

Debunking Hydrogen Fuel Cell Myths

Today's Fuel Cells for proven, reliable power.

Science experiment; futuristic technology; improbable solution; these are just some of the expressions used to describe a hydrogen fuel cell. For decades, hydrogen fuel cells have occupied a back seat to other incumbent power generation systems in North America. And, finally, we are beginning to see a shift as our nation explores ways to maximize the use of renewable energy devices, specifically hydrogen fuel cells. As a result, an effort is being made to lessen the United States' reliance on imported energy, diversify the fuel mix that powers its economy and create jobs and economic development.

But why have hydrogen fuel cells taken so long to emerge as a commercially viable solution out from the shadows of research and development? A leading culprit impacting the lag of this alternative fuel power device involves a group of myths — myths which have been disproved by one specific industry — material handling. By demolishing the myths, material handling customers have embraced the commercial viability of hydrogen and fuel cells in their daily operations, receiving business-altering benefits as a result.

Throughout North America, operations and logistics executives at leading retail, grocery, institutional food distribution and manufacturing companies are making the decision to incorporate green technologies into their business plans. At an increasing rate, these organizations are choosing environmentally friendly power solutions because they not only show their customers that they are committed to sustainable business practices, but also save these organizations money. The returns on investment are undeniable.

At the vanguard of Plug Power's fuel cells are proton exchange membrane (or "PEM") fuel cells, which convert hydrogen fuel into energy through an electrochemical reaction. PEM fuel cells are commercially available today for several mainstream applications, and one of the fastest growing is the material handling sector — a bustling industry that never sleeps.

Traditionally, the electric material handling industry has run almost exclusively on lead-acid batteries. However, vehicles employing this source of power require up to three time-consuming battery changes during each 24-hour period, greatly diminishing a company's productivity.

Using fuel cells instead of lead-acid batteries as the power source for electric lift truck fleets offers substantial benefits to the end user. Yet, despite significant payoffs in terms of financial gains and performance, many retail, grocery, institutional food distribution and manufacturing companies have yet to embrace the hydrogen fuel cell solution for their material handling needs.

About Plug Power Inc.

The architects of modern fuel cell technology, Plug Power has revolutionized the industry with cost-effective power solutions, GenDrive®, that increase productivity, lower operating costs and reduce carbon footprints for the customers who use the products. Long-standing relationships with material handling industry leaders forged the path for the company's key accounts, including Walmart, Wegmans, Whole Foods, and FedEx Freight. More than 2,200 GenDrive units shipped to material handling customers, accumulating over 6.5 million hours of runtime. And, with 95 percent of US hydrogen fuelings being performed on Plug Power products, we manufacture tomorrow's incumbent power solutions today.

For more information about Plug Power, or to locate a Plug Power sales representative, visit www.plugpower.com, or call 518.782.4004.



DEBUNKING THE MYTHS, ONE AT A TIME:

- **MYTH 1: Fuel Cells Aren't A Viable Option**

FACT: Fuel cells in material handling applications are indeed viable, evidenced by over 2,200 GenDrive fuel cells deployed by over 25 customers in North America operating around the clock.

- **MYTH 2: Financially, Fuel Cells Just Don't Make Sense**

FACT: GenDrive fuel cells provide an immediate savings in new facilities. In fact, the net present value of operating and maintaining fuel cell-powered forklifts can be up to 59 percent lower than their battery-powered counterparts.^[1]

- **MYTH 3: Hydrogen Isn't Safe And Is Difficult To Install**

FACT: "With proper handling and controls, hydrogen can be as safe as, or safer than, other fuels we use today."^[2]

- **MYTH 4: Hydrogen Is Not Readily Available**

FACT: "Hydrogen is widely used as a commodity chemical with approximately 10–11 million metric tons produced in the U.S. each year. That amount, if used directly as a fuel, would be enough to power about 30 million cars or five to eight million homes."^[3]

This document is designed to shed light on some of the leading concerns, and dispel them.

Fuel Cells Aren't A Viable Option

FACT: Fuel cells in material handling applications are indeed viable, evidenced by over 2,200 GenDrive fuel cells deployed by over 25 customers in North America.



As of early 2012, Plug Power has over 25 customers in North America. Of these customers, 10 are repeat customers that have either expanded their current fleet or deployed a second site elsewhere. No customer has ever returned their GenDrive units after purchase.

After more than 10 years of development and refinement, hydrogen fuel cells have gained significant commercial traction in the material handling industry. This is evidenced by a growing customer base, a more defined supply chain and product cost-reduction efforts made by fuel cell manufacturers like Plug Power.

Major distributors, retailers and manufacturing companies have made the strategic, long-term decision to utilize hydrogen fuel cells to power electric lift truck fleets based on the desire to improve business operations through increased productivity, lowered operational costs, improved space utilization and reduced greenhouse gas emissions.

The fuel cell industry has seen significant growth over the past 12 months; several Fortune 500 companies have purchased fleets of fuel cell-powered forklifts for use in various material handling operations, bringing the nation's total number of forklifts ordered, installed or deployed to over 2,200 units.

The following examples provide a snapshot of the leading businesses that are already experiencing attractive benefits and savings fuel cells provide over competing technologies:

- **Walmart** has acquired more than 350 GenDrive fuel cells to work in temperatures as low as -29°C at its sustainable refrigerated distribution centers, including two sites in Canada and one in the U.S. By utilizing GenDrive from the design phase, the Fortune 500 leader avoided costs associated with installing, maintaining and operating traditional lead-acid battery systems. Furthermore, with potential greenhouse gas emissions reductions of up to 72 percent, compared to batteries charged from the grid, fuel cells are helping the company become a more sustainable operation.
- Seventeen hundred miles south, **BMW** purchased GenDrive fuel cells to power its 223 forklifts, tuggers and stackers inside

its automotive manufacturing facility in Greer, SC. The units have enabled the German auto manufacturing giant to use its facility space more efficiently and with fuel cell refueling times of just 60–180 seconds (versus 20 minutes for a depleted lead-acid battery), BMW is also realizing significant gains in workforce productivity.

- Meanwhile, in San Leandro, CA, **Coca-Cola Refreshments USA** bought 56 GenDrive fuel cells to power a fleet of lift trucks at its sprawling bottling and distribution center. By moving to fuel cells, the beverage leader, which had previously relied on lead-acid batteries, gained 2,000-square-feet of battery storage space for other business operations, while also reducing its electrical consumption by an estimated 1.6 million kWh each year. The iconic brand, whose goal is to become an industry leader in energy conservation and climate protection, also reduced its carbon emissions by 15 percent.
- Showing the value of multiple site conversions, **Procter and Gamble** purchased GenDrive fuel cell units to use in distribution centers in Oxnard, CA, Alexandria, LA and Greensboro, SC. Productivity and fleet up-time are very important to this Fortune 500 Company, which is the largest consumer manufacturing company in the world, and using hydrogen fuel cells addresses the depletion issues experienced as lead-acid batteries lose charge.

In addition, as the industry-leading fuel cell manufacturer, Plug Power has greatly increased the reliability and availability of products, providing a full-suite of solutions to accommodate fleets. Strategic supply chain initiatives have also been secured within the industry to ensure robust and reliable partners.

Fuel cells, it turns out, are indeed viable. And this is evident in the decision by many of the world's leading companies to make them an integral component in maintaining their global competitiveness.

Financially, Fuel Cells Just Don't Make Sense

FACT: GenDrive fuel cells provide an immediate savings in new facilities. In fact, the net present value of operating and maintaining fuel cell-powered forklifts can be up to 59 percent lower than their battery-powered counterparts.^[1]

Fuel cells have proven that they can save end users hundreds of thousands of dollars, especially in environments where forklift trucks run multiple shifts and battery change-outs are needed. Fuel cells provide an immediate savings in new facilities. And in large, multi-shift operations, hydrogen-powered fuel cells cost less to operate than lead-acid batteries.

As the cost of hydrogen and its infrastructure continues to decline, a growing number of corporations, including Sysco, Walmart and BMW, are discovering they can obtain an immediate payback on their investments by constructing new warehouse facilities with an established hydrogen infrastructure. These “greenfield” sites eliminate the need to earmark funds for costly battery-charging and changing infrastructure, including expensive copper wire, battery watering, maintenance equipment and space-consuming racks.

As a result, valuable real estate is not occupied by large battery rooms and, instead, this space is used to generate revenue within the business, specifically moving more products with an efficient forklift fleet. Compact fueling dispensers are installed in the facility to facilitate a quick fill of the fuel cell with hydrogen, before returning to the floor to move product. When constructing a new facility, the use of fuel cells can reduce a customer's capital investment by approximately one million dollars before they even break ground.

In “brownfield” sites, customers switch from a battery room to hydrogen infrastructure to support a growing fleet, expanding business or sustainability initiatives. Paybacks on the order of 12–18 months have been experienced by companies like UNFI and Whole Foods. These customers seek to increase overall productivity, lower operational costs, recapture much needed business space, and seek to eliminate or reduce electrical charges.

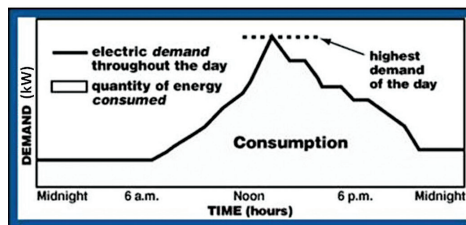
Until now, financial implications implied by traditional power units were accepted by material handling managers as a cost of doing business. Significant business improvements as a result of hydrogen fuel cells solutions, like GenDrive, have allowed decision makers to re-evaluate their power solution options. A paradigm shift has brought electricity surcharges, cost of labor, truck downtime and the value of productivity into the limelight.

Using fuel cell systems not only lowers a customer's electricity bill through the elimination of battery charging, but also reduces electricity costs for the remaining operations at the customer's distribution center. The positive impact to the electrical grid is two-fold: (1) fuel cells reduce overall energy consumptions and (2) fuel cells reduce peak power demand.

Electricity bills are built on two main cost drivers:

1. Electricity Usage ($\$ = \text{Total Usage} \times \$ / \text{kWh}$)
 - a. Eliminating electricity required for battery charging
 - b. Reduced rate of remaining electricity (the more used, the higher the incremental cost)
2. Peak Demand ($\$ = \text{Peak Usage} \times \$ / \text{kWmax}$)
 - a. Cost associated with meeting peak loads. This is typically based on the maximum amount of power used during any 15-minute to 30-minute time window throughout the month.

The chart below shows how these two factors commonly appear in a facility's load profile.



Load Profile with Electricity Usage and Peak Demand

Lead-acid battery charging represents 25 to 30 percent of a distribution center's electricity usage and approximately 50 percent of the peak demand charges, due to the spike in electricity usage when batteries are charged. Implementation of fuel cells significantly reduces this peak demand and the facility's electricity load profile.

Predictability of fleet movement can now be measured in dollars. Because fuel cells guarantee constant power to the vehicle, truck operators can now be properly allocated and activities can be streamlined. Labor dedicated to changing batteries is now better utilized somewhere else in the facility.

A battery change, which can take approximately 15 minutes, is now replaced by a refueling that is completed in as little as 60 seconds. This recaptured time, in a 100 truck fleet, operating three shifts a day for 360 days, represents over 18,000 hours each year that can now be put back into the business as a more productive workforce.

To assist companies with the initial cost of purchasing fuel cell systems, businesses can take advantage of federal and state grants and credit programs. The tax credit, which is available through 2016, covers 30 percent of fuel cell costs up to \$3,000 per kilowatt.

Additionally, an accelerated depreciation incentive is offered to customers by the IRS, providing an expedited write-down of the fuel cell value. This incentive is executed at a rate of 50 percent in the first year and the remaining 50 percent over the lifetime of the equipment. This makes fuel cells an attractive option over lead-acid batteries for customers, as the batteries do not offer the same type of depreciation incentive.

Hydrogen Isn't Safe And Is Difficult To Install

FACT: "WITH PROPER HANDLING AND CONTROLS, HYDROGEN CAN BE AS SAFE AS, OR SAFER THAN, OTHER FUELS WE USE TODAY."^[2]

Several years ago, operations and logistics executives at leading U.S. companies were skeptical about the overall safety of hydrogen, an odorless, colorless gas that is the most abundant element on earth, for use in their distribution centers.

However, times have changed and there is now a much clearer understanding of the fuel, its superior benefits and how it is used. It's now recognized that hydrogen, which offers more energy per weight than any other available power source, is safe when handled properly - safer than gasoline, propane and natural gas. Furthermore, we are now more familiar with hydrogen's wide range of commercial applications in everything from oil refining and the semiconductor industry to ammonia production and steel manufacturing.

Wegmans Food Markets, Inc. saw its growth as an opportunity to convert its entire campus from lead-acid batteries to hydrogen fuel cells. Placing its first fuel cell order in 2009, with a follow-on order in 2111, the supermarket chain purchased over 210 fuel cell units in total to power its fleet of lift trucks for a retail service center in Pottsville, PA. Operators refuel the units themselves by activating hydrogen fueling stations via an access card. All staff are trained on the safe use of hydrogen. Wegmans found the fuel cells to be lighter, making the trucks more maneuverable. And, there is no longer a worry about lead-acid overspill or food contamination.

Building A Hydrogen Infrastructure



Today's commercially viable fuel cell-powered forklift trucks run on pressurized gaseous hydrogen. To deliver the hydrogen gas safely to the fuel cell-powered forklift, a fueling infrastructure is built to maximize ease and utilization of space. In fact, today's typical fueling infrastructure was designed so that anyone would be able to safely refuel a vehicle without any training whatsoever.

The hydrogen infrastructure needed to complete a fuel cell deployment is installed by third party industrial gas providers, such as Air Liquide, Air Products and Chemicals, Linde North America and Praxair, Inc. The fuel is delivered to the customer, most commonly in liquid form, and is stored in a large OSHA-certified tank capable of holding up to 15,000 gallons of hydrogen. The holding tank is installed outside the facility in order to maximize the amount of usable space inside the building. In this area the liquid hydrogen is also vaporized into a gas and then pumped into the refueling dispenser(s) within the facility, as needed.

Inside the facility, the forklift truck driver accesses a compact fuel dispenser that closely resembles gasoline pumps. Using an industry standard fueling nozzle and hose, the operator fills the unit themselves within minutes. On demand, hydrogen safely flows into the lift truck. Deionized water and heat are the only by-products.

In contrast, recharging lead-acid batteries produce and emit heat and hydrogen as by-products, requiring costly ventilation for the facility. Lead-acid batteries leak sulfuric acid requiring spill-kits and regular clean-ups to prevent corrosion within the lift truck.

North America's expansive network of hydrogen manufacturers understands the growing fuel cell business and is working hard to meet their needs by stimulating its supply chain and building its inventory in anticipation of future fuel cell deployments. Hydrogen is safe and North American hydrogen providers are reducing installation time with every deployment.

Hydrogen Safety Facts

(Source: California Fuel Cell Partnership)

- For more than 50 years, hydrogen has been produced and used for commercial and industrial purposes with an exemplary safety record.
- By directly converting the chemical energy in hydrogen to electricity, fuel cells can efficiently provide power, while at the same time producing no harmful air pollutants.
- Liquid hydrogen trucks have carried an average 70 million gallons of liquid hydrogen per year on the nation's roadways without major incident.
- Hydrogen is non-toxic and dissipates extremely quickly, so if released it does not present a health hazard to humans and its effect on the environment is benign.



Hydrogen Is Not Readily Available

FACT: “Hydrogen is widely used as a commodity chemical with approximately 10–11 million metric tons produced in the U.S. each year. That amount, if used directly as a fuel, would be enough to power about 30 million cars or five to eight million homes.”^[3]

If there is so much hydrogen, why aren't we driving fuel cell-powered cars? A challenge experienced in automotive adoption is the “chicken or egg” conundrum. It may be believed that if a hydrogen refueling infrastructure is built and made available to car purchasers, they will come. While that debate continues, the fuel cell-powered forklift business has implemented a solution based on a closed-circuit approach. Providing a facility with its own internal infrastructure promotes hydrogen at a cost and availability for customers to adopt as their sole means of conducting business.

Operations and logistics executives typically have two specific hesitations when implementing a hydrogen infrastructure at their facility. They not only wonder whether the fuel source will be readily available to them, but also are anxious about having a failsafe backup plan should their industrial gas company's hydrogen delivery fail to arrive.

The reality is that back in the 1960s, in an effort to support the nation's growing space program, the U.S. government constructed plants along the eastern and western seaboard that continue to produce liquid hydrogen around the clock. These diverse geographic locations make hydrogen a readily available fuel source to businesses in almost every major U.S. city.

In recent years, companies employing fuel cell technologies have turned to these manufacturers in such high numbers that fuel cells used in material handling are now the fastest growing segment of the hydrogen energy market, according to Air Liquide, a leader in gases for industry, health and the environment sectors.

Each week, approximately 12,500 to 18,750 refuelings are performed on over 2,000 fuel cell units deployed in material handling centers across North America. This equates to 15,000 to 22,500 kilograms of hydrogen dispensed by operators into their forklift fleets.

In terms of a backup plan, all North American industrial gas companies have gas swap arrangements in place, so that if one plant should go offline a nearby competitor will seamlessly handle deliveries on their behalf at no additional cost to the end customer.

Most commercial hydrogen customers have a telemetry system installed on their tanks so that suppliers can quickly determine

when the site needs to be refueled. Once the tank level drops to a certain level, a liquid hydrogen tanker truck is dispatched to the facility for refueling so that a continuous supply of fuel is always maintained.

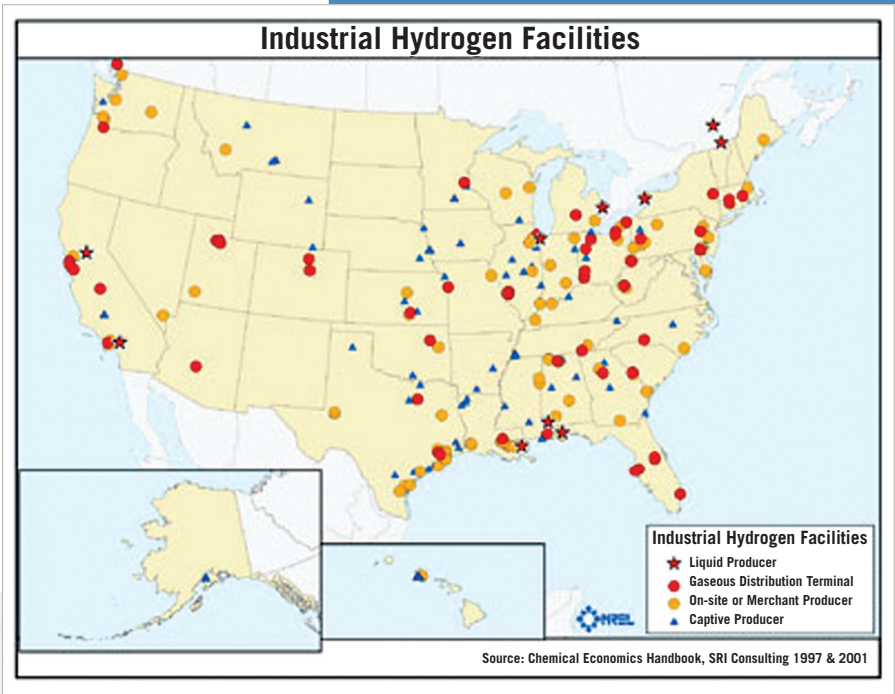
Following all hydrogen installations, fuel cell companies are dedicated to supporting their clients' needs. Staff is available around-the-clock to help ease the transition regarding how these products work. And, should any problems arise, they quickly step in to coordinate a satisfactory solution.

And, in turn, hydrogen fuel cells provide a fail-safe plan for customers in the time of a power outage. When the grid goes down, lead-acid battery-powered fleets come to a halt; but, not fuel cell-powered fleets. Using just one simple compressor connected to the customer's backup power energy source, the facility can continue operating normally.

U.S. HYDROGEN STATISTICS

- About ten million metric tons of hydrogen are produced in the United States annually, enough to power 20-30 million cars or five to eight million homes. (Source: U.S. Energy Information Administration)
- 53 percent of the hydrogen produced in North America is already dedicated to transportation. (Source: American Council on Renewable Energy)
- A large hydrogen production site exists today near almost every major U.S. and European city. They are within reach of most major U.S. metropolitan areas, which accounts for roughly 70 percent of the U.S. population. (Source: California Fuel Cell Partnership)

National Renewable Energy Laboratory (2006)



Conclusion

Since being introduced to the material handling sector, hydrogen fuel cells have proven themselves to be a more reliable product at a lower overall cost than their lead-acid battery counterparts. And, with over 2,200 GenDrive-powered lift trucks currently in operation at more than 25 North American sites, the hydrogen infrastructure continues to become more established.

Today, many fuel cell users in the retail, grocery, institutional food distribution and manufacturing sectors give little thought to the fact that they are using hydrogen. For them, filling up their forklift fleet with hydrogen gas has become as easy as plugging into an electrical outlet on the wall.

Businesses pondering hydrogen need only to tour up-and-running sites to see the operational benefits, short refueling times, simplified maintenance, and potential for increased productivity fuel cells offer. It's evident that these seasoned service personnel are laying the groundwork for a hydrogen economy on a large scale.

The unfounded fear of committing to a hydrogen economy remains the only stumbling block preventing prospective fuel cell users from embracing the benefits of this highly promising energy carrier. But the undeniable benefits and value can no longer be ignored, and the industry's top myths are not valid and have been proven to be irrelevant. In fact:

- Fuel cells **ARE** a feasible solution
- Financially, fuel cells **DO** make sense
- Hydrogen **IS** safe and easy to install
- Hydrogen **IS** readily available

It's clear, hydrogen fuel cells are tomorrow's incumbent power sources, available for use today.

GENDRIVE PROVIDES POWERFUL BENEFITS:

- **Increased Productivity** — Lead-acid batteries provide up to six hours of run time before the battery must be recharged, whereas a completely filled hydrogen fuel cell forklift significantly extends run time. By switching forklift fleet power to fuel cells, companies can reduce wasted time changing batteries. Instead, workers can use the time more productively on the floor picking goods, moving pallets, and loading trucks — the key activities of any thriving distribution hub.
- **Reduced Operational Costs** — Fuel cells operate like a fully charged lead-acid battery 100 percent of the time, resulting in less wear and tear on the forklift's electronic system. Each fuel cell lasts eight to 10 years, that's double the life of a lead-acid battery.
- **Undiminished Power** — Battery-powered lift trucks lose approximately 14 percent of their speed over the last half of the battery charge, and their autonomy fades over its lifetime. On the other hand, fueled fuel cells run at full speed throughout the entire shift and lifetime, enabling businesses to move more goods through their production facility. And, in cold storage facilities with sub-zero temperatures, an environment in which batteries experience significant power degradation, fuel cells meet or exceed performance requirements.
- **Quick and Easy Fueling** — Fuel cells refuel quickly — just one or two minutes by the forklift operator, compared to approximately 15 minutes for each battery swap. The fueling infrastructure is extremely compact, especially when compared to battery charging rooms, leaving more valuable warehouse space for operational activities. There is no need to invest in battery swapping and charging equipment, extra batteries and battery storage, as well as personnel dedicated to this task.
- **Decreased Carbon Footprint** — Fuel cells produce zero harmful emissions and eliminate the costs associated with handling and storing toxic materials. Sites can reduce greenhouse gas emissions by up to 80 percent. And, by transitioning to fuel cells, Plug Power's customers see their net and peak energy consumption reduced, resulting in significantly lower electricity charges.
- **Sound Investment** — On a lifecycle cost basis, studies show that fuel cell-powered forklifts require up to 50 percent less investment than lead-acid battery-powered trucks in high-throughput applications. In some cases, fuel cell-powered forklifts may require more capital investment than their lead-acid counterparts, but they always offer substantial savings in both operation and maintenance.

References and Notes

1. *Early Markets: Fuel Cells for Material Handling*, U.S. Department of Energy, Energy Efficiency and Renewable Energy, Fuel Cell Technologies Program, http://www1.eere.energy.gov/hydrogenandfuelcells/education/pdfs/early_markets_forklifts.pdf
2. *Safety Codes and Standards*, U.S. Department of Energy, <http://www1.eere.energy.gov/hydrogenandfuelcells/codes/basics.html>
3. *Hydrogen Production and Energy Storage*, Clean Energy States Alliance, <http://www.cleanenergystates.org/projects/hydrogen-and-fuel-cells/hydrogen-and-fuel-cell-resource-library/resource/hydrogen-production-and-energy-storage>

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