2012 DOE Hydrogen and Fuel Cells Program Review Presentation

Landfill Gas – to – Hydrogen

Validating the Business Case; Proving the Technology

Russ Keller
SCRA

Shannon Baxter-Clemmons, PhD (PI)
South Carolina Hydrogen & Fuel Cell Alliance

May 16, 2012

Project ID #: MT007

Overview

Timeline

- **Project Start Date: 17 Jun 2011**
- **Project End Date: 31 Jan 2013**
- **Percent Complete: 58%**

Budget

- **Total Project Funding: $1,045K**
  - **DOE Share: $575K**
  - **Contractor Share: $470K**

Project Lead: SCRA

Project Partners:

- **BMW**
- **Gas Technology Institute**
- **Ameresco, Inc.**
- **SC Hydrogen & Fuel Cell Alliance**

Barriers Addressed

- **Technology Validation Barrier 3.6.5.F** (Centralized Hydrogen Production from Fossil Resources)
- **Technology Validation Barrier 3.6.5.G** (Hydrogen from Renewable Resources)

Validate integrated systems and their ability to deliver low-cost hydrogen, which includes system performance, operation and maintenance, durability, and reliability under real-world operating conditions.

Project Context -- Relevance

- **This initiative (converting landfill gas to hydrogen), in this geography (South Carolina) provides an excellent "fit" for DOE's Market Transformation efforts**
  - **Why LFG-to-Hydrogen?**
    - **Probably the most challenging waste stream** from which hydrogen could be recovered; if economically and technically viable, less-daunting hydrocarbon waste streams could be "in play"(agriculture waste, wastewater treatment, etc.)
  - **Why South Carolina?**
    - South Carolina is a **"net importer" of municipal solid waste**; there are many "candidate" landfill sites in the state where this solution may be viable
    - 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 material handling equipment** (MHE), many of which are within 20 miles of an active landfill

- **Several South Carolina manufacturers *already* use landfill gas energy for heat/power; several *already* have elected to convert their MHE inventory to fuel cells; marrying the two could significantly increase fuel cell MHE market penetration goals *in the private sector***

Project Objectives -- Relevance

SCRA

SC HYDROGEN & FUEL CELL ALLIANCE www.SCHydrogen.org

- **Validate there is a viable business case for full scale operation should the LFG-to-hydrogen conversion technology prove viable**
  - Ensure we're not doing science for science's sake
  - Gives BMW leadership confidence to move forward with scale-up, should they so choose
  - Lays the groundwork for proving the business case for future adopters

- **Validate the technical solution will work in a "real world" landfill gas – to – hydrogen environment**
  - Addresses key DOE technology validation barriers
  - None of the individual technology pieces are "new science"
    …. but no one has assembled these proven pieces into this particular "whole"
    …. until now

Timeline and Milestones -- Approach

- **Project Kickoff – 17 June 2011**

- **Phase 1: Feasibility Study**
  - Completed 26 October 2011
  - Approved by BMW 21 November 2011; project team authorized to proceed to Phase 2

- **Phase 2: LFG-to-Hydrogen Conversion**
  - 8 months nominal; target completion date: July 2012
  - Critical milestones:
    - Prepare site and extend landfill gas supply and utilities
    - Land, interconnect, start up and test equipment
    - Monitor hydrogen purity for at least 2 months

- **Phase 3: Side-by-Side Trial (to be funded)**
  - 6 months from satisfactory completion of monitoring portion of Phase 2
  - Target completion date: January 2013
  - Critical milestones:
    - Operate test group of MHE to attain 25,000 run hours
    - Continue monitoring hydrogen purity of LFG-sourced hydrogen

- **Project Completion – 31 January 2013**

Technical Approach

- **Business Case Analysis**
  - BMW mandate: investigate only commercially-available equipment
  - Execute 2 separate data calls to industry seeking quotes for (1) gas cleanup equipment and (2) steam methane reformation (SMR) equipment
    - 2 iterations for hydrogen production capacity: 50 kg per day and 500 kg per day
  - Compare resultant 10-year costs with delivered hydrogen costs

- **Landfill Gas – to – Hydrogen Conversion**
  - Pilot-scale technology demonstration to be executed at the host site using host site's existing LFG source
  - Leverage previous DOE investment in "mobile hydrogen fueling station" having sufficient capacity (15 kg/hydrogen production per day) for proof-of-principle
  - Construct flow-rate compatible front-end gas cleanup skid
  - Adapt the preceding systems to take a stream of on-site LFG (post-siloxane removal), remove non-methane constituents (e.g., CO_2, sulfur, trace contaminants, etc.) , and produce hydrogen via SMR

- **Conduct "side-by-side trial" in actual fuel cell MHE (to be funded)**

Study Conclusions -- Accomplishments

- **Technologies exist and are commercially available to achieve the level of clean-up required** to meet specifications of hydrogen generation system providers. This market is very mature.

- **Large scale industrial hydrogen production by SMR** in the oil refining and petrochemical industry **is very mature**.

- **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, steam-methane reformer (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, it is probably 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.

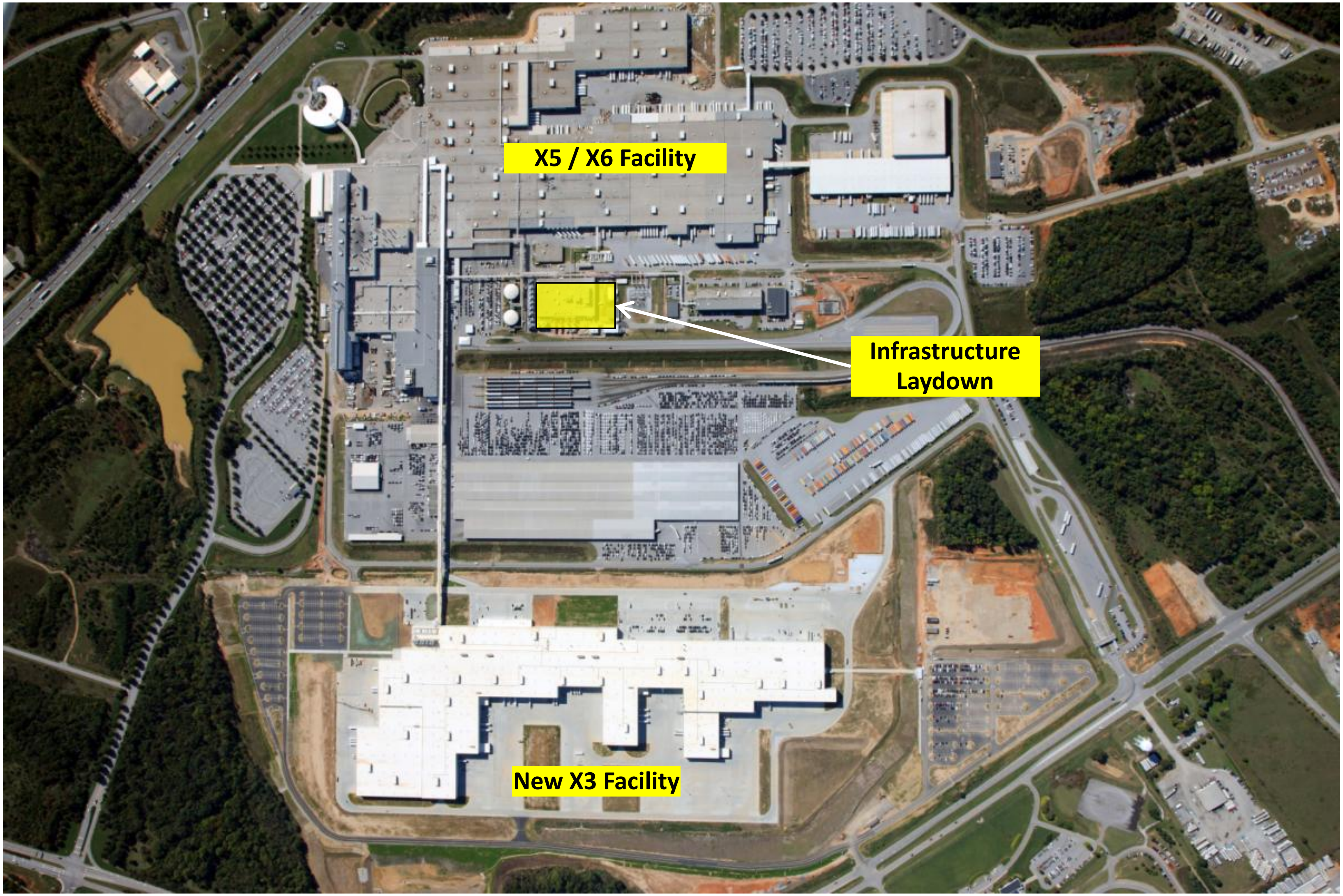
Study Conclusions -- Accomplishments, Cont'd

- The conclusions within the feasibility report 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.

- **"Bottom Line" Conclusion: At the 500 kg/day level,** with the existing landfill gas (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 Technology 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 wastewater systems, digester gases and other process off-gases.**

Coexisting in the "Real World" -- Progress



North

Schedule and Milestones -- Progress

Attachment D- Project Schedule/Milestones Chart																	
Project Element	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17
Task 1.0 -- Feasibility and Business Case Analysis (3 mon)	X	X	X														
1.1 Analyze Maximum Demand Requirement for H2																	
1.2 Determine Optimum Delivered/On-site Production Mix																	
1.3 Survey Commercially Available Equipment Options																	
1.4 Identify Overall Cost per KG of Hydrogen																	
1.5 Go-No Go Decision for Task 2.0			X														
Task 2.0 -- LFG-to-Hydrogen Production and Testing (8 mon)				X	X	X	X	X	X	X	X						
2.1 Identify Clean-up Equipment Requirements				X	X												
2.2 Determine Equipment Pad Sizes and Locations					X												
2.3 Design Clean-up Skid/Equipment and Fabricate					X	X											
2.4 Prepare MHU-Reformer/Storage/Controls to deploy						X	X	X	X								
2.5 Determine Connection to Existing Services (LFG, Nat. Gas, Power)					X	X											
2.6 Prepare site and extend utilities to the equipment pad						X	X	X									
2.7 Deliver MHU & Clean-up system, install, and connect									X								
2.9 Commission and Start-up Equipment									X								
2.10 Monitor and Test Hydrogen Purity (2 months minimum)								-	-	X	X						
2.11 Go-No Go Decision for Task 3.0									-		X						
Task 3.0 -- Side-by-Side Testing (6 mon)										-	-	X	X	X	X	X	X
3.1 Identify 3-5 pieces of MHE in Existing Facility (Test Group)												X					
3.2 Identify 3-5 Pieces of MHE in New Facility (Control Group)												X					
3.3 Procure Fuel Cell Equipment (Buy or Lease)												X					
3.5 Operate Test and Control Groups in Normal Duties												X	X	X	X	X	X
3.6 Collect Data / Compare Performance (6 months)												X	X	X	X	X	X
3.7 Go-No Go Decision for Full Scale Deployment (BMW)															-		X
Task 4.0 -- Public Education and Outreach (18 mon)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Task 5.0 -- Program Management and Reporting	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Project Team Members -- Collaboration

- **South Carolina Hydrogen and Fuel Cell Alliance (private, not-for-profit)**
  - Prime contractor with DOE
  - Providing education and public outreach
- **BMW (industry)**
  - Host site
  - Providing on-site engineering and services support and $250K cash cost share
- **SCRA (private, not-for-profit)**
  - Subcontractor to SCHFCA
  - Providing overall program management; financial management; subcontracts administration; compliance and reporting to sponsors and $70K cash cost share
- **Gas Technology Institute (private, not-for-profit)**
  - Subcontractor to SCRA
  - Principal equipment provider for technical validation portion of the project; providing support for business case analysis and $30K in-kind cost share in Phase 2
- **Ameresco (industry)**
  - Subcontractor to SCRA
  - Providing lead for business case analysis and on site engineering support for technical validation portion of the project

Next Steps / Future Work

- **Execute remaining Phase 2 tasks (target completion July 2012)**
  - Complete equipment installation at BMW site
  - Start up, test and commission
  - Operate equipment for up to 2 months, sampling output hydrogen purity frequently to ensure conformance with fuel cell MHE hydrogen quality input specifications
- **Phase 3 activities (to be funded)**
  - Conduct side-by-side trial comparing fuel cell performance and durability when using LFG-sourced hydrogen compared with hydrogen sourced from industrial gas delivery companies
- **"Beyond the scope" of this project**
  - BMW makes a business case decision regarding scale-up of the LFG-to-hydrogen process to accommodate site-wide hydrogen fuel needs

Project Summary

- **Relevance:** Validate the business case and technical feasibility of using landfill gas as a "distributed generation" option for hydrogen production; transfer "lessons learned" that may be applicable for other candidate waste streams

- **Approach:** Survey commercially-available equipment to draw conclusions regarding economic viability of LFG-to-hydrogen approach for potential end-users; actually demonstrate the technical viability of current systems to produce sufficiently pure hydrogen for use in motive or other applications

- **Technical Accomplishments and Progress:** Economic feasibility study concluded a viable business case can be made; technical proof of principle currently in progress

- **Collaborations:** Current partnership with SCHFCA, BMW, GTI and Ameresco, Inc.

- **Future Work:** Complete technical proof-of-principle; secure $150K follow-on funding ($75K DOE, $75K cost share) and execute side-by-side trial

Russ Keller
(843) 760-4358
russ.keller@scra.org

Shannon Baxter-Clemmons, PhD (PI)
(803) 545-0189
baxterclemmons@schydrogen.org