



WHITE PAPER

Making sense of hydrogen fuel cells

Why the maturing electric power technology makes financial and operational sense for lift truck fleets

What if your materials handling operation could achieve higher operational productivity, eliminate cumbersome battery charging infrastructure and deliver consistently high performance? It may be possible with lift trucks powered by hydrogen fuel cells.

Numerous organizations are integrating fuel cell technology into their lift truck fleets and looking to benefit from lower operational costs, reduced emissions and improved reliability. Now, major lift truck brands are bringing fuel cell technology in-house, with ultimate plans to offer hydrogen lift truck solutions with factory warranty coverage.

This white paper examines the adoption of hydrogen fuel cell-powered lift trucks, the availability of hydrogen and applications best-suited for this impressive technology.

What is a fuel cell?

A fuel cell is an energy conversion device used to capture and use the power of hydrogen. It produces electricity from hydrogen and oxygen, with water vapor and heat as the only byproducts. Since this process does not produce any harmful emissions or pollutants, hydrogen fuel cells serve as an ideal choice for warehousing, manufacturing, retail and food applications.



The considerations of hydrogen

A steady, cost-effective supply of hydrogen is critical to the success of any hydrogen-powered operation, and is an important consideration in the implementation of hydrogen fuel cell-powered lift trucks. In today's market, hydrogen can either be delivered or generated on-site. Options for delivery range from gaseous hydrogen shipped via tube trailers for lower-volume usage or liquid state hydrogen for higher-volume applications.

Operations contemplating hydrogen can work with suppliers to evaluate if fuel cell technology makes sense for their facility, including conducting demos, pilots and trial programs. This allows the selection of a best-fit hydrogen fuel supply option, each with variable infrastructure, permitting and installation requirements, which can differ greatly based on fleet size, method of hydrogen delivery and anticipated demand.



NATURAL GAS PRICES AT HISTORIC LOWS

Natural gas prices are at historic lows, and its use is becoming more widespread, across a variety of applications and industries. This is great news for hydrogen fuel cell users, as hydrogen is produced from natural gas and its increased availability enables more cost-effective hydrogen generation.

Building the business case – the major benefits

INCREASED UPTIME

Currently, most electric lift trucks use lead acid batteries. Once the battery charge expires, the battery must be removed and taken to a charging room, and a freshly charged battery must be installed. This equates to at least 20 minutes of lost productivity every four to eight hours. But hydrogen fuel cells can be rapidly refueled in as quick as three minutes, allowing operators to get back to work quickly. In multi-shift operations with two or more battery replacements per day, the quick refueling of hydrogen fuel cells saves time and increases operator efficiency, thus increasing productivity. Furthermore, since lift truck operators can refuel hydrogen themselves, operations can keep business moving and make more efficient use of labor resources.



Lead acid =
Lost productivity
with **20 minute**
battery change

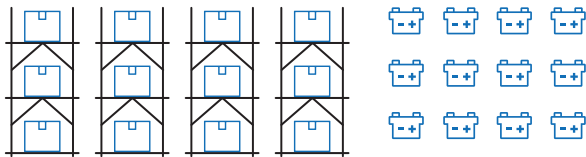


Hydrogen fuel cell =
Minimal downtime
with as quick as
3 minute refuel

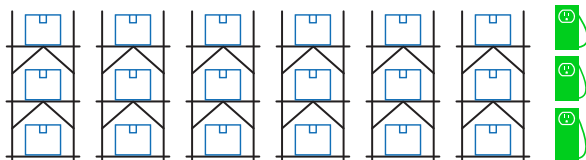
SMALL FOOTPRINT

Adopting hydrogen eliminates the need to designate significant indoor space for battery charging and storage rooms, enabling more efficient use of space, greater throughput capacity and increased productivity. This is especially beneficial for operations close to urban centers, where real-estate prices are higher and expanding or investing in a larger facility is extremely expensive.

Before



After



CONSTANT POWER

Hydrogen fuel cells deliver constant voltage until fuel tanks are depleted. This means that in normal operating conditions, fuel cell-powered lift trucks experience no performance degradation during the shift, running at full speed and reducing wear on truck motor controllers. Compared to lead acid battery-powered lift trucks that suffer performance degradation over the last half of the battery charge, hydrogen fuel cells offer sustained performance and improved component longevity.

LOWER EMISSIONS, LIGHTER IMPACT

With only water vapor and heat as byproducts, hydrogen fuel cells produce zero harmful emissions. Companies that deploy hydrogen solutions can expect a significant reduction in greenhouse gas emissions compared to lead acid battery systems charged from the electrical grid. This is important for companies that prioritize green initiatives and strive to reduce their carbon footprint.

Choosing hydrogen fuel cell-powered systems over traditional batteries affords further financial and environmental advantages. Lead acid batteries typically require replacement every three to four years, accumulating replacement costs and burdening operations with the disposal of depleted units. However, fuel cells only need replacement every 10,000 hours, resulting in a lower lifecycle cost, reduced disruption to operations and minimal environmental impact.

Operations best suited for adoption

A variety of factors make an application well suited for hydrogen fuel cell lift trucks. Some of the best opportunities include:

- Multi-shift operations that want to reduce battery replacement downtime and increase efficiency
- Growing operations that need additional indoor space to increase capacity
- Organizations striving to reduce their carbon footprint
- Confined settings in which air quality is an important consideration to protect employee health

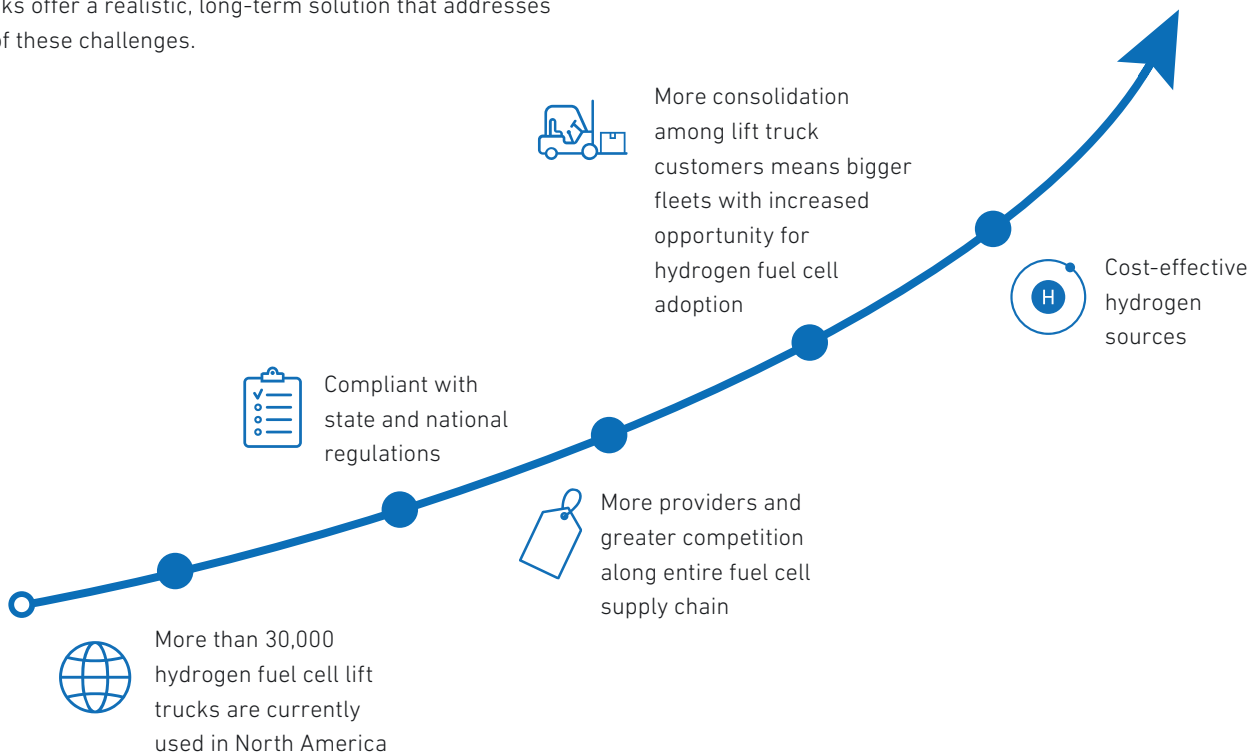


Making operational, environmental and business sense

In general, deploying hydrogen fuel cells can enable a cleaner workplace and offer productivity and financial advantages over other power sources. As more companies prioritize green supply chain management, materials handling operations not only face challenges to reduce total cost of operations and increase efficiency, but to minimize environmental impact. Fuel cell-powered lift trucks offer a realistic, long-term solution that addresses all of these challenges.

Adapt to evolving trends

Lift trucks powered by hydrogen fuel cells are an effective materials handling solution to address evolving industry trends in distribution and fulfillment, with several developments paving the way for greater commercial adoption.



To learn more about using hydrogen fuel cells to power your lift truck fleet, visit [Yale.com](https://www.yale.com).