IX.2 Landfill Gas-to-Hydrogen

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Subcontractors
- Gas Technology Institute (GTI), Des Plains, IL
- Ameresco, Inc., Framingham, MA

Project Start Date: March 1, 2011
Project End Date: September 30, 2014

Overall Objectives

- Validate that a financially viable business case exists for a full-scale deployment of commercially available equipment capable of converting 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 an operational verification of fuel cell material handling equipment (MHE) performance and durability operating on LFG-supplied hydrogen.

Fiscal Year (FY) 2014 Objectives

- Complete troubleshooting gas clean-up system to achieve methane output purity consistent with steam methane reformer inlet requirements.
- Operate project equipment to achieve J2719 hydrogen purity standards for fuel cell operations, and demonstrate repeatability of achieving these results over time to check for potential impact of seasonal variations in LFG composition.
- Conduct operational trial where actual pieces of MHE are fueled with LFG-sourced hydrogen.

Technical Barriers

This project addresses the following technical barriers from the Technical Validation section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

(F) Centralized Hydrogen Production from Fossil Resources

(G) Hydrogen from Renewable Resources

Technical Targets

There are no specific technical targets associated with this particular project. Rather, the landfill gas-to-hydrogen project will focus on validating that integrated systems comprised of commercially available equipment can deliver cost-competitive hydrogen from an initial LFG source under real-world operating conditions.

FY 2014 Accomplishments

- Corrected gas clean-up system performance and produced hydrogen that satisfied all J2719 overall hydrogen purity and individual trace constituent standards.
- Demonstrated repeatability of the results over a three month period.
- Conducted operational trial using three pieces of in-service MHE at the BMW Manufacturing Company's X5 assembly hall (completed August 2014).

INTRODUCTION

BMW Manufacturing Company incorporated more than 100 pieces of fuel cell-powered MHE into a new assembly line that become operational 2010. While BMW currently is purchasing 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 landfill gas project was implemented in December 2002, and the infrastructure currently allows 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, removing siloxane contaminants on-site, compressing and then using it as fuel for gas turbine electrical generators.

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. Subsequent management decisions by BMW leadership after commencing this project have raised the on-site fuel cell MHE inventory to more than 300 units, representing a 100% site-wide conversion from battery power to fuel cell power.

APPROACH

The over-arching objective of this effort is to validate there is a viable business case for BMW to move forward with a full-scale LFG-to-hydrogen conversion operation should the proposed LFG-to-hydrogen conversion technology prove financially and technically viable. The project would execute in three distinct phases: (1) conduct a feasibility study to examine the potential cost-competitiveness of hydrogen generated from LFG through a capital investment in commercially available equipment compared with hydrogen delivered at current market prices; (2) deploy and test a pilot-scale system (LFG clean-up and hydrogen production) to demonstrate the technical feasibility of converting BMW's unique LFG composition to hydrogen at purity levels consistent with fuel cell industry standards; and (3) provide "real world" validation of this approach via an operational trial designed to demonstrate fuel cell-powered MHE performance and durability are consistent between LFG-sourced hydrogen and hydrogen supplied by an industrial gas provider.

Successfully meeting the project objectives will give BWM leadership the confidence to move forward with scale up should they so choose. Additionally, this effort will lay the groundwork for proving the business case for future adopters. As of this writing, two different private sector organizations have approached the project team, expressing interest in potentially adapting the project's results to LFG-to-hydrogen business opportunities in their respective locations.

RESULTS

The project commenced officially on June 17, 2011, with the first phase of an anticipated three phases. 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. A copy of the feasibility study has been provided to DOE.

The "bottom line" conclusion from the feasibility study was that, at BMW's anticipated "full-scale" hydrogen production requirement, the existing LFG supply, front-end gas clean-up equipment at the BMW facility and on-site production of hydrogen using LFG as the hydrocarbon feedstock appears to be cost competitive, if not advantageous, vs. hydrogen sourced from vendors, produced offsite, and transported to the facility.

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

During FY 2014 the project team successfully overcame the technical challenges with the performance of the gas cleanup system that had stymied progress in FY 2013. Once sufficiently pure methane was recoverable, the subsequent performance of the steam methane reformation equipment produced hydrogen that met or exceeded every J2719 hydrogen purity standard for use in fuel cell equipment, as summarized in Table 1.

In 2013 the Environmental Protection Agency began a comprehensive review of its current incentive policies regarding "qualified" renewable transportation fuels. Initial decisions from these reviews have extended the existing renewable fuels incentives to transportation fuels derived from LFG. It now seems likely that hydrogen derived from these "renewable" transportation fuel feedstocks also should qualify for similar incentives. The economic advantages that flow from such a determination concerning cost competitiveness will become more pronounced at the higher daily production levels, and also might serve to lower the economic competitiveness threshold to smaller daily hydrogen production volumes.

CONCLUSIONS AND FUTURE DIRECTIONS

- A capital equipment investment in LFG cleanup and steam-methane reformation, amortized over a 10-year or greater period of time, is cost-competitive vs. delivered hydrogen for daily hydrogen demand signals of 500 kg or greater.
- The cost competitiveness of this solution will improve notably should final Environmental Protection Agency renewable transportation fuels definitions be expanded

TABLE 1. LFG-to-Hydrogen Project Results

Constituent	Specification	17 Oct 2013	14 Jan 2014
	(umol/mol)		
Total Hydrocarbons	2	1.4	1.2
Oxygen	5	<5	<5
Helium	300	<10	<10
Nitrogen	100	<5	<5
Argon	1	<1	<1
Carbon Dioxide	2	<0.4	<0.4
Carbon Monoxide	0.2	0.011	0.047
Total Sulfur	0.004	0.00072	0.0002
Hydrogen Fuel Index		99.99985%	99.99988%

to qualify transportation fuels derived from LFG (the methane itself and hydrogen derived from this methane).

- Fuel cell–quality hydrogen can be produced reliably from a LFG source with commercially available equipment.
- Future directions:
  - BMW makes business decision on whether to move forward with full-scale deployment of these technologies as the primary source of hydrogen for its MHE fleet.
  - Follow-on adopters conduct their own business case analyses, unique to their circumstances, and move forward consistent with those results.

FY 2014 PUBLICATIONS/PRESENTATIONS

1. EPA Landfill Methane Outreach Program Conference, 22 January 2014

2. DOE Annual Merit Review – 19 June 2014