

## » Economics of Fuel Cell Solutions for Material Handling

Fuel cell powered forklifts provide the productivity, delivering tangible economic benefits today. Using Ballard's comprehensive value proposition model, distribution center operators can explore the potential for significant return on investment available through a forklift fleet conversion to fuel cell battery replacement packs.

### DRIVING PRODUCTIVITY

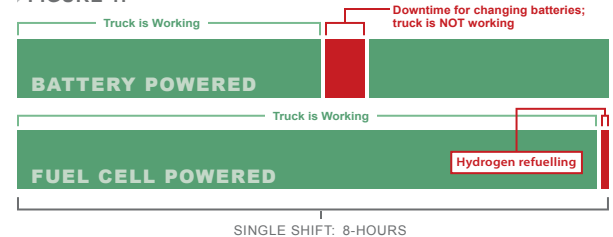
Fuel cell powered forklift fleets deliver a compelling economic business case, largely driven by productivity gains. Increased productivity comes through:

1. Range extension enabling multi-shift operation with quick refuelling, without the need for battery recharging (Figure 1) and,
2. Constant power across the duty cycle, enabling drivers to move more goods in a given period of time, i.e. more lifts, faster lifts and faster traverses. (Figure 2)

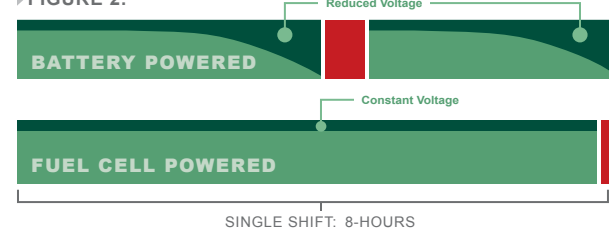
Within a battery-powered shift of 8 hours, there is typically a requirement to change out the batteries at least once. This involves the operator leaving the work area, driving to a centralized battery change-out station and getting a replacement battery. This can take anywhere between 15 and 30 minutes.

By contrast, a fuel cell truck will run up to three times longer than its battery driven counterpart, eliminating this lost productivity. During that time, the fuel cell produces constant voltage and maintains constant power output capacity throughout the shift. And by using flexible hydrogen dispensing located conveniently throughout the warehouse, truck operators can refuel their lift trucks in 3 minutes or less. These increases in productivity translate into tangible economic payback.

▶ FIGURE 1.



▶ FIGURE 2.



### RETURN ON INVESTMENT MODEL (all values in USD)

As a point of reference for end-user return on investment calculations, Ballard has created a comprehensive business model that compares the total cost of ownership of a fleet of electric forklifts, powered either by lead acid batteries or hydrogen fuel cell power packs. Below, a fuel cell battery replacement pack scenario is presented in which the key operating parameters, as well as the capital and operating cost, that make up the analysis to simulate a typical distribution warehouse. (However, each operation is unique and should be evaluated on its own merits.) Key assumptions that drive the net present value analysis in the model include:

- Fleet Size** – The example scenario is representative of a “greenfield facility” for a large grocery distribution centre, containing 180 Class 3, 40 Class 2 and 10 Class 1 lift trucks, operating 2.5 shifts per day, 350 days per year.
- Productivity Improvements** – The labor rate of the forklift driver and battery handler are used to estimate the cost of lost productivity. It is assumed that each battery change will take twenty minutes, occurring 2 to 3 times per day. Each hydrogen-refuelling event is assumed to take three minutes and occurs 1.3 to 1.5 times per day.
- Fuel Cell System Cost** – The price of a hydrogen fuel cell power pack depends on a number of factors, including the manufacturer, unit size and volume of units produced. For this scenario, a commercial price of \$14,000 to \$30,000 per unit is assumed, depending on the class of truck. This is representative of today's commercial pricing.
- Power System Lifetime** – Lead acid batteries are replaced every three years, at a cost of \$2,600 to \$5,500 per battery, depending on the class of truck. The average fuel cell system lifetime is 10 years, with the fuel cell stacks refurbished every 3 years.
- Fuelling Cost** – The cost of both electricity (for recharging batteries) and hydrogen are factored into the calculations. Hydrogen (including delivery and storage) is priced at \$8.00 per kilogram. Typically, fleets with more than 40 forklifts are large enough to make liquid hydrogen-refuelling infrastructure practical.
- Tax Credit** – The U.S. government currently offers incentives for the purchase of fuel cell solutions in the form of tax credits equal to 30% of the purchase price (up to \$3,000 per kW).



Ballard Power Systems, Inc. is recognized as a world leader in the design, development, manufacture and sale of clean energy fuel cell products. Our FCgen family of stationary power products and FCvelocity family of motive power products offer important business benefits not available from traditional power sources.

Learn how to put fuel cells to work, contact us: [marketing@ballard.com](mailto:marketing@ballard.com) or call (+1) 604.454.0900.

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► Key assumptions for the battery option are:

Cost per battery:	\$2,600 Class 3 \$4,900 Class 2 \$5,500 Class 1
Number of batteries:	3 per truck
Cost of battery chargers:	\$2,300 per truck
Electricity price:	\$0.10 per kWh
Annual battery room G&A:	\$1,000 per truck
Average battery life:	3 years
Lost productivity per battery change:	20 minutes
Labor rate of the lift-truck driver:	\$25 per hour

► Key assumptions for fuel cell option are:

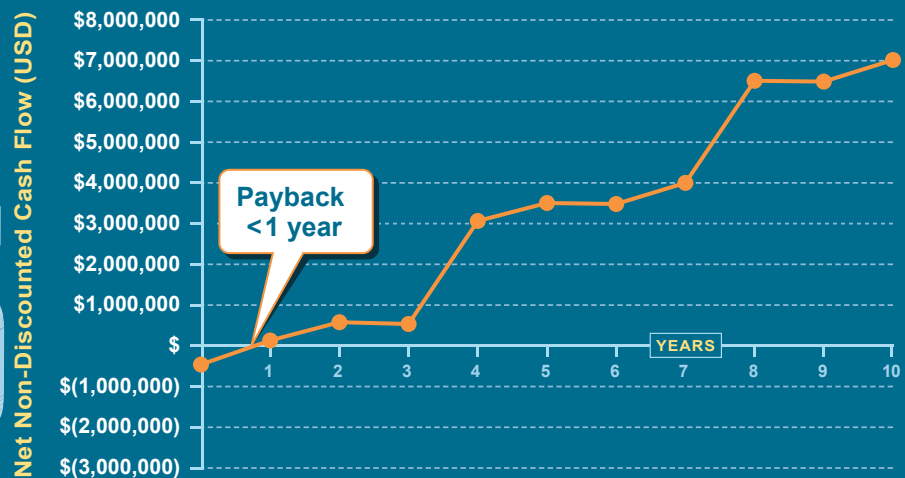
Cost per fuel cell system:	Class 1 \$30,000 Class 2 \$28,000 Class 3 \$14,000
Number of fuel cell systems:	1 per truck
Fuel cell tax credit rebate:	30%, up to \$3,000 per kW
Hydrogen price (including delivery & storage):	\$8 per kg
Annual fuel cell system maintenance:	\$2800 per truck
Average fuel cell system life:	10 years
Annual fuel cell stack life:	10,000 hours
Lost productivity per hydrogen refill:	3 minutes
Labor rate of the lift-truck driver:	\$25 per hour

## ECONOMIC RESULTS

As results of this scenario illustrate, factoring in the fuel cell tax rebate, this warehouse operation will realize a full payback in less than one year, even with an initial higher capital investment for 230 forklift trucks. Over ten years, the operation will realize a 24% savings in total lifetime ownership cost. Using this discount rate of 10%, the investment results in the Net Present Value of ~\$4.0 million. The associated reduction in lost productivity means that over 53,000 hours of work time is recovered per year.



### Net Non-Discounted Cash Flow: Fuel Cells vs. Batteries



In this scenario, the fuel cell option yields an NPV of \$3.6 million

## HYDROGEN SUPPLY

In anticipation of market growth, a number of major industrial gas suppliers are offering complete hydrogen supply and fuelling solutions tailored to the needs of the material handling industry. Temporary hydrogen supply solutions make it easy and cost-effective to evaluate fuel cell technology at your facility. And once fuel cell solutions are permanently integrated into your material handling fleet, gaseous hydrogen supply is available via tube trailer for low-volume requirements as well as liquid hydrogen delivery for users who require higher volumes. In areas where availability or delivery of industrial hydrogen is limited, on-site generation using natural gas reforming or electrolysis provides a viable alternative solution for end-users.

## CONCLUSION

Today, the economic value proposition for direct propulsion via fuel cells, when compared to incumbent technology, is strong. While each material handling site is unique, the scenario evaluated here shows that a high throughput warehouse with multi-shift operations can minimize the total cost of ownership for a forklift fleet through adoption of fuel cell technology.

Contact Ballard to have this model run for your specific parameters and explore the business results of your operation.