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

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- DJW Technologies, Dublin, OH
- E4tech, Lausanne, Switzerland
- Bowen Liu, Newmarket, Ontario, Canada
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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 systems 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) 2017 Objectives

- Map automotive fuel cell system supply chain evolution.
- Develop detailed questionnaire with current DOE cost target and process assumptions baseline shared, and conduct 30 interviews.
- Gather shareholder data on the current DOE cost model provided by Strategic Analysis.
- Generate drawings and specifications for five key components and send out to suppliers to get price quotes/guidance at 1,000 and 100,000 vehicle annual volume.
- Complete cost breakdown analysis and value stream mapping based upon quotes.
- Gather and deliver fuel cell systems shipment data for 2016.

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 [membrane electrode assembly] Processes (includes catalyst, membrane, gas diffusion layer)

(B) Lack of High Speed Bipolar Plate Manufacturing Processes

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

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

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 2017 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 annual volume levels: 1,000; 10,000; 100,000; 500,000. Seven original equipment manufacturers (OEMs) interviewed, three OEMs visited, 28 suppliers interviewed, 21 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 [GDL], catalyst, hydrogen storage vessel) and sent out to suppliers to get actual price quotes/guidance at 1,000 and 100,000 vehicle annual volume.
- Completed Design For Manufacturing and Assembly®/ discounted cash flow, cost breakdown analysis and value stream mapping of five key components in three global regions.
- Gathered and delivered fuel cell systems shipment data for 2015 and preliminary 2016 data in June 2017.

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. The outcome of this project will aid DOE/Clean Energy Manufacturing Initiative in identifying strategic investments, lay out prospective future supply chain per feedback, and identify technology areas for R&D investment.

This study will also provide a four-year analysis of units, megawatts by country and by application of PEMFC systems (automotive and stationary).

APPROACH

First GLWN developed a historical perspective on the automotive supply chain evolution. GLWN then utilized cost analysis to show components contributing most to the final automotive fuel cell system. 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. A structured interview process was conducted to gather data on the status of development of different components. Interviews and plant visits were conducted in the most important regions to allow visualization and in-depth discussion on relevant development needs. Detailed data on the fuel cell industry were gathered, including annual shipment numbers and different regional support. Value stream mapping was conducted to identify the flows within the relevant manufacturing processes. Implications for the United States were identified.

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 28 suppliers, with actual visits at three OEMs and 21 suppliers. The following are the findings and themes:

- 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 units. 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 design changes which could obsolete the current manufacturing process.
- Bipolar Plate: Europe and Asia hold the lead in bipolar plate technology. The United States is behind in forming and coating; U.S. prospects are high in far term.
- Catalyst: Europe (Umicore, Johnson Matthey) and Asia (Tanaka) are currently the world leaders in fuel cell catalyst technology. U.S. prospects are low to moderate in far term.
- GDL: Four main competitors predominate and are divided among Europe (SGL, Freudenberg), Asia (Toray), and the United States (Avcarb). Overall, the

Accomplishments: Industry Scorecard Technology and Manufacturing Readiness by Region

Global industry ready for 10k systems per year. High volume capabilities need further development

Technology Readiness

	Bipolar Plate				Catalyst				Gas Diffusion layer				Membrane				H2 Vessel			
	US	EU	Asia		US	EU	Asia		US	EU	Asia		US	EU	Asia		US	EU	Asia	
			Japan	China			Japan	China			Japan	China			Japan	China			Japan	China
1-10k	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
100k	M-L	MOD	MOD	LOW	MOD	H-M	H-M	MOD	MOD	MOD	MOD	LOW	H-M	H-M	H-M	H-M	H-M	H-M	H-M	H-M

Manufacturing Readiness

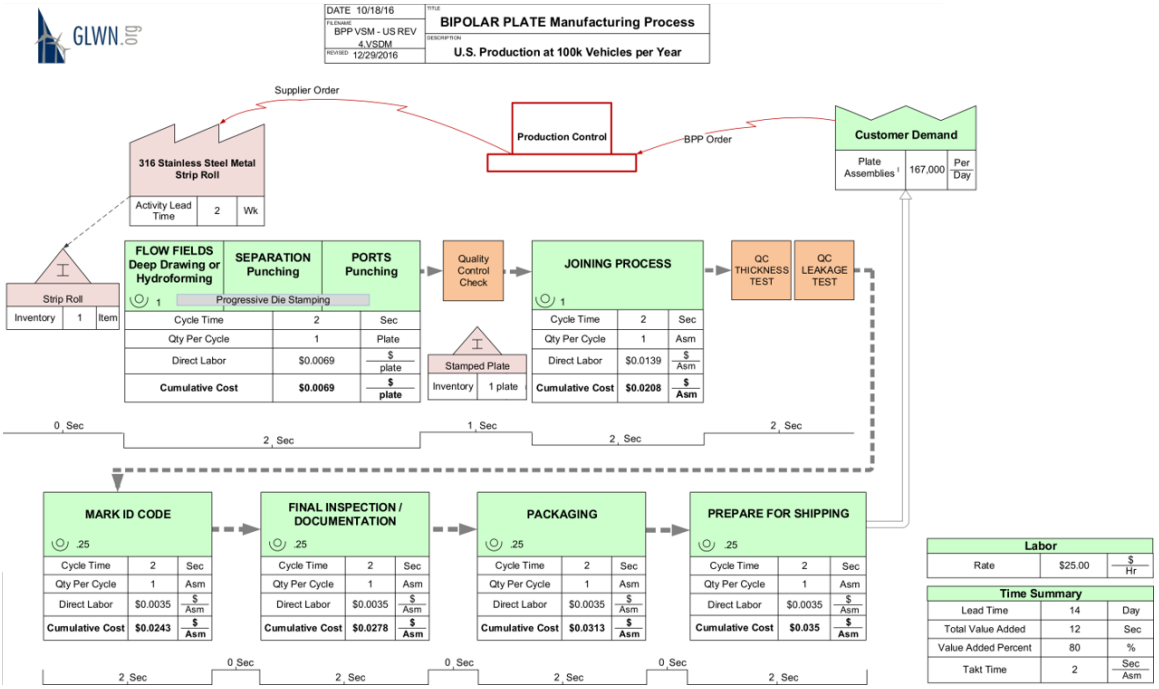
	Bipolar Plate				Catalyst				Gas Diffusion layer				Membrane				H2 Vessel			
	US	EU	Asia		US	EU	Asia		US	EU	Asia		US	EU	Asia		US	EU	Asia	
			Japan	China			Japan	China			Japan	China			Japan	China			Japan	China
1-10k	H-M	HIGH	HIGH	HIGH	H-M	HIGH	HIGH	HIGH	H-M	HIGH	HIGH	HIGH	H-M	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
100k	M-L	MOD	MOD	LOW	MOD	H-M	H-M	LOW	M-L	MOD	MOD	LOW	LOW	MOD	M-L	LOW	M-L	M-L	M-L	M-L

Readiness Legend:

HIGH	Currently sufficient to produce to stated demand
HIGH TO MODERATE	Capability and capacity exist, although no current production demonstrated at stated demand
MODERATE	Requires some advancements or capital investment to produce to stated demand
MODERATE TO LOW	Requires some advancements capital investment, and no current production demonstrated at stated demand
LOW	Requires major advancements or major capital investments to produced to stated demand

FIGURE 1. Industry scorecard of technology and manufacturing readiness by region

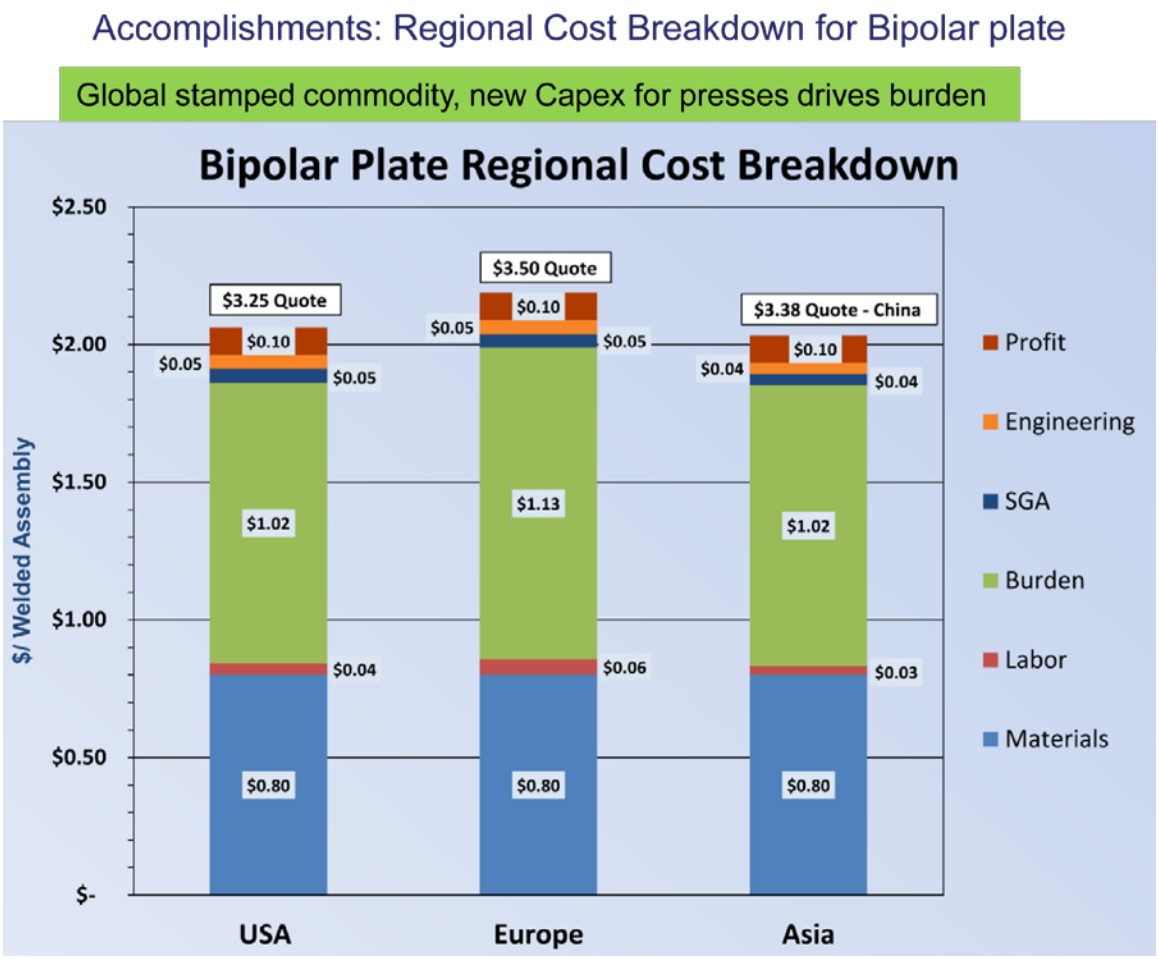
Accomp: Value Stream Map (bipolar plate example)



Value Stream Map is a hybrid of process flow used in DFMA and inputs from suppliers and OEMs VSM outputs are used for cost breakdown analysis and as a cost reduction tool

QC – quality control; Qty – quantity

FIGURE 2. Value stream map (VSM) of bipolar plate manufacturing



SGA – selling, general, and administrative expenses

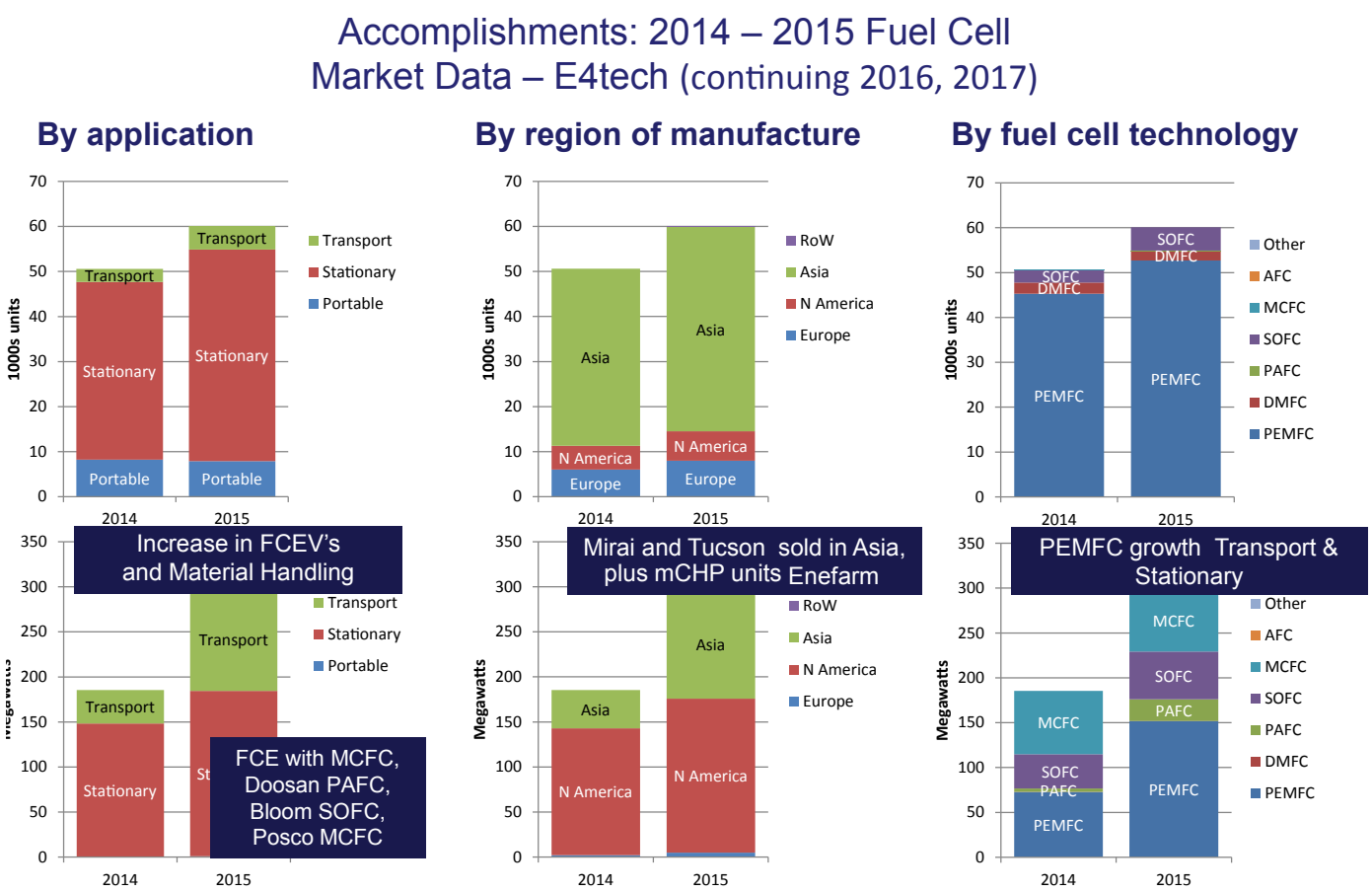
FIGURE 3. Regional cost breakdown for bipolar plates

outlook for U.S. GDL production and innovation competitiveness is rated moderate.

- Membrane: The United States currently holds the global lead in membrane technology.
- Pressure Vessel: Pressure vessel competitiveness is divided into carbon fiber production and vessel fabrication. Both areas are ripe for technology advancement; the United States is active in both areas. The prospect for U.S. production and innovation competitiveness is rated high.
- In Japan, strongly shaped by its lack of natural energy resources and diversification from fossil fuels, fuel cells and hydrogen energy are seen as an opportunity for industry. Serial production of fuel cell systems is being demonstrated by Toyota (Mirai) and Honda (Clarity), and a nascent supply chain exists.
- China's motivations are (1) to reduce reliance on overseas technology and expertise, (2) to increase potential for high-value jobs, (3) cleaner and better-performing industry, and (4) high-value exports.
- In the United States, many states support fuel cell technology, 30 include fuel cells or hydrogen as eligible renewable portfolio standards, 32 permit net metering, and 25 offer funding including rebates, grants, loans, and bonds.
- Germany's priorities include industrial and innovation policy (automotive industry strong), air quality, and climate change.

CONCLUSIONS AND UPCOMING ACTIVITIES

No single nation is clearly dominant regarding prospects for the long-term fuel cell market, but U.S. OEMs and manufacturers have fallen behind Japan and Europe in bipolar plates, membranes, GDLs, and catalysts (on par in hydrogen vessels). The U.S. potential is broadly moderate to high, though with weaknesses in bipolar plate manufacturing and ionomers in the near term.



RoW – region of world; SOFC – solid oxide fuel cell; DMFC – direct methanol fuel cell; PEMFC – polymer electrolyte membrane fuel cell; PAFC – phosphoric acid fuel cell; AFC – alkaline fuel cell; MCFC – molten carbonate fuel cell; FCEV – fuel cell electric vehicle; FCE – FuelCell Energy; mCHP – micro combined heat and power

FIGURE 4. E4tech 2014 and 2015 market data

- The United States has great depth in the science and technology of fuel cells and high quality in existing automotive industry and supply chain capability. California, in particular, has been a global driver of the fuel cell industry for two to three decades.
- The industry is only just beginning, and judicious investment now could reap benefits for many years to come.
- Increasing domestic fuel cell demand is viewed as a critical enabler of domestic fuel cell system production.
- U.S. OEMs and manufacturers need to restart local development as they have fallen behind Japan and Europe in bipolar plates, membranes, GDLs, and catalysts (on par in hydrogen vessels).

SPECIAL RECOGNITIONS & AWARDS

1. Patrick Fullenkamp, 2017 DOE Hydrogen and Fuel Cells Program R&D Award

FY 2017 PUBLICATIONS/PRESENTATIONS

1. Patrick Fullenkamp, "U.S. Clean Energy Hydrogen and Fuel Cell Technologies: A Competitiveness Analysis," Presentation at Hydrogen and Fuel Cells Technical Advisory Committee meeting, December 7, 2016.

2. Patrick Fullenkamp, "U.S. Clean Energy Hydrogen and Fuel Cell Technologies: A Competitiveness Analysis," Presentation at Annual Merit Review meeting, June 8, 2016.

3. Patrick Fullenkamp, "U.S. Clean Energy Hydrogen and Fuel Cell Technologies: A Competitiveness Analysis," Presentation at WIRE-Net Board of Directors, June 15, 2016.

REFERENCES

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