X.4 Landfill Gas-to-Hydrogen

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Project End Date: January 31, 2013

Fiscal Year (FY) 2012 Objectives

- Validate that a financially viable business case exists for a full-scale deployment of commercially available equipment capable of taking landfill gas (LFG) to hydrogen under the specific BMW operating environment,
- Validate that commercially available clean-up and reformation equipment can convert BMW's LFG to hydrogen at purity levels consistent with fuel cell industry standards.
- Conduct a side-by-side operational verification of fuel cell material handling equipment (MHE) performance and durability between a test group operating on LFG-supplied hydrogen and a control group operating on delivered hydrogen supplied by an industrial gas provider.

Technical Targets

There are no specific technical targets associated with this particular project. Rather, the LFG-to-hydrogen project will focus on validating that integrated systems comprised of commercially available equipment can deliver low-cost hydrogen, which includes system performance, operation and maintenance, durability, and reliability under real-world operating conditions. This initiative to convert LFG to hydrogen, in this geography (South Carolina) provides an excellent "fit" for advancing DOE's fuel cell market transformation efforts. Several South Carolina manufacturers already use LFG energy for heat/power; several already have elected to convert their MHE inventory to fuel cells; marrying the two could foster a significant increase in fuel cell MHE market penetration goals within the private sector.

FY 2012 Accomplishments

- Completed feasibility study October 26, 2011.
- Received BMW approval of feasibility study and "Go" decision to proceed to the second phase of the project November 21, 2011.
- Identified clean-up equipment requirements specific to BMW LFG stream.
- Determined equipment pad sizes and locations.
- Initiated and completed fabrication of LFG clean-up skid.
- Initiated and completed preparation of mobile hydrogen unit (MHU, reformer/storage/controls).
- Determined connections necessary to existing LFG, natural gas and power services.
- Commenced site prep for landing LFG clean-up skid and MHU.
- Commenced testing of LFG clean-up skid and MHU at the subcontractor's site (prior to delivery to the BMW site).

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Introduction

BMW Manufacturing Company has incorporated more than 100 pieces of fuel cell-powered MHE into a new assembly line that become operational 2010. While BMW is prepared in the short term to purchase hydrogen services from an established industrial gas supplier, they strongly desire a future option where they could produce their own hydrogen, preferably from a renewable source -- and ideally as a follow-on effort from their nationally acclaimed 2002 landfill methane project. BMW's original LFG project was implemented in December 2002, and the initial infrastructure allowed for collecting and cleaning methane gas from the Palmetto Landfill near Spartanburg, SC, transporting it through a 9.5-mile pipeline to the BMW plant, compressing and then using it to power four gas turbine generators. BMW recently expanded its on-site electrical generation capacity fueled from LFG, and integrated a new specialized treatment system to remove siloxanes from the methane gas. The project proposes to leverage the considerable capital investments to date that make pressurized, pre-treated LFG available on-site, thus providing significantly lower cost than would be the case if the LFG were uncleaned, unfiltered and 9.5 miles away from the intended MHE deployment site.

Assessments by BMW of the available quantity of LFG beyond that currently devoted to electrical power generation confirm that, should the LFG-to-hydrogen production initiative prove viable, there would be sufficient LFG available to fuel the entire BMW MHE fleet in both their existing and new facilities. This would enable BMW to fuel nearly 300 additional pieces of fuel cell-powered MHE in their existing production lines. LFG is probably the most challenging waste stream from which hydrogen could be recovered. Should this initiative prove economically and technically viable, less-daunting hydrocarbon waste streams could be considered (such as agriculture waste, wastewater treatment effluent, etc.). South Carolina has many "candidate" landfill sites in the state where this solution may be viable. Additionally, South Carolina has a high concentration of large manufacturing facilities (BMW, Boeing, Michelin, Bridgestone-Firestone, etc.) and major warehousing and distribution facilities with large inventories of MHE, many of which are within 20 miles of an active landfill.

Approach

The over-arching objective is to validate there is a viable business case for full-scale operation should the proposed LFG-to-hydrogen conversion technology prove viable. The basic components required for a fully functional LFG-to-hydrogen system at the host facility are the existing LFG supply, further gas clean-up equipment, steam-methane reformer (SMR) and hydrogen purification equipment, and the existing hydrogen delivery and dispensing equipment.

Meeting the project objectives will give BWM leadership the confidence to move forward with scale up should they choose. Additionally, this effort will lay the groundwork for proving the business case for future adopters. Validating that the technical solution proposed will work in a "real-world" LFG to hydrogen environment is critical to addressing key DOE technology validation barriers. None of the individual technology pieces are "new science;" however, no one has assembled these proven pieces into this particular solution.

Results

The project commenced officially on June 17, 2011 with the first phase of an anticipated three phase program of work. This initial phase was an economic feasibility study and business case analysis designed to assess whether a capital equipment investment in on-site LFG clean-up and methane conversion to hydrogen would enable production of hydrogen at or below the cost of having hydrogen delivered to the host site by an industrial gas company. This study completed on October 26, 2011 and was delivered to BMW management. BMW approved the study's conclusions on November 21 2011, and authorized the project team to proceed to the second phase of the project.

The business case analysis had a BMW requirement to investigate only commercially available equipment. This would allow for a quicker transition to full-scale production should the LFG testing phase of the project prove viable. The team executed two separate data calls to industry seeking quotes for gas clean-up equipment and SMR equipment. This equipment was evaluated for two hydrogen production capacities – 50 kg per day and 500 kg per day.

The feasibility study concluded that technologies exist and are commercially available to achieve the expected level of clean-up required to meet specifications of hydrogen generation system provides and that these technologies are very mature. Additionally, large-scale industrial hydrogen production by SMR in the oil refining and petrochemical industry is very mature; though applications for smaller scale SMR equipment (<800 kg/day) are less mature. Future SMR equipment may benefit from lower pricing from increased competition within the market, more efficient heat reclaim strategies within the SMR process, improved catalyst efficiency and the ability to withstand hydrocarbon feedstocks with higher concentrations of undesirable constituents. Small-scale SMR hydrogen production equipment is available, but is designed for use with pipeline quality natural gas. Although more expensive, the cost of SMR and clean-up equipment does not increase in cost as quickly as capacity rises. Therefore, the study concluded that it probably is not economically viable for installations at the 50 kg/day level while a viable business case may be made at the 500 kg/day level.

The conclusions presented from the feasibility study are based on a 10-year analysis; however, longer analysis periods most likely would result in a lower cost per kilogram of hydrogen produced because of the benefit of the initial utility infrastructure and installation costs being amortized over a longer evaluation period. The "bottom line" conclusion is that at the 500 kg/day level, with the existing LFG supply and equipment at the host facility, onsite production of hydrogen using LFG as the hydrocarbon feedstock appears to be cost competitive, if not advantageous, over hydrogen sourced from vendors, produced offsite and transported to the facility.

Implication for DOE Fuel Cell Technologies Program: Although the analysis presented within the feasibility study are specific to the LFG equipment and constituents at the host facility, the basic principles of hydrocarbon feedstock clean-up and reformation to hydrogen should apply to agricultural waste streams, wastewater systems, digester gases and other process off-gases.

Since the November 21, 2011 approval of the feasibility study by BMW and their authorization to proceed forward with the second phase of work, the team has being working toward the preparation of equipment and site work necessary to begin LFG-to-hydrogen production. This second phase of the project will construct a pilot-scale LFG-to-hydrogen production facility on the grounds of the BMW host site, commission and place it into operation, and monitor the quality and purity of the hydrogen that is produced.

The team has identified the clean-up requirements for the particular LFG stream at the BMW site necessary to produce sufficiently pure hydrogen quality for use in fuel cell-powered MHEs. Work also has begun on preparing the MHU. This is a trailer-mounted hydrogen production and fueling system that will receive the cleaned up LFG and produce purified hydrogen. This unit contains an onboard fuel processor, purification, compression and storage components, and can produced 10-15 kg/day of hydrogen, sufficient for executing the planned side-by-side testing (third phase). The unit also contains onboard controls, diagnostics and hydrogen, flame and carbon monoxide detection. The team has replaced the catalyst and reconditioned the reformer, reconfigured and replaced gas quality instruments and overhauled the pressure swing absorption unit for reinstallation into the MHU. The MHU currently is being tested prior to shipment to the BMW site for installation. Long-lead equipment for the gas clean-up skid has been ordered, the gas clean-up skid has been fabricated and the skid currently is undergoing final testing. A picture of the clean-up skid and MHU is presented in Figure 1.

Additionally, the team has identified the equipment pad size and location, and has provided a full site layout including placement of the clean-up skid, the MHU and necessary piping and electrical runs. All utilities requirements have been determined and site-prep work is nearly complete.

FIGURE 1. Gas clean-up skid and mobile hydrogen unit

Conclusions and Future Directions

The completed and approved feasibility study provided the "Go" decision to proceed to Phase 2 – LFG-to-hydrogen production and testing. We are in the final weeks of this stage with only equipment delivery, installation, start-up, testing and commissioning remaining. Additional work in this year is indicated in the following.

- Complete testing of LFG clean-up skid prior to delivery to site.
- Finalize in-house testing of mobile hydrogen unit prior to delivery to site.
- Finalize and extend utilities to equipment pad at BMW site.
- Complete equipment installation at BMW site (clean-up skid and MHU).
- Start up, test and commission equipment.

Once the equipment is up and running we will initiate a testing period of approximately six to eight weeks to determine if the purity of the hydrogen (relative to purchased hydrogen) is adequate for use in the fuel cell-powered MHEs. If the hydrogen proves to be of sufficient purity, a "Go/No-Go" decision will be made to proceed to the third phase of the project – the side-by-side trial.

This final phase of the project would take the hydrogen produced from the purified LFG source, and then compress, store, and distribute it to a single site within the host site manufacturing facility that would permit a "side-by-side" performance evaluation using actual fuel cell-powered MHE. Hydrogen already available on-site from an industrial gas provider (contracted outside the scope of this project) would fuel the "control group" of MHE; hydrogen produced from the pilot scale LFG-to-hydrogen project would fuel the "test group" of MHE.

Notionally, the test would employ 3-5 pieces of MHE in each site that have nearly identical operating requirements and profiles. Data would be gathered monthly to determine whether there is a discernible difference in fuel cell performance or reliability that can be attributed to the LFG source of hydrogen.

FY 2012 Publications/Presentations

1. Feasibility Study Report – 25 October 2011.

2. DOE Annual Merit Review – 16 May 2012.

3. NDIA Environment, Energy Security & Sustainability (E2S2) Symposium & Exhibition – 24 May 2012.