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Leading the Fuel Cell Revolution

# Overcoming Technology Barriers to Reliable, Clean-Energy Backup Power Solutions for Telecommunications Networks

## Abstract

Grid-related power failures expose telecommunications companies to millions of dollars of risk every year, and those companies invest millions to guard against long-term outages. Diesel generators and VLRA batteries provide the vast majority of on-site backup power for cell towers across the United States, and have since the 1980s. Both technologies have predictable maintenance schedules and costs, and both have performance limitations that have become accepted in the absence of commercially viable alternatives.

Batteries have relatively limited runtimes, short lifespans, and high replacement costs; generators have noise, performance, and emissions issues. Both come with characteristics that make it increasingly difficult to deploy legacy technologies to support the nation's modern communications infrastructure. Neither technology has changed significantly in decades; both take up a lot of space and are far from sustainable.

Concerns over shifting climate change regulations and the rising cost of traditional batteries and generators have caused many telecommunications companies to re-evaluate their backup power solution investments. As companies struggle to maintain profitability and look for ways to project a green image, total cost of ownership for all solutions is coming under greater scrutiny and alternatives that offer immediate savings and improved environmental performance are gaining favor.

Altergy has developed advanced Proton Exchange Membrane (PEM) fuel cell technology that can provide uninterrupted power at the source over extended runtimes, and do so with a significantly lower total cost of ownership than the status quo. Altergy has broken through technology barriers to mass-produce industrial-strength fuel cells that produce zero emissions, feature a compact footprint, and have demonstrated their reliability in hurricane and earthquake conditions.

## Overview

Increasingly, telecommunications companies are adopting clean energy backup power solutions to protect network communications during grid-failure related outages and provide continuous, on-demand power over extended runtimes. Such solutions also must simplify maintenance schedules and lower total backup power system costs.

Hydrogen power applications are being advanced in aerospace, automotive, and other sectors, and new technologies are accelerating the emergence of fuel cells as the clean energy power source of choice. Advances in catalyst technology, molecular polymer science, and automated assembly systems have driven the cost of fuel cells down, while hydrogen's increased availability and well-documented safety record have helped demonstrate the reliability of modern PEM fuel cells in real-world deployments.

The VRLA batteries and diesel generator typically used to provide outside plant (OSP) back up power to cell towers across the United States rely on old technologies and provide inefficient power, and their large footprint requirements can limit their deployment flexibility. Weight, size, and safety concerns make rooftop installations and other desirable applications extremely difficult, and the cost of maintaining such systems rises dramatically over time.

The U.S. Environmental Protection Agency regulates diesel emissions in efforts to reduce greenhouse gas emissions, with increasingly stringent regulations taking effect over time. Batteries must comply with end-of-life recycling and certification costs. Telecommunications companies can simplify regulatory compliance by choosing cleaner alternatives.

Altergy Systems has developed breakthrough technology and revolutionized the fuel cell manufacturing process to make clean energy PEM fuel cells more affordable, durable, and compact. Featuring a lightweight design and stainless steel construction, Altergy's field-proven clean energy backup power solutions have logged more than 32 million hours and demonstrated the ability to replace batteries and generators in even the most severe weather conditions.

**TABLE 1. Large Blackouts in the United States**
Statistics For Outage Cause Categories

| | % of events | Mean size in MW | Mean size in customers |
|---|---|---|---|
| **Equipment failure** | **29.7** | 379 | 57140 |
| Wind/rain | 14.8 | 793 | 185199 |
| Lightning | 11.3 | 270 | 70944 |
| Operator error | 10.1 | 489 | 105322 |
| Voltage reduction | 7.7 | 153 | 212900 |

Source: Trends in the History of Large Blackouts in the United Sates
http://www.uvm.edu/~phines/publications/2008/Hines_2008_blackouts.pdf.

## The Runtime Limitations of VRLA Batteries

The 12-volt VRLA batteries commonly deployed to provide backup power at cell tower sites have limited runtime capabilities, with most deployments providing far less than the FCC 8-hour minimum runtime requirement. Even when installed in multi-unit strings, VRLA batteries typically deliver up to four hours of performance. Batteries cannot produce enough power over sufficient runtimes to adequately back-up critical systems.

Limited runtime capabilities can expose network performance to extended downtime, as the nation's power grid has proven vulnerable to periodic longer-term outages. Diesel generators often are necessary to supplement battery back up power and provide runtimes of eight hours or more, particularly in high-value markets and severe-weather regions. Extended diesel generator use, however, has been shown to lead to mechanical failure, and adding diesel generators to the solution results in higher costs and larger footprint requirements.

## VRLA Battery Life Expectancy

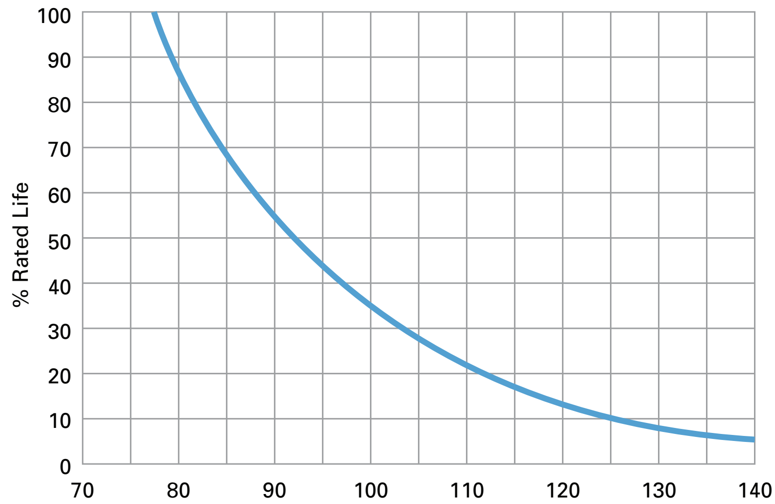
While heralded in the 1980s as a long-lived solution, VRLA batteries have failed to live up to initial longevity expectations, and have proven to be vulnerable to multiple conditions that can shorten the battery's lifespan.

Heat can be particularly detrimental to VRLA battery longevity, with temperatures only 10°F above optimal resulting in up to a 30 percent decrease in battery life expectancy. Most battery storage cabinets are not temperature controlled, and heat-related impacts continue to be the leading cause of battery degradation.

VRLA batteries also are susceptible to shortened lifespans due to high deep discharge cycle rates and continuous overcharging. VRLA batteries typically are maintained at full charge, which is achieved by continuous charging at a constant voltage, known as "float charging." Increases in the batteries' internal temperature and corrosion on the positive plate due to excessive float current can lead to battery failure and shortened battery life.

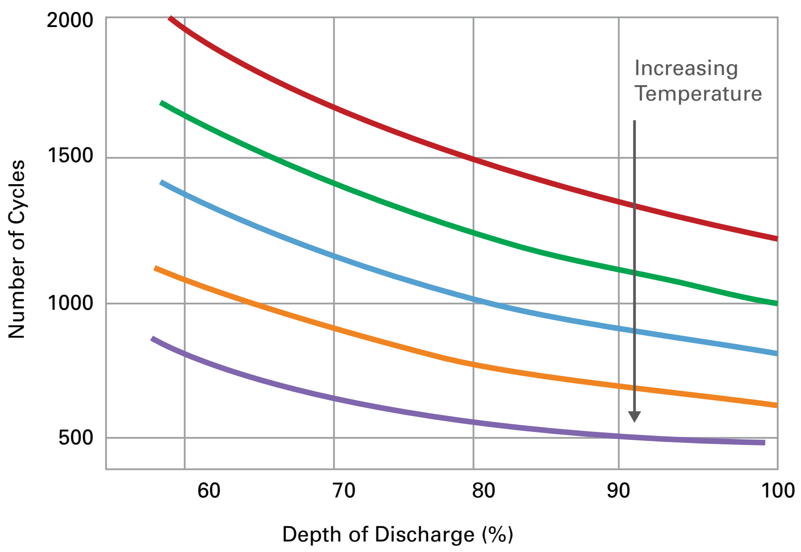
For many cell tower applications, VRLA batteries are replaced in 3-to- 5-year budget cycles.

Actual Life Exected ($L_1$) = Derating Factor at Operating Temperature ($D_1$) x Design Life ($L_2$)




Temperature (F)
Lead Acid Battery % Life ($D_2$) vs. Temperature

Based on the equation Actual life = Derate factor x Design Life, a VRLA battery with a design life of 10 years, operating at 85 degrees F, per the graph, will have an actual life of 6.9 years (6.9 = 69% of 10).



### Battery-Related Cell Tower Failures

Approximately 62 percent of cell tower failures are power related, and 80 percent of those failures are due to battery problems.*

*Source: Battery Power Magazine

### Weight and Space Limitations

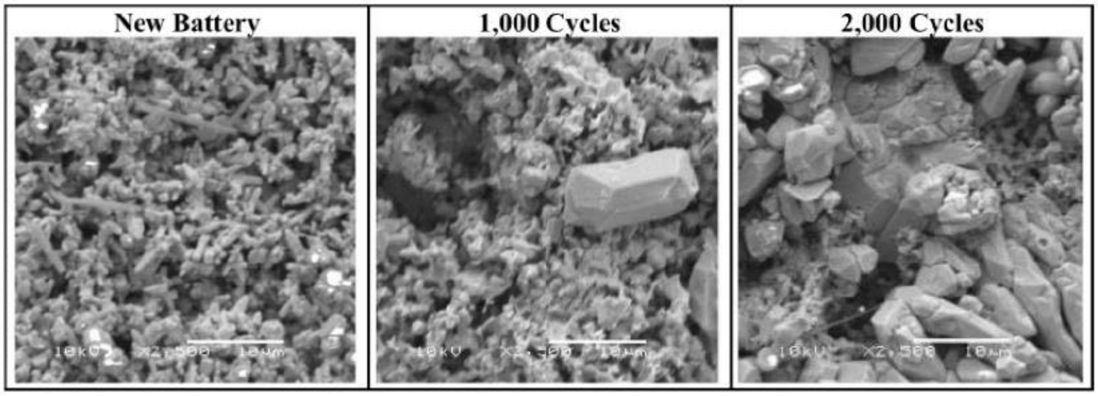
For most cell tower backup power applications, batteries are deployed in strings of multiple units; the more batteries in the string, the greater the total weight and space footprint of the OSP cabinet. The weight and size footprint necessary to provide adequate battery backup power for critical loads often limits the feasibility of rooftop or tight-space installations and raises implementation costs.

Rooftop deployments have become highly desirable in urban centers and densely populated regions. The weight, size, and fire-safety concerns associated with batteries make rooftop installations virtually impossible and limit operational flexibility.

### Sulfation Degradation

During prolonged charge deprivation (i.e., a Partial State of Charge of (POSC) application, amorphous lead sulfate can convert to a stable crystalline that deposits on the negative plate of the battery. The development of large crystals can reduce the battery's active material and conductivity. In some cases, the lead sulfate can be dissolved during the subsequent charging cycle, however as the battery ages the lead sulfate typically grows into larger crystals and causes sulfation.

Sulfation lowers charge acceptance, and results in longer recharge cycles due to elevated internal resistance as the sulfate crystals grow larger. Sulfation is a known cause of premature battery failure.



### Battery Maintenance and Disposal

Batteries require constant monitoring and field maintenance conducted by skilled technicians. Such labor-intensive efforts result in higher annual operating costs. Even with regular maintenance, VRLA batteries tend to be replaced every three-to-five years.

When batteries are replaced, depleted batteries must be processed through a thoroughly regulated, extensively documented recycling and disposal procedure. The end-of-life requirements inherent with VRLA batteries raise costs and have a significant impact on landfill management.

### Climate Change and Diesel Emissions

The U.S. EPA regulates emissions from diesel engines in an effort to address climate change, and as regulations have become increasingly restrictive, the cost of modifying generators to maintain compliance has risen significantly.

The EPA first regulated off-highway compression ignition diesel engines in 1996 and began enforcing limitations on exhaust emissions for stationary diesel generators in 2006.  To meet more stringent EPA standards, diesel engine manufacturers have employed exhaust after treatment systems, such as selective catalytic reduction (SCR), diesel particulate filters (DPF), exhaust gas recirculation (EGR) systems, which have significantly increased the upfront capital costs of generators. Compliance modifications can, in some cases, double costs.

Stationary diesel engine and gas-engine generator sets used strictly for emergency standby power (ESP) usually run less than 200 hours per year and are exempt from EPA Tier Tier 4 regulations in most of the United States. However, mobile diesel and spark- ignited generators used for temporary backup power (generator on wheels) usually are subject to Tier 4 emissions regulations.

Furthermore, many states and municipalities set emissions limits more strict than those established by the EPA, which can result in additional equipment modification. Many "non-attainment" areas, particularly in dense or large population centers, set standards that can inflate back-up power costs. Examples of non-attainment areas include California, many New England states, and the cities of Atlanta and Houston.

### Diesel Generators and Load Following

Diesel generators produce a constant current that does not vary to meet energy demand; they do not provide load following capabilities. Many generators produce far more power than is actually needed, which is an inherently inefficient system that produces inordinate amounts of wasted energy.

### Diesel Generator Maintenance

The cost of ownership for generators over a 10-year span is determined by more than the initial capital acquisition expense, and must factor in maintenance schedules and replacement part expenses. Also, when operating in municipalities that enforce noise ordinances, additional costs may be incurred. Severe conditions such as extreme temperatures, prolonged periods of inactivity, extended continuous runtime, and exposure to inclement weather or saltwater can further increase maintenance and operational costs.

As diesel fuel gets older a fine sediment and gum can form, caused by the reaction of diesel components with oxygen from the air. Fuel tanks and other storage systems can foster aerobic and anaerobic bacteria. Fine sediments and bacteria can block fuel filters, leading to fuel starvation and the engine stopping. Frequent filter changes are required to keep the engine operational; while scheduled maintenance costs vary with generator size they typically range from $1,000 to $2,500 annually for the life of the equipment.

### Prohibitions on Diesel Rooftop Deployment

Fire risks and weight considerations often prevent diesel generators from qualifying for the permits required for rooftop deployment. There is a risk of secondary fire in the event of a fuel leak that pools below the generator and onto the roof surface, and many roof structures cannot safely support the weight of high-capacity diesel generators.

Many major metropolitan cities have little available ground-level real estate to house generators for existing cell sites or new small cell deployments, which makes rooftop deployments highly desirable.

### Wet Stacking and Longevity

"Wet stacking" is a term used to describe a diesel engine dripping a thick black gooey substance from its exhaust piping or "stacks." This serious condition is caused by operating the engine at light load for extended periods, sending unburned fuel and soot into the exhaust system. Wet stacking can seriously degrade diesel engine performance and useful life.

Wet stacking is not entirely uncommon given the standard operating procedures of diesel-powered back-up generators deployed in telecom facilities. Many generators in the field are routinely tested at no load or at light loads instead of at or near full load. Also, in telecom applications generators are typically oversized when initially specified to accommodate anticipated load growth that often does not materialize. In general, diesel generators that are not regularly exercised or operated at 33% to 50% of the nameplate rating are at risk for wet stacking over the long term.

### Runtime Impacts on Mechanical Failure

Even with established maintenance schedules, diesel generators are subject to wear and tear. Being pressed into extended duty can stress machinery that is often idle and features many moving parts. Such stress can lead to mechanical equipment failure in diesel generators.

During the 2003 grid outage in the Northeastern U.S. many diesel generators failed after running continuously for more than 24 hours. The reported breakdowns were due to mechanical component failures in generators not adequately designed for continuous runtime duty.

### Fuel Cell Technology Potential

Fuel cells have long been envisioned as a source of clean energy. Fuel cells produce energy – an electrical current – by creating a chemical reaction between hydrogen, the most abundant gas in earth's atmosphere, and the air we breathe. The only byproduct of the process is water (H2 + O = H2O); there is no combustion and there are no greenhouse gas emissions.

NASA, the U.S. Navy, and other organizations have deployed fuel cell technology in limited applications since the 1960s. Until recently, however, high production costs and an inability to automate mass production were considered insurmountable obstacles to fuel cells realizing their dramatic commercial potential.

### Fuel Cell Background

The origin of fuel cells can be traced to 1776, when Henry Cavendish discovered that water is not an element, but a compound formed when hydrogen reacts with oxygen. In 1839, Sir William Robert Grove confirmed that this reaction also generates an electrical current, earning him the title "The Father of Fuel Cells."

Fuel cells produce an electric current by means of an electro-chemical reaction between hydrogen and oxygen, not the combustion of fossil fuels as diesel generators do. Water is a natural by product of the electro-chemical reaction. There are no carbon emissions, and there is very little noise.

Charles Langer and Ludwig Mond coined the term "fuel cell" in 1889, and scientists developed fuel cell technology for another 60 years before it found its first practical uses in the 1950s in mobile applications that would eventually range from space missions to public transportation. Every Apollo and Space Shuttle mission by NASA since the early 1960s has had fuel cells aboard supplying power and drinking water to the astronauts.

Since the turn of the 21st century, fuel cells have seen widespread implementation in the U.S. and around the world, in stationary prime power electric only, and combined heat and power (CHP) applications.

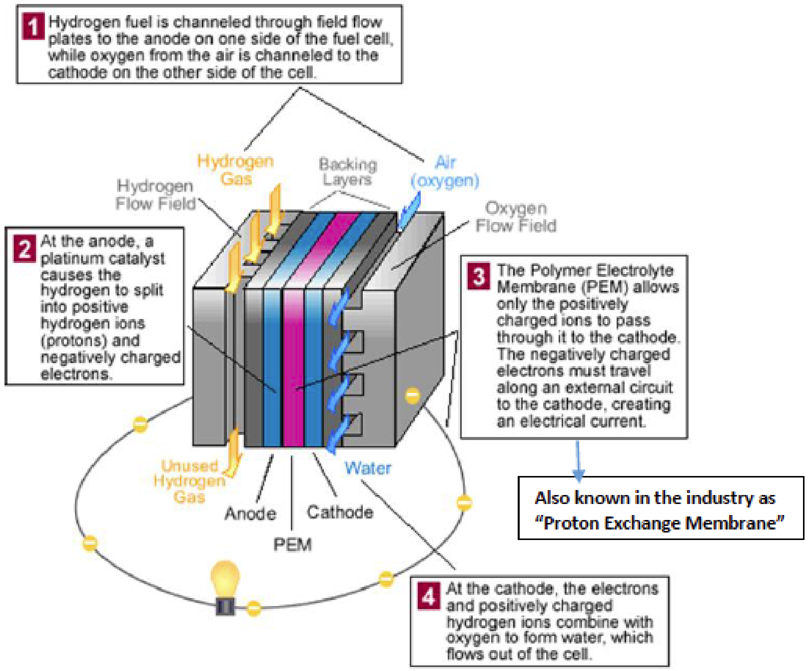
### Reliability and Easy Refueling

Proton Exchange Membrane (PEM) fuel cell technology has been commercially proven in thousands of deployments and millions of reliable operational hours. Fuel cells have performed consistently even when subjected to wide temperature swings and harsh weather conditions experienced in telecommunications back-up power applications. PEM fuel cells have provided critical back-up power to hospital life-support systems when back-up batteries failed, and have provided uninterrupted power through hurricanes, earthquakes, and desert sand storms.

Fuel cells provide Direct Current (DC) electricity without the emissions of diesel or gas generators and without the constant recharging batteries require. Hydrogen is the most commonly used industrial gas in the United States, and as the nation's hydrogen infrastructure has grows, refueling options have become more plentiful and convenient. A continuously fueled PEM fuel cell will produce DC power with unlimited runtime and zero emissions at the point of use.

## PEM Fuel Cell Technology – How it Works

A PEM fuel cell produces DC power as the result of an electro-chemical reaction between hydrogen gas and oxygen from the air in the presence of a catalyst.




## Altergy Breakthroughs

Altergy is the first company to successfully design, mass-produce, and commercially deploy rugged, reliable, low- cost fuel cells.

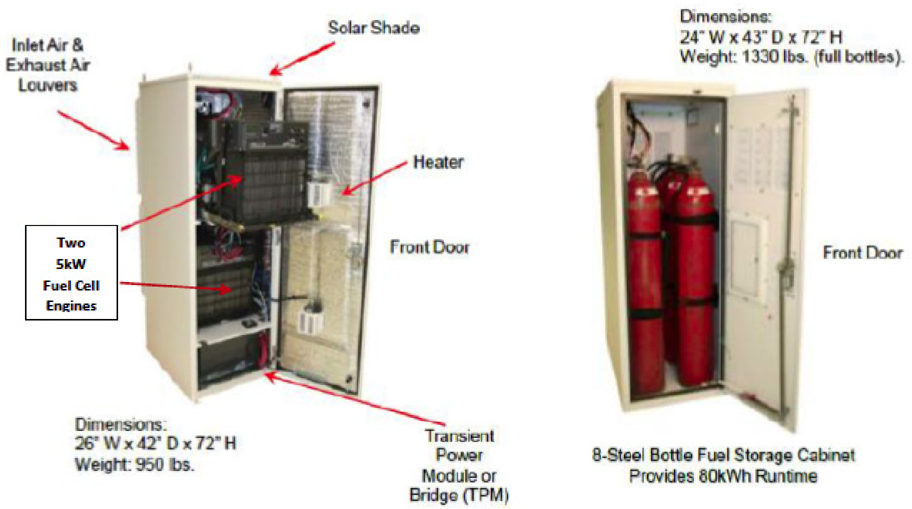
Altergy replaced the graphite plates and other fragile components used in traditional fuel cells with low-cost, highly durable components that withstand the severe conditions experienced in industrial use. Altergy fuel cells provided uninterrupted power when Hurricane Sandy knocked-out grid power for extended periods of time in the Northeast in 2012.

Altergy also has overcome traditional cost and volume-production barriers, and made fuel cells more compact. Altergy fuel cells are made with readily available off-the-shelf materials on the world's first and only automated fuel cell fabrication and assembly line. These breakthroughs translate to greater deployment flexibility and lower costs.

## Reduced Footprint

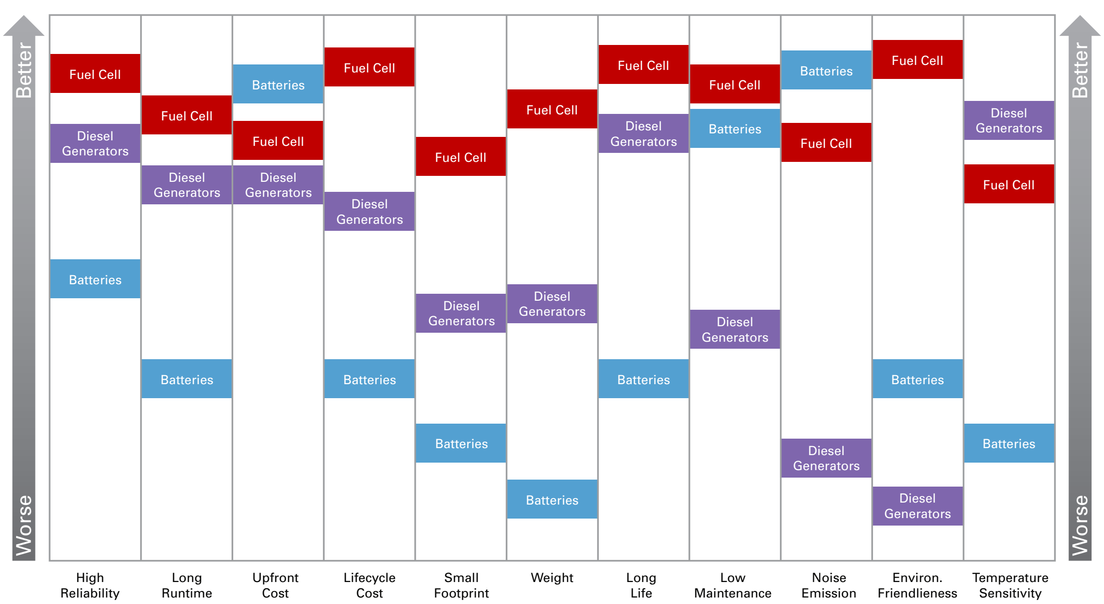
Altergy's products have the smallest footprint of any PEM fuel cell on the market, and often can be deployed in smaller spaces where other fuel cell systems, batteries, and generators cannot. One standard cabinet, for example, can provide 10kW of back-up power capacity, and another small cabinet can provide fuel storage for up to 80kWh runtime.

Altergy's lightweight, small-footprint fuel cells simplify rooftop deployment and are ideal for urban applications – rooftop permitting is easy because there are no weight limitations or fire risks to address.




## Critical Characteristics Comparison – Batteries, Diesel Generators, and PEM Fuel Cells

PEM Fuel Cells - Best Value in Backup Power



## Total Cost of Ownership

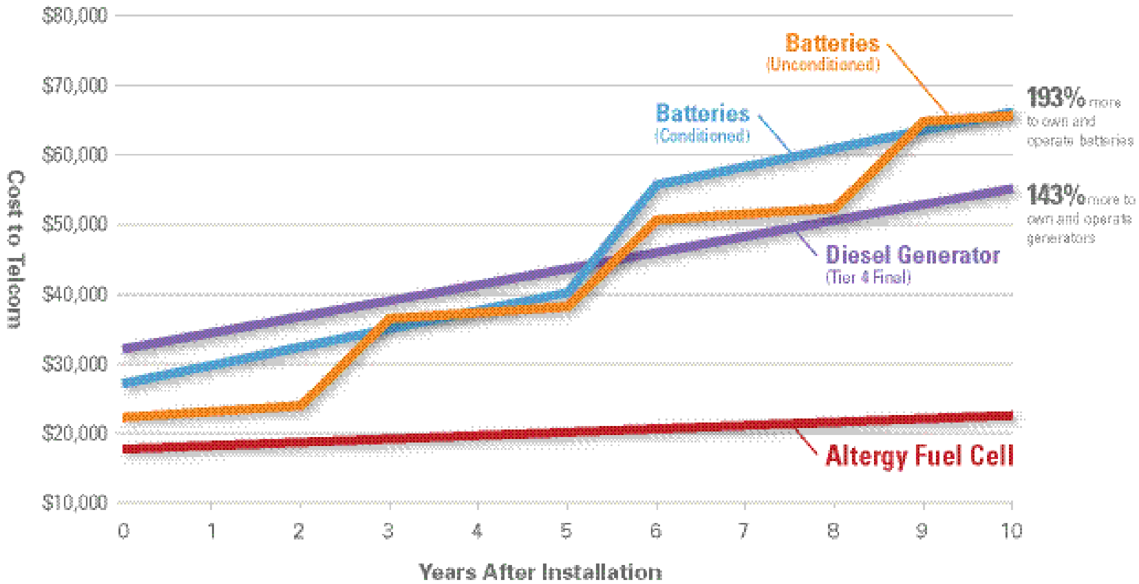
Altergy's innovative product design reduces critical component costs by more than 80%, and the use of readily available materials and automated manufacturing processes reduces costs further. Altergy fuel cell solutions are cost-competitive with traditional power sources and far more sustainable.

With no moving parts in the cell stack, maintenance is simply cleaning or replacing air filters once per year or every 1000 hours of operation, whichever comes first (~$100/year). The only other ongoing operating expense is the cost of H2 fuel and delivery, which is significantly less than the cost of diesel fuel and delivery.

Altergy fuel cell products have been zero-emission certified by the California Air Resources Board, and rebates and incentives that encourage the use of sustainable technology may be available in some states. An Investment Tax Credit (ITC) may be available at the federal level providing $3000/kW or 30% of the total project costs, whichever is less. This represents a dollar for dollar reduction in tax liability for system owners.

PEM fuel cells, depending on the design, cell stack components, balance of plant (BOP) material used, and manufacturing techniques employed, have a design life of greater than 15 years. Fuel cells also avoid the cost of diesel fuel theft.

### Altergy Fuel Cells – The Best Value in Backup Power

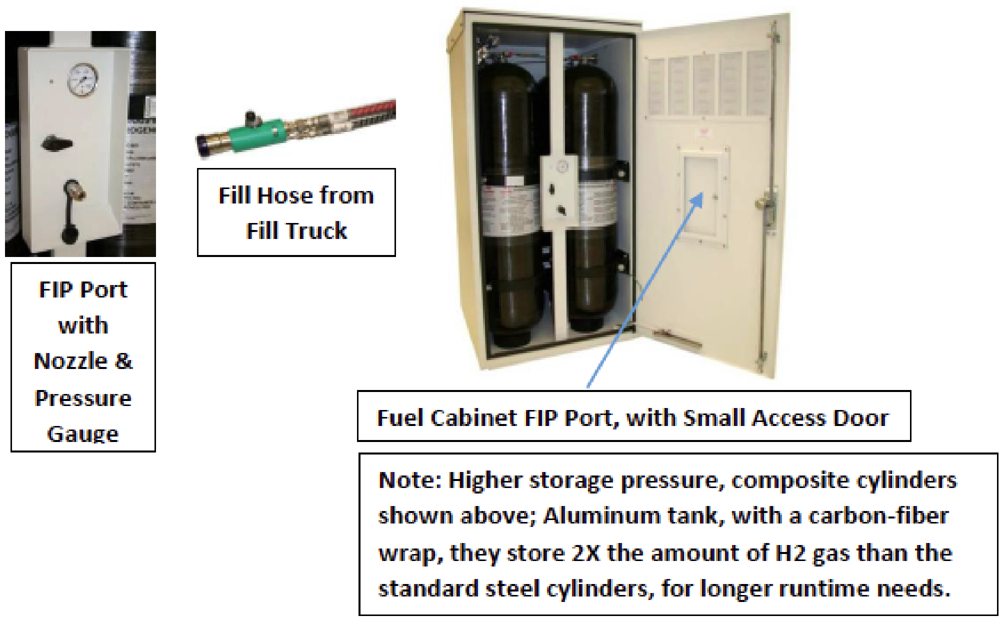



*TCO based on a 5kW load, 8 hours of runtime. Battery quantities and size determined at end of the life (2.5 years). Generators are Tier 4 Final. Analysis includes acquisition costs, plus permitting and installation costs, as well as ongoing maintenance (and battery replacement) costs for all three technology alternatives. Data sources for the analysis include research reports (Batelle, Battery Council International, etc.), Manufacturer data sheets, prices, white papers and Altergy Systems information.*

## Flexible Fueling Options

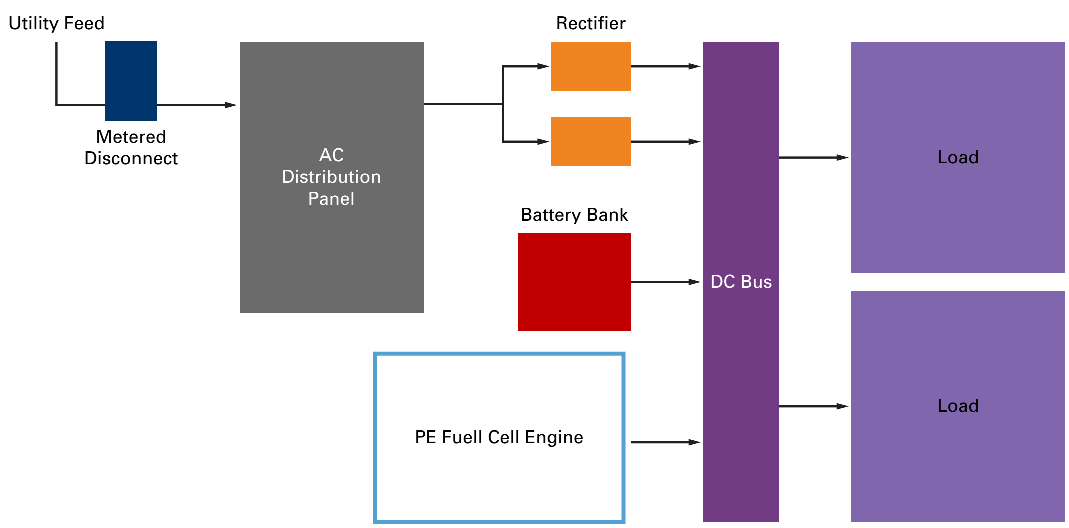
Hydrogen gas (H2) is readily available in most U.S. cities and municipalities and has an excellent safety record. For typical OSP applications, the H2 is stored in steel tanks or cylinders, and enclosed in a telecom grade OSP cabinet.

Re-fueling H2 "Fill" trucks today use "Fill-In-Place" technology (FIP) to re-fuel PEM fuel cell sites, replacing traditional "bottle swapping" practices. With FIP, a fill truck fitted with a Department of Transportation (DOT) certified hose connects to a fill port located on the fuel cabinet front door. The hose simply connects to the fill port nozzle, and in minutes all cylinders are re-filled in place, with no access inside the cabinet required.




## Typical Telecom or CATV Application

For a typical Telecom or CATV OSP application the PEM fuel cell's DC output connects directly to the system DC bus just like the VRLA battery bank.



### Summary

Rising costs and performance limitations have caused telecommunications companies to explore alternatives to traditional backup power sources for cell tower networks and other critical loads. Clean energy sources that provide more efficient power, simplify regulatory compliance, and reduce the space required for installation are preferred.

Modern PEM fuel cells use safe, abundantly available hydrogen gas to provide uninterrupted DC power with no emissions, no noise concerns, and no expensive maintenance schedules. PEM fuel cells provide reliable on-demand power over greater runtimes than batteries and generators, and their lightweight, compact construction increases deployment flexibility.

Altergy Systems has developed breakthrough technology and manufacturing processes to produce durable, high-performance fuel cells that deliver reliable backup power at a fraction of the cost of batteries and diesel generators. Altergy's advanced PEM fuel cells produce zero-emissions, have been proven in severe weather conditions, and are well suited to limited-space applications.

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