Final Progress Report

Project Title: American Recovery & Reinvestment Act: Fuel Cell Hybrid Power Packs and Hydrogen Refueling for Lift Trucks

Project Period: August 1, 2009 to July 31, 2011
Date of Report: February 8, 2012

Recipient: Nuvera Fuel Cells, Inc.
Award Number: DE-EE0000489

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Executive Summary

H.E.B. Grocery Company, Inc. (H-E-B) is a privately-held supermarket chain with 310 stores throughout Texas and northern Mexico. The company converted 14 of its lift reach trucks to fuel cell power to verify the value proposition and environmental benefits associated with the technology. H-E-B management has determined that fuel cell forklifts help alleviate several issues in its distribution centers, including truck operator downtime associated with battery changing, truck and battery maintenance costs, and reduction of grid electricity usage. It is also interested in other uses of hydrogen produced on site in the future, such as for APUs used in tractor trailers and refrigerated transport trucks in its fleet.

The H-E-B San Antonio distribution center operates a total of approximately 300 Class II electric reach trucks and 700 Class III electric pallet jacks over 2 shifts, for a total of 20 working hours per day. There are 3 temperature zones in the facility, ranging from dry goods at ambient temperature, to refrigerated goods at 34°F (1°C), to freezer goods at -13°F (-25°C). The 14 Nuvera PowerEdge™ RL25 fuel cell units operated under this project repowered Class II fork lift trucks that were designed for use with 1000 Ah (18-125-17) lead acid batteries, and are capable of operation in both the ambient and refrigerated goods temperature zones of the facility.

Issues associated with the increasing power requirements of the distribution center operation, along with high ambient temperature in the summer and other operating conditions (such as air quality and floor surface condition), highlighted shortcomings in the fuel cell system design in some high-throughput forklift environments. These provided key learnings to Nuvera in the redesign of its fuel cell product offering for industrial trucks.

The project included on-site generation of hydrogen from a steam methane reformer, called PowerTap,™ manufactured by Nuvera. The hydrogen is generated, compressed and stored in equipment located outside the facility, and provided to the forklifts by 2 hydrogen dispensers located in high forklift traffic areas.

Nuvera developed a service plan for the H-E-B facility that includes service documentation, a training program, and training manuals. Training was provided to Parkway Systems and to Airgas, the local service providers for the fuel cell systems and the hydrogen refueling equipment, respectively.

Data collected from this initial installation demonstrated a 10% productivity improvement, which enabled H-E-B to make economic decisions on expanding the fleet of PowerEdge and PowerTap units in the fleet, which it plans to undertake upon successful demonstration of the new PowerEdge reach truck product. The PowerEdge fuel cell units logged over 25,300 operating hours over the course of the project period. The PowerTap hydrogen generator produced more than 11,100 kg of hydrogen over the same period, and hydrogen availability at the pump was 99.9%. Data on fuel cell and hydrogen equipment operation was also provided to the National Renewable Energy Laboratory, which published Composite Data Products pertaining to this and other ARRA-funded fuel cell forklift projects.

Project Objective:

The project was undertaken to validate DOE market transformation activities by demonstrating (1) fuel cell-powered forklifts operating in highly transient motive applications, and (2) a distributed natural gas-based hydrogen refueling system as a precursor to future automotive fueling stations**.** Under the project, one PowerTap™ hydrogen generation system and 14 PowerEdge™ RL25 fuel cell power pack units were deployed for use in the dry goods and perishable sections of the H.E. Butt Grocery Company (H-E-B) distribution center in San Antonio, Texas.

Work Plan:

Task 1: Build

Fourteen PowerEdge fuel cell systems were fabricated and a rigorous factory acceptance test (FAT) for each system was completed. The original RL25 hybrid design incorporated a 5 kW PEM fuel cell stack system, absorbed glass mat (AGM) sealed batteries, and balance-of-plant, including thermal management, power conditioning, fuel system, counterweight, and a separately mounted user interface. The 30-second peak power rating of the system is 25 kW.

A hydrogen generation, compression, storage, and dispensing system called PowerTap was manufactured and tested prior to deployment at H-E-B. The PowerTap system is rated to produce 56 kilograms of hydrogen per day. It consists of 2 main subsystems: the PTG-50 hydrogen generation module and the PTH compression, storage, and dispensing system. The PTG-50 hydrogen generation module consists of a steam methane reformer, pressure swing adsorber (PSA), fuel and water supply, and gas conditioning sections. The PTG-50 system converts water and natural gas into hydrogen syngas (reformate), which consists primarily of hydrogen and carbon dioxide and residual CO, CH_4, and H_20. The hydrogen reformate is then compressed to approximately 150 psig and fed into the PSA where it is purified to the required fuel cell grade.

The PTH hydrogen compression and storage equipment consists of a hydraulic intensifier to compress the hydrogen from the generation module and feed it into a 3-bank hydrogen cascade storage system where it is stored at 6,000 psig. As the dispenser calls for hydrogen for truck refueling, a priority and sequencing panel transfers hydrogen from the cascade storage system into the vehicle's hydrogen tanks in up to 3 pressure equalization steps.

This task was completed in Q409.

Task 2: Create Site Specific Service Plan

A survey of H-E-B's site was conducted to identify potential locations for the on-site hydrogen generation and refueling infrastructure. Nuvera and H-E-B personnel collaborated to identify hydrogen dispensing points that minimized travel time to the dispensing locations. As part of this process, site-specific hazards were identified to ensure compliance safety and code requirements.

Training to undertake fuel cell service was provided by Nuvera to Parkway Systems personnel. The role of the local service personnel is to provide a first tier of support, enabling a fast response to diagnosing and repairing system faults, as well as undertaking routine maintenance tasks. Tier 1 maintenance support consists primarily of changing of air filters and water cartridges. Nuvera's Customer Care group provided an additional second tier of field support. Tier 2 support includes repair and overhaul activities involving high pressure and/or high voltage portions of the system.

Two Parkway Systems personnel were trained for one week at Nuvera headquarters in Billerica, Massachusetts in September 2009. Parkway Systems is the service provider for the forklifts in use at H-E-B. The training consisted of the following topics:

- Hydrogen properties and safe work practices
- Overview of fuel cell technology
- PowerEdge system operation
- PowerEdge controls, fault codes, and troubleshooting
- Basic repair procedures
- Business processes and logistics (filing claims, returning parts, etc.)

The Parkway Systems personnel were certified as Nuvera Tier 1 fuel cell service providers. Supplemental training was provided afterwards at H-E-B for Tier 2 certification (advanced diagnostics and proven technical proficiency in providing service at Tier 1 level).

Training to conduct service requirements for the PowerTap hydrogen system was provided to Airgas.

Three Airgas personnel (two from Airgas Southwest, and one from Airgas Bozrah, the latter responsible for 24 hour hydrogen system monitoring) were trained and qualified for Tier 1 service of the PowerTap PTG hydrogen generator and the PTHS hydrogen station (compression, storage, dispensing). Training was conducted on-site at H-E-B in November 2009 for one week. The training consisted of the following topics:

- Hydrogen properties and safe work practices
- Service provider roles and responsibilities
- Working with stainless steel compression fittings and tubing
- Overview of natural gas steam reforming
- Overview of the PowerTap hydrogen generation system
- Introduction to hydraulics and pneumatics pertaining to the compression system
- Hands-on repair procedures for PowerTap hydrogen generation, compression, storage and dispensing systems
- Business processes and logistics (filing claims, returning parts, etc.)

User Manuals for PowerEdge and PowerTap were completed and provided to all trainees.

This task was completed in Q409.

<u>Task 3: Deploy Fleet</u>

The permitting and installation process was undertaken to enable a safe, code compliant and cost-effective deployment of the fuel cell fleet and the hydrogen refueling infrastructure. The scope of the process consisted of site planning, permitting, construction, data collection, and the actual deployment of the fuel cell fleet and the hydrogen generation and refueling infrastructure as detailed below.

Hazards & Operability Analysis (HAZOP): The goal of this analysis was to ensure the safe design, installation, and operation of the equipment by rigorously identifying all potential hazards, and quantifying the resulting risks. The design team then developed safeguards to the design, installation, or the operating procedures in order to minimize the likelihood of the hazard from occurring, or to minimize the severity of its consequences.

Site Layout: National and local codes applicable to the deployment were used to ensure proper offset distances between the hydrogen generation and refueling equipment, structures, and potential hazards. The location of all safety devices and features on the site drawing were indicated.

Permitting & Approvals: The site plan was submitted to a local Fire Protection Engineer for approval. The approved site plan was reviewed with local Authorities Having Jurisdiction (AHJ's) with regard to applicable permits and approvals. Applicable permits to allow commencement of site construction activities were obtained.

Site Construction: Final site drawings for use by mechanical, electrical, and civil contractors were prepared. Contractors were retained who built the pad and installed required equipment.

Wireless Data Collection Infrastructure: A wireless infrastructure that collects operational and fault data from the fuel cell fleet and hydrogen generation and refueling equipment was installed.

Installation, Commissioning, and Training: The fuel cell fleet and hydrogen generation and refueling equipment were deployed and a Site Acceptance Test (SAT) for each was completed. Training was provided to the local fire company and to forklift operators regarding safety, operation, refueling procedures and appropriate responses to system faults.

Final Approval: Operation of the forklift fleet and hydrogen infrastructure began once Nuvera and H-E-B obtained all required permits and approvals from local Authorities Having Jurisdiction.

A total of 60 H-E-B forklift operators received hydrogen and fuel cell training. The full fleet was operational beginning in January 2010.

The task was completed as of July 31, 2011 (end of project).

A discussion of the experience operating the fuel cell power systems and the hydrogen generation and refueling equipment is below.

PowerEdge Fuel Cell Systems

After the first 3 months of operation, H-E-B conducted an analysis to determine whether any productivity benefits were realized in association with the fuel cell forklift conversion. H-E-B concluded that the fleet was 10% more productive than it was running on lead acid batteries. The measurement was done by comparing the amount of work accomplished by the same drivers operating battery-powered trucks and fuel cell trucks over the course of 16 shifts. Lift truck operators are responsible for meeting a standard number of work cycles in the shift. In the test that was conducted, battery-powered trucks performed approximately 12 percentage points better than the standard, and fuel cell-powered trucks performed approximately 22 percentage points better than the standard. The fuel cell productivity improvement over batteries therefore equates to 10 percentage points.

We attribute the productivity improvement to a combination of the elimination of the battery changing task and to the improved performance of the trucks. H-E-B estimates that an average battery change-out now takes

11 minutes to perform, including travel time to the battery changing area. In contrast, a fuel cell takes approximately 3 minutes to refuel, including travel time to a conveniently located dispenser. It is important to note that the battery change time was greater at the beginning of the project, in the range of 13-15 minutes. The reduction of this change time is attributed to the reduced demand on the battery room from the conversion of the 14 reach trucks. The result is a time savings not only for the re-powered trucks, but for the rest of the equipment in the warehouse as well.

The second source of productivity gain for fuel cell forklifts is associated with improved truck performance. Battery discharge over the course of a work cycle is accompanied by degradation in output voltage, which in turn is associated with slower truck performance (motive and lifting). The extent of this effect depends on the truck type (AC or DC), age, and other factors, but the effect is significant. Of the 10% productivity gain measured at H-E-B, 7% is the result of the differential between battery swapping vs. fuel cell refueling, while the remaining 3% is associated with improved AC truck performance.

We learned from H-E-B that one of the major benefits associated with the use of PowerEdge motive fuel cell power systems is reduced truck maintenance. This is due to fewer instances of lift and drive motor repairs and replacements, which are exacerbated by overheating when forklift trucks are running on batteries with diminishing voltage over the course of a shift, causing higher current draw.

During the project period, Nuvera provided data to the National Renewable Energy Laboratory using jointly-agreed data templates. Information collected during the course of daily operations included the following:

- Power pack fault code indication
- Service notifications
- Operating status
- Fuel cell run time
- Fuel cell power
- Total kWh energy produced
- Total kWh energy consumed

The PowerEdge fuel cell units logged a total of 25,392 operating hours over the course of the project period.

The full fleet of 14 fuel cell-powered trucks was operational until July 2010, when hot weather combined with several other factors caused reliability of the systems to decline and to negatively impact operations. Since these issues were disruptive to H-E-B's operations, Nuvera scaled back the number of units in service. The root causes of the problems were identified and the required corrective actions were determined. The solutions were implemented on 4 PowerEdge fuel cell units in early October, 2010. The solutions were validated, and Nuvera implemented them on the remaining 10 PowerEdge units and introduced them back into service in December 2010.

Reliability of the fleet increased 7-fold from July through December, 2010, with a Mean Time Between Failure (MTBF) increasing from 21 hours to 155 hours. The biggest improvement in reliability was associated with the replacement of the original AGM batteries with a new battery formulation. However, the new technology ultimately proved no more reliable than the original AGM batteries, causing a decline in fuel cell system reliability from January to April, 2011. Water balance issues (associated with high ambient temperatures) also resurfaced in April 2011. These issues were remedied with preemptive water replacement.

At the project close, MTBF had again risen to the 150 hour level. Four main issues were responsible for 79% of the number of mission disabling faults (MDFs) that did occur, as discussed below.

1. Water Management: Low Water. While preemptive water replenishment of the RL25 units during the summer months was instituted, this was not always sufficient, particularly during heavy duty cycles. The need to add water to the systems adds a maintenance burden to the operation.

   The fundamental issue associated with water balance is a load requirement at elevated ambient temperatures that is frequently near the limits or in excess of the PowerEdge power rating. The next generation PowerEdge system not only has twice the stack power (>10 kW), which will eliminate many of the reliability issues encountered throughout this project, but will also include a mechanism for determining the amount of water in the system, enabling better automated water management protocols.

2. Battery Failures. As ambient temperatures increase in the summer months, batteries are more prone to off-gassing during heavy operation, resulting in decreased capacity. This is compounded by decreased power contribution from the fuel cells that also suffer from reduced performance in high-ambient conditions.

   Batteries with an improved formulation, in combination with the higher-power fuel cell stacks being incorporated into our next-generation PowerEdge product, will mitigate these issues in next-generation product.

3. CVM (Cell Voltage Monitor) Contact Issues. The CVMs retrofitted onto the PowerEdge units in the spring of 2011 experienced spring-clip material relaxation due to a combination of high temperatures and accumulating operating hours. We are improving the quality of the clips now that the root causes have been identified.

4. Fuel Cell Voltage Degradation. High temperature, along with material contamination and high concentration of nitrogen in the stack due to ambient air quality resulted in reduced cell performance and overall voltage degradation to the point where 3 fuel cell stacks needed to be replaced during the course of the project. The higher power stack in the next product generation, more reserve battery capacity during startup, and improved cathode air filtration will contribute to longer stack life.

Reliability of the RL25 units for the entire project period (covering field operations between January 2010 and July 2011) is shown in Figure 1.

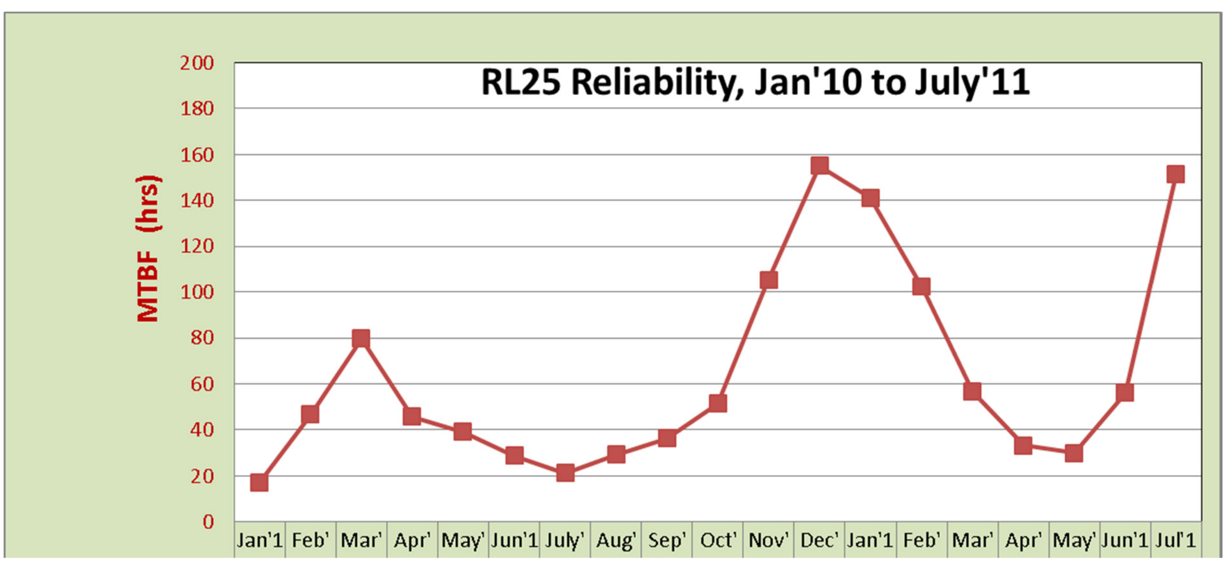

Figure 1. PowerEdge Reliability at H-E-B, January, 2010 – July 2011

The top MDF reasons for the entire project period (January 2010 to July 2011) are shown in the graph below.

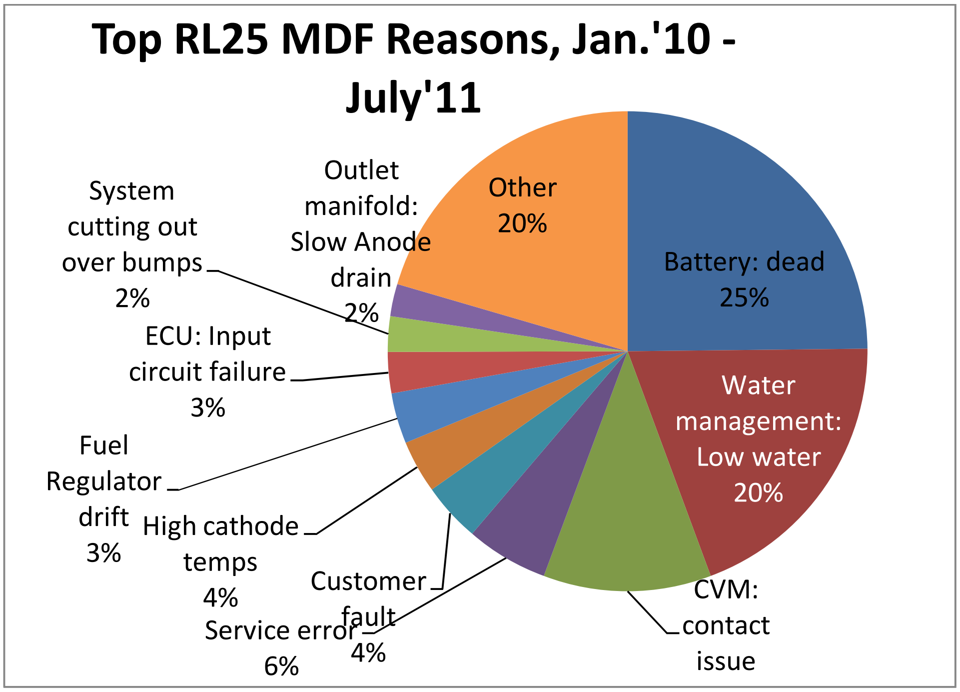

Figure 2. PowerEdge Mission Disabling Faults (MDF) at H-E-B, January, 2010 – July 2011

PowerTap Hydrogen Generation and Refueling System

Hydrogen was supplied to the H-E-B fleet by the Nuvera PowerTap PTG hydrogen generator and PTH hydrogen compression, storage, and dispensing system. The generated hydrogen is supplemented, if needed, by hydrogen delivered by tube trailer. Apart from a single port reliability issue in July 2010, there was 100% hydrogen availability at the pump for the entire project period.

Figure 3 shows the amount of hydrogen provided at the site from the PowerTap system and from the back-up tube trailer. The percent of hydrogen supplied by PowerTap is also indicated. Reduced usage from July through November reflects reduced fuel cell fleet size. One beneficial consequence of the reduced demand resulting from the fleet reduction discussed above was that frequent cycling of the PTG provided accelerated durability data that is proving valuable in system validation. Fuel and steam control and ambient temperature effects are reliability issues being addressed with a reliability campaign that is on-going beyond the project period.

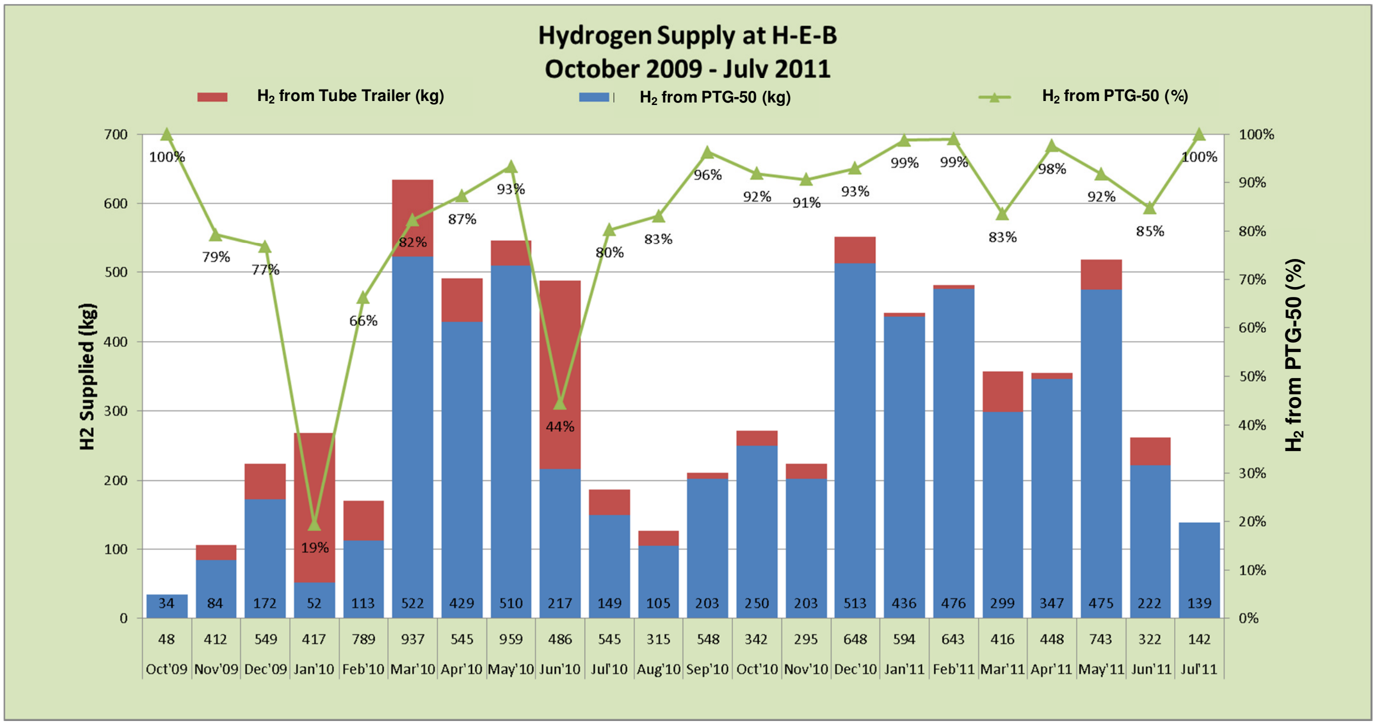

Figure 3. Hydrogen Supply at H-E-B, October 2009 – July 2011.

Reliability of the PowerTap Hydrogen Station (PTHS), which provides the compression, storage, and dispensing functionality of the PT-50 system, has been extremely high throughout the project period. Preventive maintenance has been required on the compression and storage systems; this has been scheduled during planned downtimes in order to avoid any effect on fleet operations. We experienced a significant issue involving the PTHS compressor in August 2010, associated with a hydraulic line fitting (port connector) failure due to an inadequate plumbing support, resulting in a hydraulic fluid spill of approximately 20 gallons on the outside pad where the PowerTap is installed. H-E-B's HAZMAT team cleaned up the spill within hours; the hydraulic line was immediately repaired and there was no effect on operations.

The PowerTap PTG-50 generated over 11,000 kg of hydrogen on-site during the project period, and will continue to supply the operational PowerEdge fleet. The combined PowerTap system provided 99.9% hydrogen availability at the dispenser.

<u>Task 4: Confirm Value Proposition.</u>
At the conclusion of the project, Nuvera conducted a business case analysis using the financial model it developed in order to analyze the value proposition associated with the conversion of all or a part of a forklift fleet from batteries to fuel cells. The model calculates the simple payback, internal rate of return, net present value, and net value of an investment in PowerEdge and PowerTap hydrogen and fuel cell motive power products compared with standard lead acid batteries, chargers, and battery handling equipment. The project term is 10 years, which is the product life of the PowerEdge fuel cell power modules and the PowerTap hydrogen equipment.

The inputs to the model were acquired in consultation with H-E-B's facility and maintenance staff. H-E-B still runs battery-powered forklifts alongside the fuel cell-powered lifts in its grocery distribution center, which allows for a direct comparison. The inputs to the Nuvera financial model include the capital cost of batteries and battery-related equipment, the amount of time spent changing out and maintaining batteries, H-E-B's electricity and natural gas rates, and the labor rate for lift truck operators and maintenance personnel.

On the fuel cell side, the price of PowerEdge units and the PowerTap hydrogen refueling system are required, along with associated operational and maintenance costs. The financial analysis does not include any cost-sharing, other than the 30% investment tax credit available for fuel cell power systems.

Figure 4 shows the Fleet Input Sheet for the analysis. Fourteen trucks were involved in the H-E-B project. In the model, half of these are Crown RR52755-45 reach trucks and half are Crown RM6000 high-lift trucks. The Fleet Input Sheet shows the assumptions associated with each of these trucks, the only difference being the purchase price. There are two 36V, 1000 Ah batteries (18-125-17) per truck in the fleet which cost $5,600 each, and there is one charger per truck that costs $2,166 each. According to H-E-B, maintenance costs are $507 per battery per year.

We learned from H-E-B that one of the major benefits associated with the use of PowerEdge motive fuel cell power systems is reduced truck maintenance. This is due to fewer instances of lift and drive motor repairs and replacements, which are exacerbated by overheating when forklift trucks are running on batteries with diminishing voltage over the course of a shift, causing higher current draw. H-E-B estimates the cost of maintaining battery-powered lift trucks to be $2,000 per truck per year, while the cost of maintaining fuel cell-powered lift trucks is approximately $1,000 per truck per year, 50% of the normal expense.

Another input to the model on this worksheet is the price of the PowerEdge units themselves (not shown). For this purpose we have used the price that we will charge H-E-B and similar customers for the PowerEdge Model RL40, our current offering for this truck class (18-125-17 battery replacement). We also use the most recent projections for lifecycle maintenance costs of fuel cell power packs that we quote to commercial customers.

Nuvera TPS Financial and Economic Evaluation

FLEET INPUT SHEET

	GROCERY TRUCK TYPE	TRUCK TYPE
Truck Data		
Manufacturer	CROWN	CROWN
Model Number	RR5795	RM6000
Selling Price per truck	$35,500	$37,000
Number of trucks being re-powered	7	7
Truck Purchased with Fuel Cell ('0' if NO, '1' if YES)	0	0
Battery Data		
Type	**18-125-17**	**18-125-17**
Purchase price per battery	$5,600	$5,600
Single Point Watering (if used), $ per battery		
# of batteries per truck	2	2
Expected battery life (1 - 5 yrs., whole number)	5	5
Charger Data		
Model Number, if known	PF18E-1050EMEP	PF18E-1050EMEP
Price per unit	$2,166	$2,166
Permitting/insurance (typically 10%)	0%	0%
Total Installation Cost (all chargers)	$1,260	$1,260
Battery Change Data		
# of battery changes per day per truck	3	3
Time per change, not including travel time (minutes)	9	9
Travel time for battery change (roundtrip, minutes)	2	2
Battery Repair/Maintenance Data		
Repair cost per battery per year	$507	$507
Watering cost per battery per year	$0	$0
Truck Repair/Maintenance Data		
Battery truck repair/maintenance per truck per year	$2,000	$2,000
Fuel cell truck repair/maintenance per truck per year	$1,000	$1,000
Charger and Handling Repair/Maintenance Data		
Maintenance per charger per year	$50	$50
Maintenance for battery handling per year	$0	$0

Figure 4. Fleet Input Sheet for the Nuvera Financial Analysis of the H-E-B Deployment (14 trucks).

A Facility Input Sheet (not shown) was also completed for the analysis. H-E-B runs 2 shifts per day, 10 hours per shift, 7 days a week, 52 weeks a year. The full complement of trucks is not operational for the entire shift; the average number of reach truck key hours per year is 2,000. There are 3 fully-burdened hourly wage rates used in the calculation: For battery changing personnel, for lift truck operators, and for in-house maintenance personnel who would be engaged in battery, fuel cell, or truck repairs. This information is used to calculate the cost of the labor involved with truck operation, battery changing or fuel cell refueling, and with maintenance tasks.

The energy data is used to calculate the cost of electricity used for battery charging and for running the PowerTap hydrogen generation, compression, storage, and dispensing equipment, and for the natural gas reformed as part of the on-site hydrogen generation process. The model calculates the number of PowerTap systems required to support the fuel cell fleet operation (in this case, 1), and the monthly facility fee and utility cost H-E-B will pay.

The cost of battery handling equipment which is avoided by the fuel cell conversion in this case is included, which is calculated by prorating the actual cost of the equipment by the portion of the fleet which is being served (23%). The prorated value of the floor space taken by the battery handling equipment is also taken into account in the analysis.

The bottom section of the Fleet Input Sheet provides a comparison of the fuel cycle emissions of a battery and a fuel cell fleet based on the state in which the deployment is located. In Texas, we estimate that 879 kg of CO_2 per day is produced as a result of charging the batteries in the 14-truck H-E-B fleet (using 2005 emissions data from eGrid 2007), compared with 694 kg of CO_2 produced as a result of refueling the fuel cell trucks, using hydrogen generated on-site from natural gas – a 21.0% reduction.

Results and Analysis

The Customer Summary Sheet for the H-E-B model run is shown in Figure 5. There are 4 financial indicators that are calculated: Simple Payback, Net Value, Net Present Value (NPV), and Internal Rate of Return (IRR).

Simple Payback is calculated by dividing the difference between the capital investment required for a battery-powered forklift fleet and a fuel cell-powered fleet by the annual operational cost savings (or added expense) of the fuel cell option. In this case the simple payback is "Not Applicable" because the capital cost associated with the fuel cell option is less than the battery option. Although the fuel cell power packs themselves are more expensive than the batteries, the other factors considered are the following:

1. The 10% productivity gain associated with the fuel cell enables the same amount of work to be done with a fleet that is 10% smaller. Therefore, in accounting for the investment required for fuel cells, an assumption is made that 10% fewer trucks and fuel cell units are required. The benefit could be analyzed in a different way, that the productivity boost enables the same fleet to accomplish 10% more work. We do not have the data from H-E-B to inform us what this is worth to them, but for any capacity-constrained operation it likely has more value than the alternative we assumed.

2. We assume that H-E-B is not purchasing the PowerTap hydrogen equipment outright, but has opted for hydrogen supply from our commercial partner Airgas. In this arrangement, Airgas purchases the hydrogen equipment from Nuvera, locates it at H-E-B's site, and charges H-E-B a monthly fee to operate the equipment for a specified period (10 years). This means that no capital investment is required in the fuel cell case to offset the capital investment on the battery side for changers and changing equipment. The hydrogen capital costs are therefore captured on the operational side.

3. We've accounted for the 30% Federal Investment Tax Credit available for the purchase of the fuel cells. Note that one fuel cell replaces 4 batteries over a 10 year period.

Net Value is calculated as the difference between quarterly cash flow (covering both capital and operational expenses) for the battery and the fuel cell options over a 10 year project term, and IRR is calculated on the same quarterly cash flow basis. Net Present Value is calculated based on a 12% annual discount rate. The Lifecycle Costs are the Net Value for the 10 year project presented on an annualized per truck basis.

Simple Payback (Years)	Not applicable
Net Value	$2,884,095
NPV @12%	$1,580,941
Internal Rate of Return (IRR)	infinite

Truck performance improvement: *3%*
Truck utilization improvement: *7%*

BENEFITS

Lifecycle Costs		
Savings per Truck	**$20,601**	**per year**
ENVIRONMENTAL		
Electricity Savings per Truck	63	kWh/day
TOTAL Electricity Savings	**318,731**	**kWh/year**
CO_2 Savings per Truck	13.2	kg/day
TOTAL CO_2 Savings	**67,051**	**kg/year**

DISCLAIMER: Results are indicative of potential savings and may differ from actual results

Figure 5. Customer Summary Sheet for the Nuvera Financial Analysis of the H-E-B Deployment.

Benefits other than the financial metrics discussed above are also calculated. These are the amount of electricity consumption avoided by the fuel cell option, and the amount of CO_2 emissions avoided for a deployment in Texas.

Conclusions and Future Work

During the course of the deployment at H-E-B, Nuvera discovered multiple ways in which its PowerEdge and PowerTap products could be improved in a high intensity materials handling environment such asH-E-B's. These learnings have been documented in progress reports submitted quarterly to DOE. The PowerEdge Model RL25 unit proved not to be adequate for all of H-E-B's forklift power needs for several reasons, including increased power demands at certain times of the year that were not anticipated at the project outset, and overall increasing duty cycles over the project period. Our newest fuel cell power system model, the PowerEdge RL40, has a 100% higher fuel cell stack rating than the RL25, and a battery chemistry that is better suited to the load cycle requirements than the battery type used in the RL25. The PowerEdge RL40 has a 30-second peak power rating of 40 kW, 60% higher than the peak power rating of the model RL25. H-E-B will be evaluating this new equipment in early 2012. Assuming the technology is validated in field trials,
H-E-B intends to expand the PowerEdge fleet to complete the conversion of all material handling equipment in its San Antonio dry goods and perishable distribution center sections (total of 42 fuel cell units) that take this size battery. The fleet expansion will include the addition of 2 additional PowerTap hydrogen refueling systems.

<u>Project Accomplishments:</u>

- ✓ Installed PowerTap hydrogen refueling station and introduced 14 PowerEdge systems into 24/7 service
- ✓ Generated 11,144 kg of hydrogen on site during period
- ✓ Provided 99.9% hydrogen availability at the pump
- ✓ Logged 25,392 operating hours on 14 PowerEdge fuel cell power units
- ✓ Demonstrated 10% productivity gain associated with fuel cells vs. lead acid batteries.

- ✓ Obtained field data that has been fundamental in next-generation PowerEdge fuel cell system and PowerTap hydrogen refueling equipment designs
- ✓ Provided data on PowerTap and PowerEdge performance to the National Renewable Energy Laboratory

Patents: No patents applied for or resulting from this award.

Presentations and Publications: U.S. DOE Hydrogen and Fuel Cells Program and Vehicle Technology Program Annual Merit Review and Peer Evaluation Meeting (2010 and 2011)