive Association
AC – Alternating Current
AHJ – Authority having jurisdiction
ARRA – American Recovery and Reinvestment Act
CD – construction document
DC – Direct Current
DOE – Department of Energy
GHG – Produced Greenhouse Gas Emissions
HFC – hydrogen fuel cell
HSM – hydrogen storage module
MPHSS – Medium Pressure Hydrogen Storage Solutions
NEBS – Network Equipment Building System
NEPA – National Environmental Policy Act
NOC – National Operations Center
NTP – Notice to Proceed
OPEX – Operational Expenditures
PEM – Proton Exchange Membrane
psi – Pounds per Square Inch
RBS – Radio Base Station
scf – Standard Cubic foot
UL – Underwriters Laboratory
VRLA – Valve Regulated Lead-Acid

# APPENDIX A

| Hydrogen Fuel Cell (HFC) Site Survey | |
|---|---|
| Unique Site Identification No.: | |
| Site Auditor: | |
| Site Auditor Contact Information: | |
| Audit Date: | |

| Section1 - General Site Information | |
|---|---|
| Directions to the Site: | |
| Access Restrictions: | |
| Access Contact (if applicable) | |
| Site Address (Street Address / City / State / Zip): | |
| **Section 2 - Utility Information** | |
| Name of Local Power Provider: | |
| Service Size - 100 or 200 AMP: | |
| Existing Meter No: | |
| Existing Transformer Information: | |
| Fixed Generator Present (Y / N): | |
| Generator Manufacturer and Model No: | |
| Mobile Generator Present: | |
| Mobile Generator Manufacturer and Model No: | |
| Mobile Generator Receptacle (Y / N): | |
| Service Size - 100 or 200 AMP: | |
| Mobile Generator Receptacle Manufacturer and Model No (Y / N): | |
| Receptacle - 3 or 4 pin: | |
| Natural Gas Meter or Stubup location within existing compound: | |
| Natural Gas company: | |
| Propane tank present: | |
| Propane tank owner: | |
| Propane tank condition: | |
| Can Hydrogen Fuel Cell truck access the site: | |
| If "No", provide details: | |
| Are there any alternative fixed backup sources available like building/compound generator protected AC service? | |
| If "Yes", provide detailed description of feasbiility of use (i.e. distrance to location, core drilling required, amperage: | |
| Describe obstacles to accessing the site like elevators, stairways, etc and/or any obstacles that may hinder truck deliveries like low trees, power lines, etc.: | |

| Section 3 - Existing DC Rectifiers and Batteries | |
|---|---|
| Current Installed Rectifier Count and Size (e.g. 6 @ 500 Watts) | |
| Available Rectifier Slots: | |
| Battery Manufacturer: | |
| Battery Voltage Input: | |
| Battery Amp Hours (AH) | |
| Battery Count: | |

| Section 4 - PPC / Service Panel Schedule | |
|---|---|
| PPC Manufacturer: | |
| PPC Breaker Manufacturer and Model No: | |

| Section 5 - Conflicting Projects | |
|---|---|
| Are there any current projects or issues concerning this site: | |
| If "Yes", describe: | |

| Section 6 - Existing Concrete Pad/Platform | |
|---|---|
| Concrete Pad Dimensions (L x W): | |
| Concrete Pad Thickness: | |
| Platform Dimensions (L x W): | |
| Platforom Height: | |

Site Audit and Assessment

| | | |
|---|---|---|
| MAIN Breaker: | | Amps |
| Fed From (utility, bldg,xfmr): | | Source |
| Wire Size | | Gauge |
| Measured AC (Panel) | | Amps |
| Measured DC (Bus Bar) | | Amps/Volts |

| Description | BKR[1] | CKT | | BKR[1] | Description |
|---|---|---|---|---|---|
| | | 1 | 2 | | |
| | | 3 | 4 | | |
| | | 5 | 6 | | |
| | | 7 | 8 | | |
| | | 9 | 10 | | |
| | | 11 | 12 | | |
| | | 13 | 14 | | |
| | | 15 | 16 | | |
| | | 17 | 18 | | |
| | | 19 | 20 | | |
| | | 21 | 22 | | |
| | | 23 | 24 | | |
| | | 25 | 26 | | |
| | | 27 | 28 | | |
| | | 29 | 30 | | |
| | | 31 | 32 | | |
| | | 33 | 34 | | |
| | | 35 | 36 | | |
| | | 37 | 38 | | |
| | | 39 | 40 | | |
| | | 41 | 42 | | |

Notes:
1. For each breaker indicate Amp rating

**Site sketch must contain:**

| | |
|---|---|
| 1 | North Arrow |
| 2 | Size and Location of all fixed objects within compound (to include proposed lease area, if required) |
| 3 | Telco and Power demarcation |
| 4 | Note any relevant topography features. Sketch must be legible and properly labeled. Sketch need not be to exact scale, but must show dimensions and be of sufficient size to be understood. If possible, use straight edge for drawings. Locate proposed equipment locations on sketch and call out. Show conduit routings. |

| Photo Log | | |
|---|---|---|
| | *Photo Name* | *File Name* |
| 1 | Unique site ID sign or NOCC Sign | |
| 2 | Site Owner Sign, Tower ID, FCC/RF | |
| 3 | Entire Compound Facing North | |
| 4 | Entire Compound Facing East | |
| 5 | Entire Compound Facing South | |
| 6 | Entire Compound Facing West | |
| 7 | Main Utility Rack | |
| 8 | Existing electrical routes from utility rack toward cabinets | |
| 9 | Natural gas meter | |
| 10 | Natural gas routing from meter to eqiupment | |
| 11 | Equipment (Equipment Platform) - Facing North | |
| 12 | Equipment (Equipment Platform) - Facing East | |
| 13 | Equipment (Equipment Platform) - Facing South | |
| 14 | Equipment (Equipment Platform) - Facing West | |
| 15 | Existing Battery label | |
| 15 | Existing Batteries (all) | |
| 16 | Existing DC bus and future electrical connection point | |
| 17 | Site PPC/Telco overall view | |
| 18 | Site PPC (door open) | |
| 19 | Site PPC (close up of existing breakers<br>(2 pictures - top & bottom breakers)) | |
| 20 | Site Telco (door open) | |
| 21 | Existing telco routes from telco cabinet toward cabinets | |
| 22 | Generator Plug<br>(4 pictures - Plug, Pins, Label & Parking Location) | |
| 23 | Existing equipment ground bar | |
| 24 | Proposed ATS Location | |
| 25 | Proposed Hardening Solution Location (2 vantage points) | |
| 26 | Existing Transformer (if applicable) | |
| 27 | Access Road/Path and Obstacles(Gates, low hanging Branches, Tight Turns/Turnarounds, distance from gate to public road; Lots of Pics if needed) | |
| 28 | Adjacent Property Issues(Chemicals, Weeds or other flammable materials, Other hazards or issues) | |

| Review Completed by: | |
|---|---|
| Name: | |
| Contact Information: | |
| Date: | |

| Section 1 - General Information | |
|---|---|
| Unique Site Identification No.: | |
| Site Reference # / Name: | |
| Site Address (Street Address / City / State / Zip): | |
| Site Owner / Landlord: | |
| Contact Name: | |
| Mailing Address (Street Address / City / State / Zip): | |
| Phone / Fax / E-mail: | |
| Landlord ID: | |

| Section 2 - Current Lease Information | |
|---|---|
| Lease Document Available: | |
| Specify Lease Area Dimensions (in square feet): | |
| Is Installation of Generator Addressed in the Lease? | |
| If "Yes", list Paragraph Number in Lease: | |
| Is Notice or Consent Required for Installation of a Generator and/or improvements? | |
| List Paragraph Number in Lease that Addresses Notice/Consent: | |
| Are Drawings Required for Consent: | |
| Is Leasing Required Due to Lease Language: | |
| Comments: | |
| Is Additional Leased Area required to deploy a Backup Solution: | |
| If "Yes", specify New Lease Area Dimensions (in feet): | |

| Section 3 - Zoning/Building Permit Requirements | |
|---|---|
| Zoning/Permit Jurisdiction: | |
| Original Zoning Drawings Available: | |
| Comments: | |
| Zoning Approval Documents Available: | |
| | |
| | |
| Comments: | |
| Is Zoning Required for Installation of Backup Power Solution: | |
| If "Yes", list the timeframe: | |

| | |
|---|---|
| Is a Permit Required for Installation of Backup Power Solution: | |
| If "Yes", Specify Permit Type: | |
| Section 4 - PPC / Service Panel Schedule | |

| **Section 4 - Generator/HFC Sizing Information** | |
|---|---|
| Is the site a shelter? | |
| Does plant host other customers? | |
| Is future growth planned / expected? | |
| Additional Cabinet(s) required? | |
| Mhz RRH Quantity | |
| Mhz RRH Quantity | |
| Mhz RRH Quantity | |
| Recommended Generator Size: | |
| Recommended FC Size: | |

| **Section 5 – Contractor Recommendation for Backup Power Solution** | |
|---|---|
| **Engineer's Recommendation** | |
| *Note: For each option, please detail the exact location of desired backup power generator, and any site modifications that will be required such as a new platform, a new concrete pad, or removal of platform railings.* | |
| First Recommended Option: | |
| Comments: | |
| Second Recommended Option: | |
| Comments: | |

# APPENDIX B

# Burns & McDonnell is leading the way in the deployment of Hydrogen Fuel Cells

## Introduction

A decade ago fuel cells were in their experimental phase. The development of fuel cells for use as backup power in the cellular communications market has matured significantly since then. These machines are now robust and proven in many applications and environments. Fuel cells provide an environmentally friendly replacement for the diesel, propane, and natural gas generator sets that have been traditionally favored in this market segment.

The Department of Energy (DOE) has given considerable time and effort to help educate the public and commercialize fuel cells. One of the first industries to partner with the DOE is the commercial telecommunications industry. With more than 250,000 cell tower sites in the United States alone there is a huge potential for increasing the use of fuel cells to provide green backup power.

Using pressurized hydrogen gas as fuel for back-up power fuel cells that utilize proton exchange membrane technology are becoming increasingly popular. Fuel cells are energy-conversion devices that can efficiently capture and use the energy-carrying capacity of hydrogen to power nearly every end-use energy need. Energy uses include portable devices, transportation vehicles, and stationary power stations, such as those used for the telecommunications industry.

## Burns & McDonnell Engineering Inc.

Burns & McDonnell (BMcD) has rapidly become the national leader for hydrogen fuel cell deployment. With a strong resume of roll-out projects, a nationally renowned expertise in power delivery and fueling operations and professional engineering registrations in all 50 States, BMcD was uniquely positioned to lead the hydrogen fuel cell deployment effort. BMcD is a 113 year old employee owned engineering and construction company. BMcD has a long history of successfully introducing new technologies into the market using an Integrated Project Delivery (IPD) method. This IPD method covers all aspects of the project including candidate identification, physical site assessment, zoning, permitting, code compliance, design, logistics, installation, and commissioning.

## Hydrogen Fuel Cell Advantages

The vast majority of cell tower sites have a battery bank to provide power backup. However, when these batteries are new they only provide two to six hours of backup power. Fuel cells last longer and are more predictable than batteries. Even though batteries have a five-year life expectancy, their rechargeable energy capacity diminishes over time, and they can be ruined if their charge is drawn too often. Fuel cells, however, can operate for ten years or more with undiminished power quality and quantity.

Compared with generators, fuels cells are cleaner, quieter, pollute less, and require less on-site maintenance. Fuel cells are environmentally friendly because they convert the chemical energy in hydrogen directly to electricity with pure water and heat as the only by-products. Other advantages of fuel cells for backup power include:

- Operating efficiencies around 50%
- Scalable and modular to operate in parallel
- Wider operating temperature range (-40°F to 122°F)
- Indoor or outdoor use with a minimal footprint
- Longer life with no moving parts

## Jurisdictional Education

An important part of the process is to educate the local authority having jurisdiction (AHJ) that hydrogen is a safe and viable fuel source when used in accordance with current codes and industry standards. Their main safety concern involves the storage quantity and pressure of the compressed hydrogen gas on site. A secondary concern is for how it will react in an open environment in the event of an incidental release. Recently deployed systems will store anywhere from 4,000 to 8,000 standard cubic feet (scf) of hydrogen in a single storage cabinet. The average storage pressure of these systems can be as much as 3,000 pounds per square inch (psi), with system operating pressure ranging from 5 psi to 100 psi. The hydrogen fuel used for a proton exchange membrane (PEM) fuel cell generator is a pure product greater than 99%. This gas is 14 times lighter than air and will disperse to the atmosphere and quickly drop below the flammable concentration limits. Compressed hydrogen is most readily available in the commercial industry in metal cylinders which are designed to transferred to the site full and exchanged in the same manner as a propane tank under your gas grill.. Hydrogen's versatile fuel characteristics provide for a wide range of operating temperatures allowing it to be placed in many regional locations. Ensuring a safe operating environment is critical when designing a fuel cell system that stores, processes, and converts hydrogen gas into usable electricity.

## Site Assessment

Site assessment and selection are the most critical components to ensuring that a fuel cell candidate site can be carried through the entire design, permitting, and construction process. The geographic considerations for a large roll-out program will typically involve a combination of factors, such as population, weather patterns, and electrical grid performance. After these parameters are defined, cell towers can be located in metropolitan, rural, and remotely isolated locations. Existing documentation such as a property leases, construction drawings, and an internet search can be a quick and efficient way to make an overall determination of existing conditions for a specific candidate site location before putting people in the field to perform a site walk investigation.

The physical site audit is where the most information can be collected about the layout of a site, the existing conditions and equipment, and the overall viability for the installation of a fuel cell generator. During this process you should first document the exact location of the project and any obstacles that may potential effect the ability of a candidate site to be constructed, fueled, or maintained for the life cycle of the fuel cell. These considerations should include the use or storage of any alternative fuel types, generators, or other back-up power equipment, and the main utility or power supply. Gathering as much information about the current operation and functionality of the equipment or facility, along with taking a real time measurement of the actual DC or AC load will provide the framework for determining the type, size, and runtime of a fuel cell system deployment.

When siting an area or location for a fuel cell generator it is important to consider the optimal installation location, but to also investigate the surrounding areas and make considerations for how the property or adjacent properties may be developed or utilized in the future. There are several national, state, and local jurisdictional codes that must be adhered to when deciding the final location of a fuel cell generator. Code compliance is not necessarily reflective of the type of fuel cell system being installed, but typically is more influenced by the fuel type, quantity, and pressure at which the fuel is kept during standard operating conditions. Below is a list of the most common site conditions that must be observed when evaluating the viability of a fuel cell generator.

- Buildings and structures on the same property
- Underground flammable or combustible liquid and gas storage
- Ignition sources
- Overhead electrical utilities
- Public streets, walkways, and gathering areas
- Property lines
- Above ground flammable or combustible liquid and gas storage

## Site Acquisition

The site acquisition process involves challenges based on proposed equipment technology; land owner's approval, lease agreement terms, and jurisdictional ordinances and code requirements. This is where the jurisdictional education most often takes place.

Site acquisition consists of:
- Leasing
- Design
- Zoning
- Permitting

The leasing portion of site acquisition is where the landowner's consent is obtained to install the fuel cells. There are multiple types of consent that may be required and the current lease language is used to determine the type of consent for each site. The BMcD team has seen many forms of leases in this roll-out project, and has the experience and knowledge to make the determination as to which type of consent is required for each site.

It is necessary to complete the site layout portion of the design in order to begin the leasing process as these layout drawings will be used to communicate to the tower aggregator or landowner the proposed installation. If the proposed layout falls within the current lease limits, then the lease language will indicate if the lessor needs to be notified of the modification or if the lessor needs to consent to the modification. If the proposed layout falls outside the current lease limits then a lease amendment will be required. The leasing process is complete when a receipt of the courtesy letter delivery is received, the signed consent letter is received, or the amendment is approved.

The design process begins by using the proposed equipment layout generated during the site assessment process as the basis for the construction documents (CDs). Using the constraints of national and local code compliance, setbacks, maintenance clearances, wiring, existing equipment and open space available, a site layout is designed, reviewed, and finalized. Layouts are manipulated to utilize the existing lease area as much as possible while maintaining a fully operational and code compliant site. Each site is designed on an individual basis so that the completed product is a functionally efficient site.

Depending on the authority having jurisdictions (AHJ) over a site, there are three categories that most sites fall into for the zoning process. The first case is a no zoning approval required prior to filing for the building permit. The jurisdiction review is performed simultaneously with the building permit. The second scenario requires an administrative process prior to filing for a building permit. This process typically consists of submitting a zoning package which includes; an application, design plans, and a fee for compliance with local zoning ordinances. The third category entails a formal public hearing approval process. This process requires an extensive application, legal representation, public hearing meetings with board officials, and possibly signed and sealed site survey. The public hearings require attendance of the licensed engineer, a lawyer, and most often a licensed city planner.

Building permits must be obtained prior to starting construction. They encompass electrical, plumbing, structural and fire approvals. In most jurisdictions this process starts with submitting signed and sealed plans along with a fee, application, equipment data sheets, and engineering calculations. The permit approvals come with a list of inspections that are required during construction, including a final inspection. Once these inspections are completed, the site is considered permit closed. Through the permitting experiences the BMcD team has gained knowledge of consistently requested requirements, such as compressed gas warning placards and warning signs on compound entry gates and the hydrogen storage module cabinet. The AHJ's also prefer to see the maximum amount of gas stored on site written on the plans. Some regions of the country will require a separate fire department submittal with its own review fee, process, and approval.

## Construction

The construction process includes not only the site modification, installation of the new equipment, fueling and commissioning, but also includes the quality control, safety inspections, construction oversight, commissioning, and any additional testing. The construction process begins with picking up the building permit from the local AHJ. Once the building permit is picked up, a copy is sent to the property manager to receive approval to start construction. Once the notice to proceed is received, the layout of the site has been completed, and the underground utilities have been located then site modifications can begin.

The site modification process can include any number of situations from simply modifying anchor bolts to constructing an elaborate raised steel platform. The installation of the new equipment includes setting the new equipment, installing the anchor bolts, routing electrical wiring, alarm communications wiring, and the fuel tubing. One of the major challenges is the lifting and placement of the cabinets into compact spaces, not having a staging area for crane access, or utilizing other lifting devises. Some sites are so compact that finding a route for electrical lines requires additional coordination between the field staff, the engineers, and sometimes the property manager. Another complicating factor is that remote cell tower sites have recently become a prime target for copper thieves and consequently grounding at many candidate sites has been compromised by the theft of the copper grounding bar and often many of the larger copper ground wires. This vandalism requires the installation team to install new grounding for equipment and site safety before the fuel cell can be brought online.

Once the site modifications are complete and the new equipment has been installed, the fueling and commissioning process can begin. The fueling of the site is done by a the hydrogen gas supplier and this activity has to be coordinated and scheduled after installation of the new equipment but prior to commissioning. During the commissioning process, the alarm wiring is punched down and communications is verified back to the central switch. The equipment is then turned on and run through a full diagnostic program to ensure that the equipment is functioning properly. A series of tests are then performed to simulate the outages and situations that the equipment is expected to encounter. Once the commissioning is complete the site is online and operational.

Quality control, safety inspections, and construction oversight are some of the other items that are included in the construction process. Quality control includes verifying that the correct units, electrical wiring and piping are being installed. Safety inspections are preformed daily at the sites to insure that all contractors know the dangers in the activities they are performing. Additional testing that has been required, includes verifying the internal hydrogen leak detection system is working and will shut down the system in the event of a leakage. It can also include measuring the decibel level of the unit running to insure that it conforms to the AHJ noise ordinances. The additional testing could also include monitoring the unit remotely via a modem connection to capture data on the performance and usage of the system.

## Conclusions

From beginning to end, fuel cell roll-out programs require careful and diligent logistical planning. Many of the factors that influence the project budget and schedule are controlled by municipal organizations. A successful project requires diligence and flexibility to work with all the people involved in all phases throughout the process.

We believe that based on Burns & McDonnell's capabilities and experience, we are uniquely positioned to successfully execute fuel cell programs.

# APPENDIX C

BURNS McDONNELL

# Hydrogen Back-Up Power – "A Success Story"

## Introduction

In the aftermath of Hurricane Katrina it became apparent that cellular communications was an integral part of public safety for a large part of the American population. Consequently it has been a priority of the Department of Energy as well as the major cellular communications providers to provide backup power solutions for their equipment to ensure continuous cellular communications service even in a prolonged power outage. Working with the Department of Energy it was determined that 72 hours of backup power would provide a sufficient amount of buffer to allow the grid power to be put back online or to allow for refueling of the backup power systems so that the communication operations could continue under emergency power.

## Green Backup Power

Traditionally the telecommunications industry has utilized large battery banks for short term power backup and diesel generators for longer term backup power needs. In an effort to be responsible corporate partners in the communities that they serve, the major telecommunications providers have been looking for green power solutions to reduce the number of batteries needed and replace the environmentally unfriendly diesel generators that have been used since the 1980's. One of the most popular green power solutions is the proton exchange membrane (PEM) hydrogen fuel cell (HFC) coupled with stored gaseous hydrogen.

These units can be configured to provide a full 72 hours of backup power for many different types of cellular tower sites.

## Hydrogen Fuel Cell Advantages

Fuel cells last longer and are more predictable than batteries. Even though batteries have a five-year life expectancy, their capacity diminishes with time, and they can be ruined if their charge is drawn too often. Fuel cells, however, can operate for ten years or more with undiminished power quality and quantity.

Compared with generators, fuels cells are cleaner, quieter, pollute less, and require little on-site maintenance. Fuel cells are environmentally friendly because they convert the chemical energy in hydrogen directly to electricity with pure water and heat as the only by-products. Other advantages of fuel cells for backup power include:

- Operating efficiencies around 50%
- Scalable and modular to operate in parallel
- Wider operating temperature range (-40°F to 122°F)

- Indoor or outdoor use with a minimal footprint
- Longer life with no moving parts

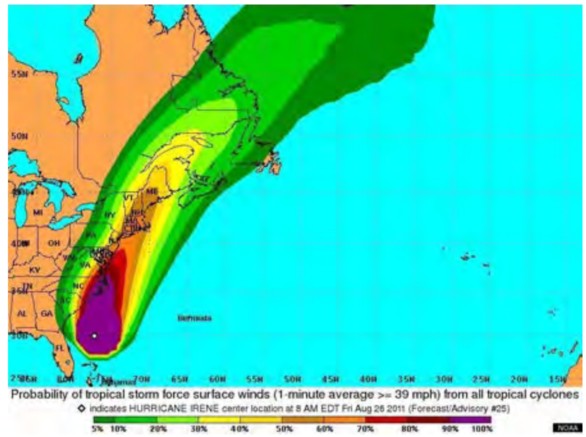
## Hydrogen Back-Up Power – "A Success Story"

As a part of the American Recovery and Reinvestment Act program administered by the DOE, Sprint set forth to install PEM type Hydrogen Fuel Cell (HFC) backup power systems at sites which were considered to support specific types of "Critical Infrastructure" traffic.

Part of the Sprint DOE program was also to ensure that the selected hydrogen storage solution could support the required 72 hour runtime for the site specific power load and could be refueled on-site while the HFC is either in operation or in standby.

In partnership with the gaseous hydrogen supplier (Air Products) the Sprint DOE program is developing a refueling infrastructure that involves the use of small single frame refueling trucks some of which have been equipped with four wheel drive systems to aid in reaching the tower sites after a storm.

One of the target markets for the initial roll-out of the Sprint DOE program was the Northeast. About 15 months after the program was started the systems were given their first real test and they passed with flying colors.




Hurricane Irene swept across the Northeast United States in August of 2011 leaving more than seven million people without power. Irene was the fifth costliest and second largest storm in US history in terms of power outages.

The damages from Irene have been estimated between seven and ten billion dollars. Irene caused power outages in 14 states and caused widespread flooding and property damage. Thousands of cellular communication sites were left without power for extended periods.

Before Hurricane Irene struck, the Sprint DOE program had already placed 56 hydrogen fuel cell backup power systems into service in New York, New Jersey and

Connecticut each fueled to support 72+ hours of continuous operation.

Of the 56 units installed, 46 experienced outages in excess of six hours. All 46 systems operated throughout the entire outage duration without any known issues. The cumulative outage time for these 46 sites was 725 hours with an average outage of sixteen hours. The maximum single outage was 50 hours. All 46 sites were successfully refueled by Air Products within the 72 hour window.

The operation of these backup power systems allowed the residents of these communities as well as emergency workers to maintain full use of their cellular telephones through the storm and during the recovery efforts.

# APPENDIX D

# Water Tower Facility Case Study for Hydrogen Fuel Back-Up Power: Gaining Momentum Through Education

## Introduction

Cellular telecommunication is not considered to be a staple utility of modern life necessities by most jurisdictional definitions, although there are more than two hundred million people across the United States that currently subscribe to a cellular telecommunications provider. The continuing changes in communication speed, processing power, and data usage has turned smartphones into a way of life. This lifestyle demands constant network stability and can be intolerable to dropped calls, slow data transmission, and power outages.

One of the earliest and most popular locations for cellular network equipment is within a municipal water supply facility with network antennas located on top of a water tower structure. These types of facilities are ideal for the telecom industry because of the large amount of ground space and the naturally high water tower structure. In an effort to protect the United States water supply, several government mandated regulations have restricted the use of these towers and facilities. The proposed use of hydrogen fuel cells as the primary backup power supply immediately heightens jurisdictional awareness and reluctance to permit or approve this technology alternative.

## Water Tower Site Audit

In July of 2010, a field team set out to survey the potential for installing a fuel cell backup power generator at a water tower facility in Blackwood, New Jersey. Upon arrival at the water tower compound, first implications were that this water tower would be an ideal location for a hydrogen fuel cell installation. The fenced compound measured approximately 150’ by 130’ with a 100’ diameter water tank centered within a chain-link fence with barbed wire. A 10’ wide asphalt vehicle driveway leads around the east side of the property to a concrete equipment pad located on the northwest corner.

The Cellular equipment pad is a standard 10’ x 20’ rectangle, with a traditional five cabinet network configuration.

This setup included a power center, telephone backboard, battery cabinet, rectifier, and base transceiver station. All the equipment was placed on the west end of the pad which left an available expansion area, right sized for the fuel cell installation on the east end near the water tower structural support legs. After collecting information on all the existing equipment including system load capacity measurements, the team produced a field sketch and site assessment ranking. This water tower facility appeared to be a prime candidate site for a quick and easy installation of a 4kW hydrogen fuel cell system with a 72 hour estimated runtime.

## Site Acquisition

### Leasing

With the site audit producing a favorable outcome, the project proceeded into the site acquisition process. The land owner is the Township of Deptford, New Jersey. The Township was contacted to ascertain information on the approval processes. The initial response was that they had serious reservations about the hydrogen technology's safety in relation to their municipal infrastructure. They were concerned that hydrogen posed an explosive threat that might damage property or facilitate a contamination of the water supply. The fear associated with a hydrogen system is often a misleading reputation affiliated with the Hindenburg disaster of 1937. In an effort to educate the Township, hydrogen technology information was provided including:

- Hydrogen material safety data sheets.
- Hazardous material business plan
- Manufacturer data sheets
- Fuel cell permitting guide
- Hydrogen safety facts sheet

In response to this data, the Township's representative contacted the State of New Jersey Homeland Security Office to obtain their determination. The New Jersey Homeland Security Office was reluctant to provide any feedback or approvals prior to a full evaluation of the hydrogen fuel cell technology as an allowance to a water tower facility by the Federal Department of Homeland Security (DHS). The DHS would have sole discretion to approve or decline the installation of a hydrogen fuel cell on the basic principle of safety for the people and protection of the township water supply. The site acquisition team kept in close contact with the Township's representative in order to get progress updates on the discussions with DHS. Once their approval was given, lease negotiations began with the Township's executive director. We generated a template lease amendment for use since the Township did not have one to provide. The template was modified to fit the terms of the site, reviewed by both parties and eventually executed.

### Design

The hydrogen fueling company, Air Products evaluated the site and determined the existing access drive was not adequate for truck fueling operations. They required an additional gravel turn-around to be designed, so the delivery truck could make a three-point turn within the fenced compound. The Township required this new access drive area to be designed and constructed of asphalt.

The site audit sketch proposed the new fuel cell cabinets be located in line with the existing equipment on the concrete pad and steel rail system. When this layout was reviewed by the authority having jurisdiction (AHJ), they considered the legs of the water tower to be a "structure" as commonly associated with buildings and therefore requested the hydrogen storage module to be relocated at least 10' away from any part of the water tower. In order to satisfy this requirement, the hydrogen storage module and fuel cell were redesigned and located onto a new concrete pad adjacent to the existing equipment. This new design, along with all other requested facility upgrades and modifications was eventually approved by the owner and permitted by the AHJ for construction.

**Construction**

On November 9th of 2011, the groundbreaking began on construction of the new fuel cell equipment pad and asphalt driveway extension. A standard installation from start to finish can typically be done within a week. The public works department was assigned to maintain facility security and provide daily access for the construction workers. The project passed all construction inspections and was completely installed and filled with hydrogen gas on November 18, 2011.

The only remaining task was the commissioning and initial startup of the system.

This was the moment that Deptford Township and other surrounding jurisdictions had been waiting for. We were actively pursuing the permitted use of other water towers within the state that had also been curious to see how this new technology would perform and impact standard water tower facility operations. The commissioning process tested the communications alarming, power output, and performance reporting capabilities of the system.

**Conclusion**

Fuel cell technology is quickly becoming a more prevalent and viable solution for providing stationary back-up power for a large range of applications. This installation helped to provide an educational learning experience for multiple jurisdictions and effectively debunked the common misconceptions that hydrogen gas is inherently dangerous. Since completion, eight other jurisdictions in New Jersey have permitted the use of hydrogen fuel cells as a means for providing back-up power for cellular equipment within water tower facilities.