VI.4 U.S. Clean Energy Hydrogen and Fuel Cell Technologies: A Competiveness Analysis

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Subcontractors:

- Strategic Analysis, Inc, Arlington, VA
- DJW Technology, LLC, Dublin, OH
- E4tech, Lausanne, Switzerland
- Bowen Liu, Newmarket, Ontario, Canada
- Brent Fourman, New Paris, OH

Project Start Date: June 1, 2015
Project End Date: May 31, 2019

Overall Objectives

- Global competitiveness analysis of hydrogen and fuel cell systems and components manufactured including 700 bar compressed hydrogen storage system in the United States, Europe, and Asia to determine the global cost leaders, the best current manufacturing processes, the key factors determining competitiveness, and the potential means of cost reductions.
- Analysis to assess the status of global hydrogen and fuel cell markets for four years, 2014 to 2017. The analysis of units, megawatts by country and by application, will focus on polymer electrolyte membrane fuel cell (PEMFC) systems (automotive and stationary).

Fiscal Year (FY) 2016 Objectives

- Map automotive fuel cell system supply chain evolution.
- Develop detailed questionnaire with current DOE cost targets and process assumptions baseline shared and conduct 30 interviews.
- Update the current DOE cost model as provided by Strategic Analysis.
- Generate drawings and specifications for five key components and send out to suppliers to get actual price quotations at four vehicle volume levels: 1,000, 10,000, 100,000, and 500,000 units/year
- Complete cost breakdown analysis and value stream mapping based upon quotations.
- Gather and deliver fuel cell systems shipment data for 2015.

Technical Barriers

This project addresses the following technical barriers from the Manufacturing R&D section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan.

(A) Lack of High-Volume MEA Processes (includes catalyst, membrane, gas diffusion layer)

(B) Lack of High-Speed Bipolar Plate Manufacturing Processes

(I) Lack of Standardized Balance-of-Plant Components

(K) Lack of Low-Cost Fabrication Techniques for Storage Tanks

Contribution to Achievement of DOE Manufacturing R&D Milestones

This project will contribute to achievement of the following DOE milestones from the Manufacturing R&D section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan.

- Milestone 1.6: Develop fabrication and assembly processes for PEMFC MEA components leading to an automotive fuel cell stack that costs $20/kW. (4Q, 2020)
- Milestone 2.1: Develop manufacturing processes for PEMFC bipolar plates that cost <$3/kW while meeting all other technical targets. (1Q, 2017)
- Milestone 3.3: Develop fabrication and assembly processes for automotive PEMFC stacks that meet the cost of $20/kW. (4Q, 2020)
- Milestone 6.1: Develop fabrication and assembly processes for high-pressure hydrogen storage technologies that cost $12/kW for Type IV, 700 bar tanks. (4Q, 2017)

FY 2016 Accomplishments

- Mapped automotive fuel cell system supply chain evolution.
- Detailed questionnaire developed with current DOE cost target and process assumptions with baseline shared and input gathered at four vehicle volume levels of 1,000, 10,000, 100,000, and 500,000 units/year: seven original equipment manufacturers (OEMs) interviewed, three OEMs visited, 21 suppliers interviewed, 19 suppliers visited.
- Updated the current DOE cost model as provided by Strategic Analysis from interview input.
- Generated drawings and specifications for five key components (bipolar plate, membrane, gas diffusion layer, catalyst, hydrogen storage vessel) and sent out to suppliers to get actual price quotations at four vehicle volume levels: 1,000, 10,000, 100,000, and 500,000 units/year.
- Completed cost breakdown analysis and value stream mapping of five key components in three global regions with request for quotations in process.
- Gathered and delivered fuel cell systems shipment data for 2015.

INTRODUCTION

A healthy component supply chain is needed to support global OEMs as they launch hydrogen fuel cell vehicles into the market. OEMs need suppliers that can meet performance quality and cost targets. This project will provide a global analysis of the current supply chain technology and manufacturing readiness levels and cost levels through updated cost modeling and actual quotations and recommendations. This will aid the DOE Clean Energy Manufacturing Initiative in identifying strategic research and development (R&D) investments. This study will also provide a four-year analysis of units, megawatts by country and by application of PEMFC systems (automotive, portable, and stationary)

APPROACH

A questionnaire was developed for OEMs and suppliers which reflected the DOE cost model of five key components at four production levels to serve as the baseline for discussion. Feedback was requested on the cost breakdown, process assumptions, technology and manufacturing readiness, R&D projects and investment needed to support cost reductions. Interviews were conducted by phone and/or plant visits. Generic drawings and specifications were developed to get actual quotations. The quotations will be compared to the current DOE cost models and adjustments made.

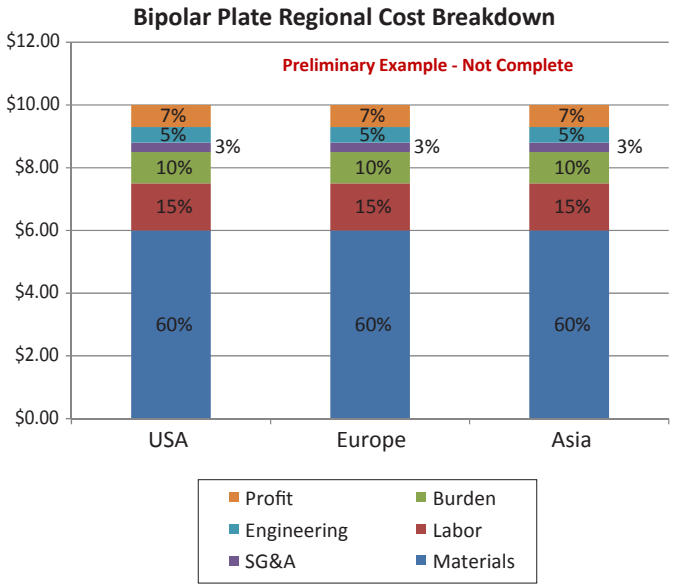
Supplier relationships will be identified and mapped with annual shipment data of automotive and stationary PEMFCs. Data will be gathered on government funding, capital available, and technology focus.

RESULTS

A comprehensive questionnaire was developed to gather key industry information in an information sharing manner that enabled OEMs and suppliers to provide directional and discrete information on the DOE cost model, technical and manufacturing readiness, current and future manufacturing process assumptions, and future development to meet the high volume needs of this industry at >100,000 vehicles per year. A large quantity of data has been gathered from the questionnaire interview with seven OEMs and 21 suppliers with actual visits at three OEMs and 19 suppliers. The following are the findings and themes to date:

- Global OEMs have a focus on performance and cost through design and manufacturing process development to build a positive business case for hydrogen fuel cell vehicles with a targeted sales price of $50,000. The leading OEMs are reporting 30–40% incremental cost reduction as they introduce next generation models. OEMs are in the initial phases of growing the supply chain. Most have a lead supplier for each of the key components, with a goal of at least two per component in maturity.
- Suppliers have a focus on component design and process development with no OEM or supplier capable of producing 100,000 vehicle units/year. Most are comfortable with 1,000 to 5,000 units per year. Suppliers are very cautious about investing in new manufacturing facilities with the limited book of business and the concern for potential major designs which could obsolete the current manufacturing process.
- Bipolar plate suppliers have current capability up to 10,000 vehicle units/year with further substantial investment needed for 100,000 units/year. R&D projects would be stamping in line process or roll-to-roll continuous production, elimination of plate coatings, sealing solutions, and electrical conductivity.
- Membrane suppliers have current capability up to 10,000 vehicle units/year with further substantial investment needed for 100,000 units/year. R&D projects to improve output would be: defined tolerance, improved inspection and quality metrics, high volume roll to roll processing, and improved performance at lower Pt loading targets.

- Pressure vessel suppliers have current capability up to 50,000 units/year with further substantial investment needed for 100,000 units/year. R&D projects would be design and manufacturing alternatives to carbon fiber winding, and lower carbon fiber strength/higher quality resin.
- Table 1 shows the range of the OEM cost projections for the fuel cell stack components studied with Strategic Analysis DOE cost. OEMs are in closer agreement at the 100,000 and 500,000 volumes.
- Figure 1 is the cost breakdown analysis preliminary example of quoted supplier data. The actual data is just beginning to be gathered on all five key components.
- Figure 2 is a value stream map of the bipolar plate manufacturing process flows. Maps will be made of all five key components.
- Figure 3 is the E4tech 2015 market data.
- In Japan, national support for markets (e.g. fueling infrastructure) has built a level of tentative certainty in the market which has enabled suppliers to develop manufacturing knowledge and capability. Serial production of fuel cell systems is being demonstrated by Toyota (Mirai) and Honda (Clarity) and a nascent supply chain exists.
- In China, support in the form of subsidies for consumers at the national and provincial level is focused on applications relevant to China's national goals of reducing greenhouse gas emissions and air pollution starting with buses. We are in the process of acquiring a copy of China's policy statement. One supplier has reported that the use of the China government funded and constructed research facility is being turned over to the company at no cost and 60% of the equipment is covered by the government. The company will only have to pay for 40% of the cost of the equipment.



USA – United States of America; SG&A – selling, general and administrative

FIGURE 1. Preliminary example Cost breakdown analysis. The $10.00 price is only a placeholder along with the % of the major cost categories. This graph will be adjusted once we get actual quotes.

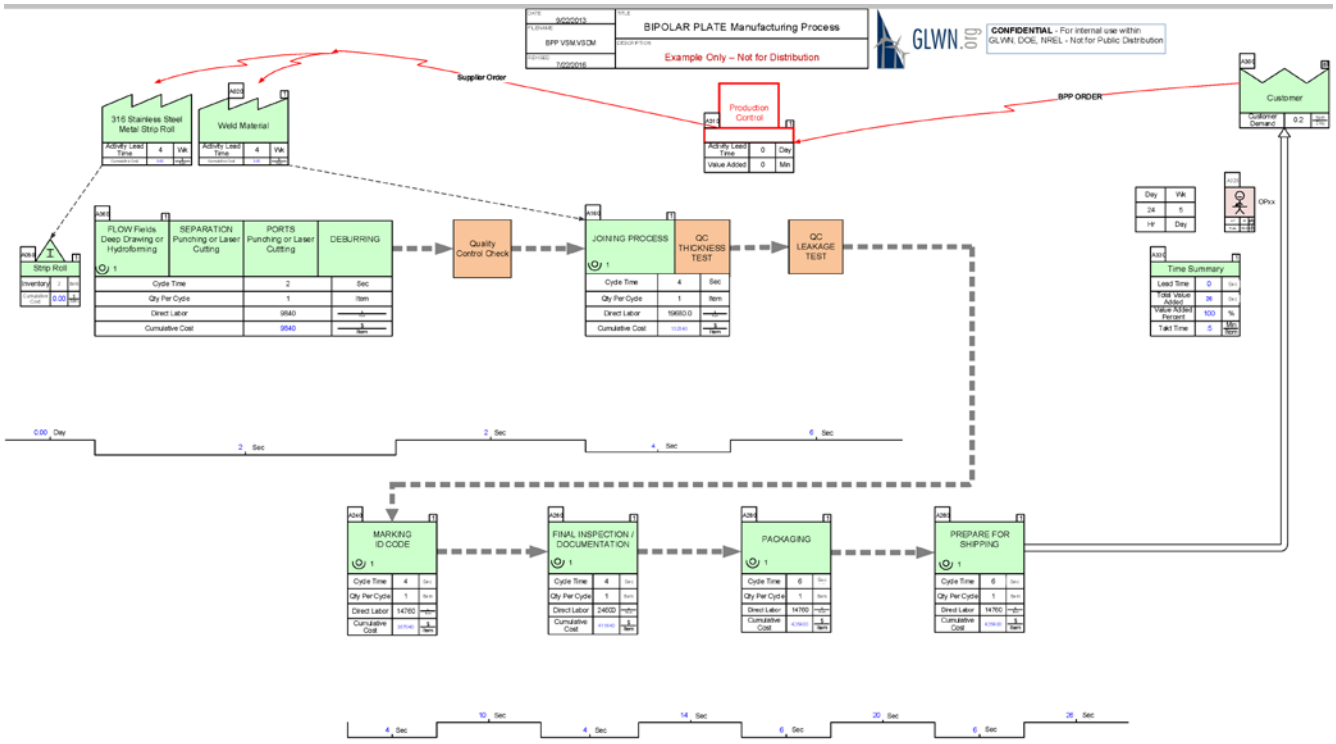
CONCLUSIONS AND FUTURE DIRECTIONS

The fuel cell supply chain is in the development/introduction stage with further design and manufacturing readiness development and substantial investment needed to get to the growth/maturity stage. OEMs are still developing the Tier 1 supply chain with most having one lead supplier per component with the target of two. Tier 1s state they need to invest in automated fabrication lines but are very cautious with high potential for major design changes. Five more months of work is required to complete the competiveness analysis portion of the project which includes the following: finish request for quotes; identify three

TABLE 1. Strategic Analysis Projected Cost versus OEM Forecast for Fuel Cell Stack Components (i.e., example: For bipolar plates at 1,000 vehicle units the OEMs average cost is 14 times higher than the SA cost numbers. For bipolar plates at 500,000 vehicle units the OEMs average cost is the same as SA cost numbers)

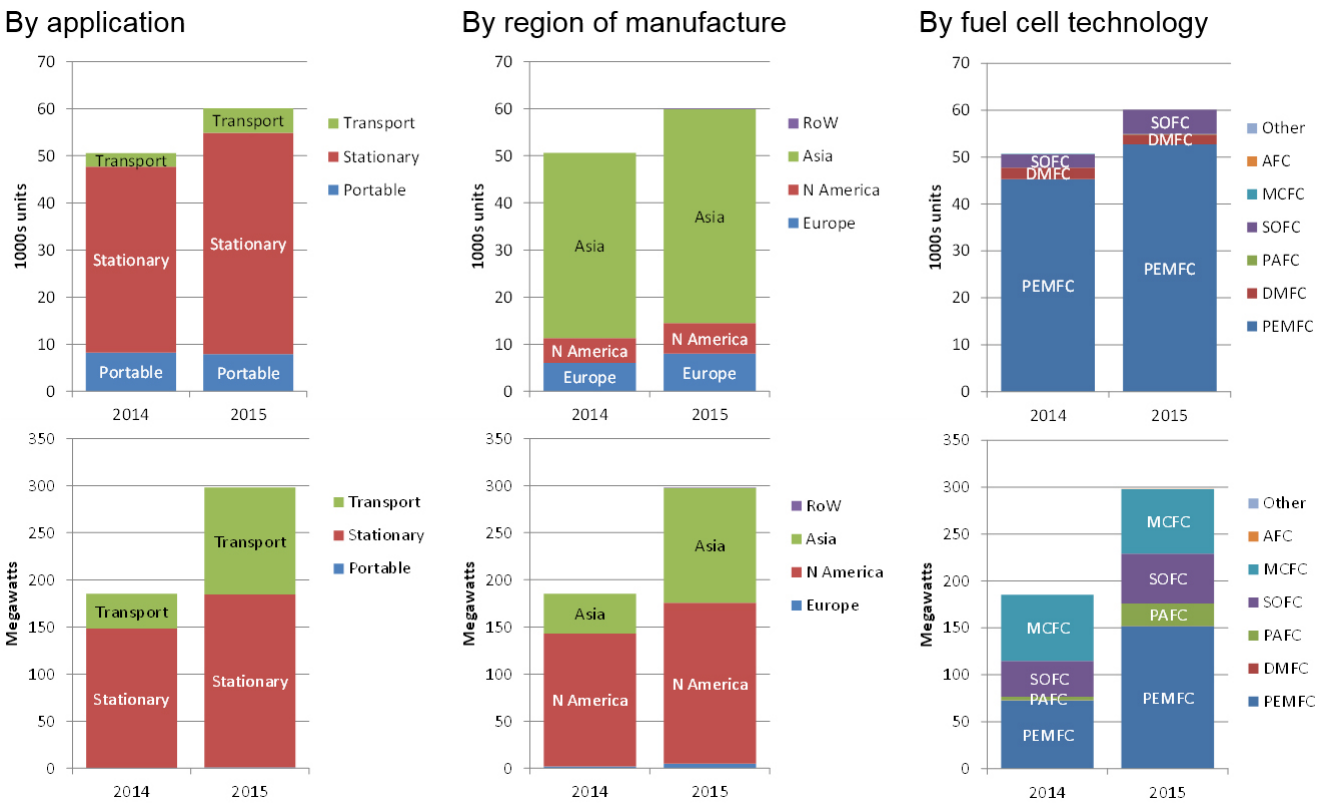
	Annual System Production Rate			
	1,000	10,000	100,000	500,000
Catalyst Ink & Application	9x	5x	3x	1.5x
Bipolar Plates	14x	18x	10x	1x
Membranes	2x	2x	2x	2x
GDLs	1.4x	4x	3x	1.3x

GDLs – gas diffusion layers



QC – quality control

FIGURE 2. Value stream map of the bipolar plate manufacturing process flow



SOFC – solid oxide fuel cell; DMFC – direct methanol fuel cell; MCFC – molten carbonate fuel cell; PAFC – phosphoric acid fuel cell; AFC – alkaline fuel cell

FIGURE 3. E4tech 2015 market data of fuel cell systems shipped by MW and number of units.

manufacturing opportunities, three tipping points, three high value opportunities, three strengths for United States manufacturers; complete assessment of trade flows, supply and demand, global suppliers, government funding, capital available, country's development technology, and the United States' manufacturing advantage.

FY 2016 PUBLICATIONS/PRESENTATIONS

1. Patrick Fullenkamp, "U.S. Clean Energy Hydrogen and Fuel Cell Technologies: A Competitiveness Analysis" Presentation at HTAC, April 22, 2015.

2. Patrick Fullenkamp, "U.S. Clean Energy Hydrogen and Fuel Cell Technologies: A Competitiveness Analysis" Presentation at AMR, June 11, 2015.

3. Patrick Fullenkamp, "U.S. Clean Energy Hydrogen and Fuel Cell Technologies: A Competitiveness Analysis" Presentation at HFC Seminar, Los Angeles, November 17, 2015.

4. Patrick Fullenkamp, "U.S. Clean Energy Hydrogen and Fuel Cell Technologies: A Competitiveness Analysis" Presentation at WIRE-Net Board of Directors, December 2015.

REFERENCES

1. Pike Research Report, executive summary at http://www.navigantresearch.com/wp-content/uploads/2012/02/FCSC-12-Executive-Summary.pdf