V.F.7 Stationary and Emerging Market Fuel Cell System Cost Analysis–Primary Power and Combined Heat and Power Applications

Vince Contini (Primary Contact), Fritz Eubanks, Mike Heinrichs, Mike Jansen, Paul George and Mahan Mansouri
Battelle
505 King Avenue
Columbus, OH 43201
Phone: (614) 424-7249
Email: continiv@battelle.org

DOE Manager: Donna Ho
Phone: (202) 586-8000
Email: Donna.Ho@ee.doe.gov

Contract Number: DE-EE0005250/001

Project Start Date: September 30, 2011
Project End Date: January 31, 2017

Overall Objectives

The objective of this project is to assist the U.S. Department of Energy in developing fuel cell system technologies for stationary and emerging markets by developing independent cost models for manufacture and ownership. In particular:

- Identify the fundamental drivers of system cost and the sensitivity of the cost to system parameters.
- Help DOE prioritize investments in research and development of components (e.g., metal bipolar plates versus composite graphite plates in polymer electrolyte membrane [PEM] fuel cells for low volume markets) to reduce the costs of fuel cell systems while considering systems optimization.
- Identify manufacturing processes that must be developed to commercialize fuel cells.
- Provide insights into the optimization needed for use of off-the-shelf components in fuel cell systems.

Fiscal Year (FY) 2016 Objectives

- Finalize cost estimates of 100-kW and 250-kW PEM and solid oxide fuel cell (SOFC) systems for primary power and combined heat and power (CHP) applications at annual production volumes of 100, 1,000, 10,000, and 50,000 units.
- Finalize cost estimates of 5-kW and 10-kW PEM fuel cell systems for backup power applications at annual production volumes of 100, 1,000, and 10,000 units.
- Revisit all applications in previous four budget periods and update reports.

Technical Barriers

This project addresses the following technical barriers from the Fuel Cell section of the Fuel Cell Technologies Program Multi-Year Research, Development, and Demonstration Plan.

(B) Cost

Technical Targets

To widely deploy fuel cells, significant strides must be made in lowering the cost of components and overall systems without compromising reliability and durability. Through estimating system costs at varying production volumes this analysis will:

- Identify the fundamental drivers of component and system cost and the sensitivity of the cost to various component and system parameters.
- Provide the DOE information on the impact of production volumes on lowering costs of fuel cells and the types of high volume manufacturing processes that must be developed to enable the widespread commercialization.
- Provide insights into the optimization needed for use of off-the-shelf components in fuel cell systems to drive down system costs.
- Analyze the lifecycle costs of owning and operating a fuel cell to estimate primary costs drivers for the end user in applicable markets.

FY 2016 Accomplishments

- Completed detailed manufacturing cost analysis of 100-kW and 250-kW PEM and SOFC systems for primary power and CHP applications.
- Completed detailed manufacturing cost analysis of 5-kW and 10-kW PEM fuel cell systems for backup power applications.

✧ ✧ ✧ ✧ ✧

INTRODUCTION

Fuel cell power systems may be beneficially used to offset all or a portion of grid-purchased electrical power and supplement onsite heating requirements. For this application the fuel of choice will usually be pipeline natural gas or onsite propane storage. These fuel sources generally have much higher reliability than utility electric power, being less subject to damage related outages, and can therefore provide for some continued operation in the event of grid outage – performing both primary power and back-up power functions. Battelle evaluated low temperature PEM and SOFC systems for use as a continuous power supplement (primary power) and to provide auxiliary heating in CHP configurations. The power levels considered this year were 100 kW and 250 kW. A primary-power or CHP commercial market has not yet developed in this size range; however, our analysis suggests an attractive business opportunity under the right conditions.

APPROACH

Battelle will apply the established methodology used successfully in previous fuel cell cost analysis studies performed for the DOE [1-3]. This technical approach consists of four steps: market assessment, system design, cost modeling, and sensitivity analysis (Figure 1). The first step characterizes the potential market and defines the requirements for system design. The second step involves developing a viable system design and the associated manufacturing process vetted by industry. The third step involves building the cost models and gathering inputs to estimate manufacturing costs. Manufacturing costs will be derived using the Boothroyd-Dewhurst Design for Manufacture Assembly Software (DFMA®). Custom manufacturing process models will be defined where necessary and parametrically modeled based on knowledge of the machine, energy, and labor requirements for individual steps that comprise the custom process. The fourth step will evaluate the sensitivity of stack and system costs to various design parameters. In addition to the sensitivity analysis, we will conduct a lifecycle cost analysis to estimate total cost of ownership for the target application and markets.

RESULTS

To provide insight into the cost drivers that may be unique to primary power and combined heat and power, the final system cost was broken into three categories associated with different aspects of operation and production: total stack manufacturing cost, the expense of balance of plant (BOP) hardware, and the final cost of complete system assembly and testing. BOP was further broken out into four subsets of:

- Fuel, water, and air supply components
- Fuel processor components
- Heat recovery components
- System assembly

A sales markup of 50% was integrated at the end and is called out separately in Tables 1–4. At high production volumes, the final ticket prices are estimated to be $2,437 and $1,697 per kW, respectively, for 100-kW and 250-kW CHP PEM fuel cell systems and $1,443 and $1,181 per kW for the 100-kW and 250-kW CHP SOFC systems. This work provides a detailed cost breakdown that helps identify key

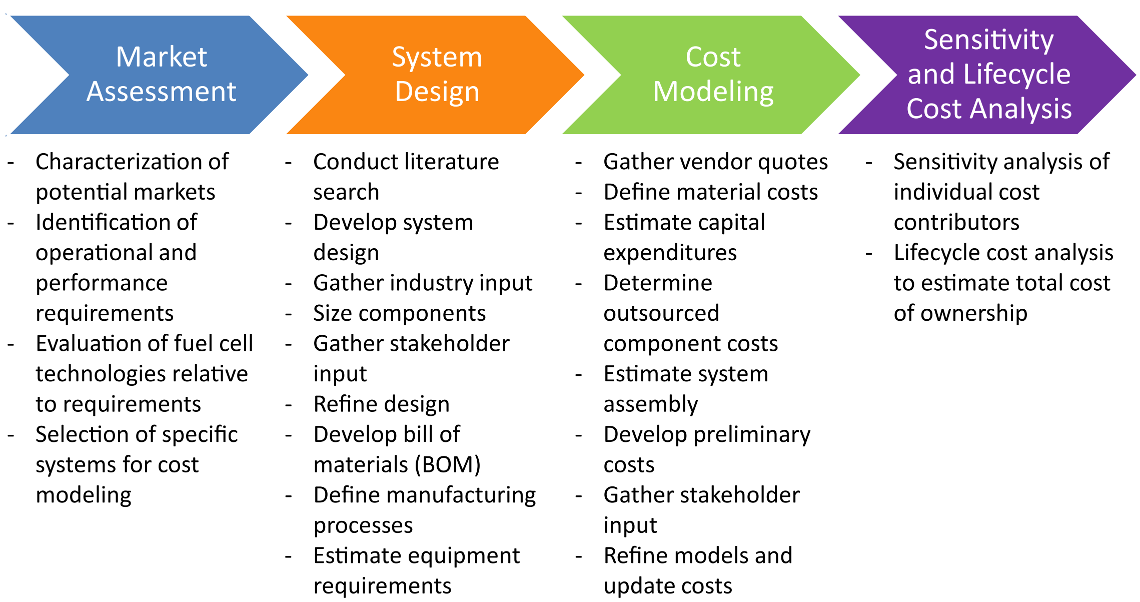

FIGURE 1. Battelle's Cost Analysis Methodology

TABLE 1. 100-kW CHP PEM Fuel Cell System Cost Summary

Description	100 Units	1,000 Units	10,000 Units	50,000 Units
Total Stack Manufacturing	$73,522	$34,480	$23,303	$20,390
Fuel, Water, and Air Supply Components	$25,832	$22,857	$20,894	$19,622
Fuel Processor Components	$55,616	$48,005	$43,629	$41,395
Heat Recovery Components	$37,440	$33,994	$30,868	$29,466
Power Electronic, Control, and Instrumentation	$52,536	$43,221	$35,258	$29,859
Assembly Components	$29,500	$26,790	$24,080	$21,705
Total system cost, pre-markup	$274,446	$209,348	$178,032	$162,438
System cost per kW_{net}, pre-markup	$2,744	$2,093	$1,780	$1,624
Sales markup	50%	50%	50%	50%
Total system cost, with markup	$411,670	$314,021	$267,048	$243,657
System cost per kW_{net}, with markup	$4,117	$3,140	$2,670	$2,437

TABLE 2. 250-kW CHP PEM Fuel Cell System Cost Summary

Description	100 Units	1,000 Units	10,000 Units	50,000 Units
Total Stack Manufacturing	$126,587	$71,151	$53,494	$48,737
Fuel, Water, and Air Supply Components	$35,472	$31,447	$28,662	$26,881
Fuel Processor Components	$94,462	$79,221	$70,458	$66,491
Heat Recovery Components	$56,215	$51,218	$46,680	$44,665
Power Electronic, Control, and Instrumentation	$117,058	$94,238	$74,725	$61,509
Assembly Components	$46,840	$42,590	$38,340	$34,500
Total system cost, pre-markup	$476,635	$369,865	$312,359	$282,782
System cost per kW_{net}, pre-markup	$1,906	$1,479	$1,249	$1,131
Sales markup	50%	50%	50%	50%
Total system cost, with markup	$714,952	$554,797	$468,538	$424,174
System cost per kW_{net}, with markup	$2,860	$2,219	$1,874	$1,697

TABLE 3. 100-kW CHP SOFC System Cost Summary

Description	100 Units	1,000 Units	10,000 Units	50,000 Units
Total Stack Manufacturing	$48,191	$32,005	$28,537	$28,273
Fuel and Air Supply Components	$10,108	$8,306	$7,465	$6,956
Fuel Processor Components	$8,245	$5,693	$5,247	$4,962
Heat Recovery Components	$21,057	$19,698	$18,430	$17,621
Power Electronic, Control, and Instrumentation	$52,988	$43,627	$35,622	$30,213
Assembly Components	$11,105	$10,080	$9,055	$8,175
Total system cost, pre-markup	$151,694	$119,410	$104,354	$96,200
System cost per kW_{net}, pre-markup	$1,517	$1,194	$1,044	$962
Sales markup	50%	50%	50%	50%
Total system cost, with markup	$227,541	$179,115	$156,532	$144,300
System cost per kW_{net}, with markup	$2,275	$1,791	$1,565	$1,443

TABLE 4. 250-kW CHP SOFC System Cost Summary

Description	100 Units	1,000 Units	10,000 Units	50,000 Units
Total Stack Manufacturing	$94,814	$73,566	$70,452	$70,113
Fuel and Air Supply Components	$18,298	$15,700	$14,309	$13,556
Fuel Processor Components	$14,347	$9,797	$8,604	$8,253
Heat Recovery Components	$33,857	$31,718	$29,718	$28,470
Power Electronic, Control, and Instrumentation	$117,962	$95,050	$75,453	$62,217
Assembly Components	$19,110	$17,410	$15,710	$14,180
Total system cost, pre-markup	$298,389	$243,241	$214,244	$196,789
System cost per kW_{net}, pre-markup	$1,194	$973	$857	$787
Sales markup	50%	50%	50%	50%
Total system cost, with markup	$447,583	$364,861	$321,367	$295,184
System cost per kW_{net}, with markup	$1,790	$1,459	$1,285	$1,181

cost drivers and offers insight at various value propositions through the lifecycle cost analyses.

CONCLUSIONS AND FUTURE DIRECTIONS

The following lists some of the conclusions drawn from this analysis:

- BOP costs dominate system cost.
- Within BOP costs
  - Power electronics is a major contributor for both technologies.
  - Heat recovery and fuel processing contribute significantly for PEM systems.
  - An attractive value proposition exists under specific utility rate conditions (high spark-spread) and is improved if able to utilize waste heat.
- Manufacturing readiness level for many BOP components not ready for mass production—significant cost driver.

By the end of FY 2016 Battelle will have completed full cost assessments of 5-kW and 10-kW PEM fuel cell systems for backup power applications.

FY 2016 PUBLICATIONS/PRESENTATIONS

1. V. Contini, F. Eubanks, M. Heinrichs, M. Jansen, P. George and Mahan Mansouri, November 2015. “Manufacturing Cost Analysis–Primary Power and Combined Heat and Power Applications.” Fuel Cell Seminar, Los Angeles, CA.

2. V. Contini, F. Eubanks, M. Heinrichs, M. Jansen, P. George and Mahan Mansouri, June 2016. “Stationary and Emerging Market Fuel Cell System Cost Analysis – Primary Power and Combined Heat and Power Applications.” DOE Annual Peer Review. Washington D.C.

REFERENCES

1. Battelle. 2011. “The High Volume Manufacture Cost Analysis of 5 kW Direct Hydrogen Polymer Electrolyte Membrane (PEM) Fuel Cell for Backup Power Applications.” Contract No. DE-FC36GO13110.

2. K. Mahadevan, K. Judd, H. Stone, J. Zewatsky, A. Thomas, H. Mahy, and D. Paul. 2007. “Identification and characterization of near-term direct hydrogen proton exchange membrane fuel cell markets.” Contract No. DE-FC36GO13110.

3. H. Stone, K. Mahadevan, K. Judd, H. Stein, V. Contini, J. Myers, J. Sanford, J. Amaya, J. Upton, and D. Paul 2006. “Economics of Stationary Proton Exchange Membrane Fuel Cells.” Contract No. DE-FC36-03GO13110.