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## The Fuel-Cell Decision

Written by: MHM Staff

*Thinking of converting your lift truck fleet to fuel cells? Consider these three factors first.*

By Scott Greenway

Hydrogen lift truck refueling is fast, compact and opportunistic. It is doubtful that many researchers or new technology experts in the past would have guessed that these competitive advantages would drive the commercialization of fuel-cell applications.

However, companies in the material handling business are using hydrogen and fuel cells to achieve higher ROI on their lift truck fleets.

While the verdict is still out on the long-term benefits of moving entire lift truck fleets to hydrogen, fuel-cell-powered lift trucks have many attributes that are proving advantageous for material handling.

### **Batteries Vs. Fuel Cells**

Batteries and fuel cells share many characteristics. Both convert chemical energy directly to electricity and can be connected in series and parallel to give desired electrical characteristics.

The main difference is that a battery is what one could consider a 'batch' electrochemical reactor, while a fuel cell is considered an 'open' electrochemical system. In a 'batch' electrochemical reactor, the battery either has to be discarded or recharged when all the chemicals in a battery have reacted. In an 'open' fuel-cell system, the electrochemical reaction will continue as long as fuel is supplied.

Most material handling applications currently use PEM (proton exchange membrane) fuel cells that operate at relatively low temperatures, between 120°F and 180°F. A PEM fuel cell reacts hydrogen and oxygen to create electricity, heat and water. The electrochemical reaction in a fuel cell is approximately 45% efficient at converting chemical energy to electricity, while the combustion engines on natural-gas lift trucks are only 15% to 20% efficient.

Although fuel-cell systems are often described as battery replacements, fuel cells in lift trucks are usually integrated with smaller-capacity batteries to provide better load management. This allows the fuel cell to run with a more constant load. Transient loads, such as acceleration, require more energy than the amount produced by the fuel cell and will pull energy from the batteries. When the load returns to normal, the fuel cell will use excess energy to recharge the batteries.

Fuel-cell-powered lift trucks provide many economic benefits through increased productivity due to on-demand refueling, decreased floor space for storage and maintenance of battery packs, and no 'power fade' during extended shifts.

Companies considering conversion should also understand the fundamental changes in logistics that come with hydrogen lift truck conversion. For example, supplying hydrogen for the lift truck fleet, outfitting facilities to ensure workplace safety and workforce education for hydrogen technologies should all be critical factors in the decision-making process.

### **Local Hydrogen Demand**

For lift truck applications, it is easiest to think of hydrogen in terms of kilogram (kg) quantities; it has the same

energy content as a gallon of gasoline (1 GGE) or 33 kilowatts (kWh) of electricity.

In terms of standard volume, a kilogram of hydrogen is 422 SCF (11.1 Nm<sup>3</sup>), but the actual volume will vary depending on the temperature and pressure at which it is stored. To store a large amount of hydrogen in small volume, the typical full hydrogen storage pressure for the majority of fuel-cell lift trucks is 5,000 psig (350 bar). Newer, experimental tanks can hold up to 10,000 psig (700 bar).

The tank on Plug Power's commercial class 3 lift truck holds 0.8 kilograms of hydrogen and powers the truck for six to 12 hours, depending on the load. In Plug Power's pre-commercial, class 1 trucks, used in the Bridgestone/ Firestone deployment in Aiken, S.C., the tanks hold 2.2 kilograms of hydrogen, and the truck can operate for eight to 12 pedal hours from this quantity. (Editor's note: For more information about the Bridgestone/Firestone deployment, see "Fuel-Cell Power Payback" in *MHM's* May 2008 issue.)

Large industrial gas companies, such as Air Products or Linde, have many off-the-shelf hydrogen distribution solutions depending on demand. Also, on-site methods of hydrogen production, such as water electrolysis or steam reforming of natural gas, are competitive with hydrogen delivery in many situations.

With hydrogen delivery or onsite generation, the price point of hydrogen decreases significantly as demand at a facility increases. Therefore, switching to hydrogen makes the most sense at facilities where a significant number of lift trucks can be converted and the trucks operate on three shifts.

### **Workplace Safety**

Hydrogen is a flammable gas with a flammability range between 4% and 75% in air. Hydrogen is odorless and colorless and therefore cannot be detected by human senses.

Safe use of hydrogen in the chemical and aerospace industry has been ongoing for more than 40 years. The primary engineering control for an environment where there is the potential for hydrogen release is to maintain the concentration of hydrogen below 1% (i.e., less than 25% of the lower flammability limit). The concentration of hydrogen is best controlled by working with hydrogen in well ventilated environments, and ventilation systems, coupled with hydrogen detectors, to dissipate rapidly any concentration of hydrogen greater than 1%.

In environments where hydrogen release is possible, it is also important to control potential sources of ignition. The risk of hydrogen ignition from sparks or static discharge is very high, and all wiring near hydrogen installations should conform to National Electrical Code standards.

There are numerous codes dealing with the use of hydrogen and other flammable gases in an industrial environment. These standards should be consulted to ensure that hydrogen installations are properly engineered. In addition, state and local code officials will want to be engaged early in the planning stages of hydrogen projects to ensure compliance with relevant statutes.



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### **Workforce Education**

Hydrogen has been extensively and safely used in various processes in the food, chemical and aerospace industries for more than 50 years. However, hydrogen has many unique properties that need to be understood by employees to ensure a safe working environment.

Also, the erroneous historical attribution of the Hindenburg disaster to ignition of hydrogen gives many employees reservations about working with hydrogen technologies, such as fuel cells. Workforce education programs can educate employees about hydrogen best practices, properties of hydrogen and dispel myths associated with using hydrogen and help to speed acceptance of these technologies in an industrial environment.

A key property of hydrogen is that it is 14 times lighter than air. This density difference is a safety feature of

hydrogen, since it causes any hydrogen released in the work environment to rise and disperse quickly in open spaces.

However, it also requires that workers be alert of possible ignition sources above them in the work environment when there is the possibility of hydrogen release. In addition, hydrogen flames are nearly invisible in daylight and do not radiate large amounts of heat from the flame. Employees need to recognize the signs of a hydrogen fire, understand the proper safety precautions and know how to use personal protective equipment (PPE).

Hydrogen lift trucks have the potential to generate a lot of interest in a facility and significant publicity. Before considering deployment of hydrogen lift trucks at a facility, however, time should be invested to understand the opportunities and challenges of hydrogen and fuel-cell technologies.

There are many potential economic benefits to be gained by moving away from battery-powered lift trucks, such as increased floor space and productivity. Also, these economic benefits increase significantly with the number of units adopted at a facility due to the lower cost of hydrogen.

Facility safety analysis and workforce hydrogen education should be integral parts of any hydrogen lift truck deployment and will help to increase community awareness about hydrogen projects.

*Dr. Scott Greenway is the president of Greenway Energy LLC, a hydrogen and fuelcell consulting company. He is also a certified Plug Power technician and trainer. He works with organizations, such as the Center for Hydrogen Research (CHR) and Aiken Technical College (ATC) in Aiken, S.C., that are assisting local industries in conversion to hydrogen lift trucks. Hydrogen education programs at ATC have been so successful that the education is now incorporated into credit courses, and education will be given at the CHR for local industry on all aspects of hydrogen use.*