V.I.6 Stationary and Emerging Market Fuel Cell System Cost Analysis – Material Handling Equipment

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Overall Objectives

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

- Identify the fundamental drivers of system cost and the sensitivity of the cost to system parameters.
- Help the 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) 2014 Objectives

- Finalize cost estimate of 1- and 5-kW solid oxide fuel cells (SOFC) for auxiliary power unit (APU) applications at annual production volumes of 100 units, 1,000 units, and 10,000 units.
- Finalize cost estimate of 1- and 5-kW PEM fuel cell for material handling equipment applications at annual production volumes of 100, 1,000, and 10,000 units.
- Initiate cost estimates of 1-, 5-, 10- and 25-kW PEM and SOFC fuel cell 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.

Technical Barriers

This project addresses the following technical barrier from the Fuel Cells section of the Fuel Cell Technologies Office 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 systems without compromising reliability and durability. This cost 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 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 cost drivers to the end user in applicable markets.

FY 2014 Accomplishments

- Completed manufacturing cost analysis of 1-kW and 5-kW SOFC systems for APUs.
- Completed manufacturing cost analysis of 1-kW and 5-kW direct hydrogen PEM fuel cell systems for material handling applications.
- Detailed performance specifications and system requirements and completed preliminary system design of 1-, 5-, 10-, and 25-kW PEM and SOFC fuel cell systems for primary power and CHP applications.

Next Steps

In FY 2014/15, Battelle will:

- Complete full cost assessment of 1-, 5-, 10-, and 25-kW PEM and SOFC systems for primary power and CHP applications.

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APPROACH

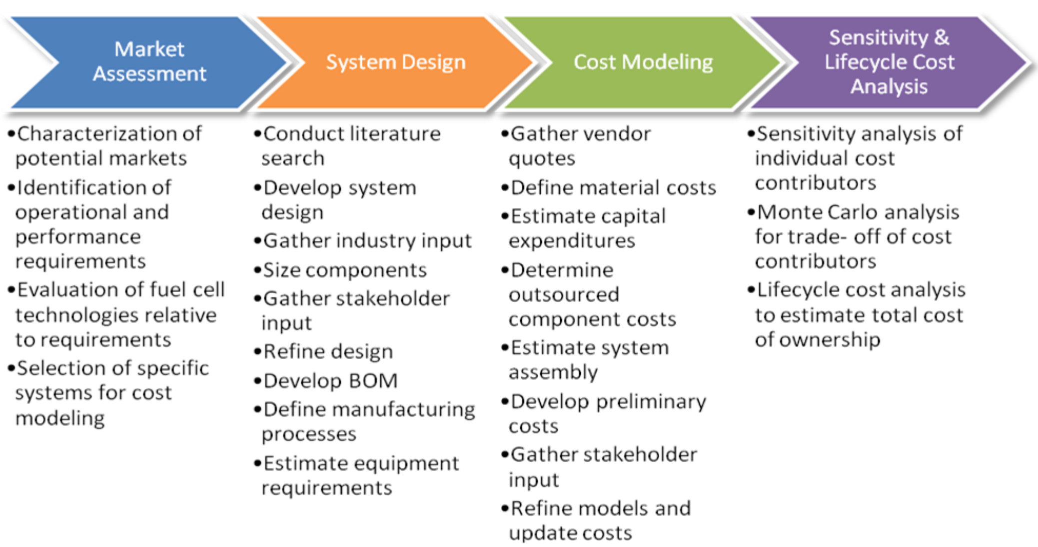
Battelle will apply the established methodology used successfully on the previous fuel cell cost analysis study for the DOE (Battelle, 2011; Mahadevan, 2007; Stone, 2006). The technical approach consists of four steps—market assessment, system design, cost modeling, and sensitivity analysis (Figure 1). The first step characterizes the potential market and defines the requirements for system design. The second step involves developing a viable system design and 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 and Assembly software. 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

Overall, the final cost was analyzed in four distinct categories: the capital cost of manufacturing equipment, the direct cost of material and assembly of the stack, the expense of balance-of-plant (BOP) hardware, and the final cost of complete system assembly and testing.

TABLE 1. 1-kW SOFC APU Fuel Cell System per Unit Cost Summary

Description	100 Units	1,000 Units	10,000 Units	50,000 Units
Total stack manufacturing cost, with scrap	$590	$511	$481	$473
Stack manufacturing capital cost	$4,757	$495	$69	$43
BOP	$9,597	$8,204	$7,383	$7,383
System assembly, test, and conditioning	$475	$451	$448	$448
Total system cost, pre-markup	$15,419	$9,661	$8,381	$8,347
System cost per net KW, pre-markup	$15,419	$9,661	$8,381	$8,347
Sales markup	50.00%	50.00%	50.00%	50.00%
Total system cost, with markup	$23,129	$14,491	$12,571	$12,520
System cost per net KW, with markup	$23,129	$14,491	$12,571	$12,520



BOM - bill of materials

FIGURE 1. Battelle's Cost Analysis Methodology

TABLE 2. 5-kW SOFC APU Fuel Cell System per Unit Cost Summary

Description	100 Units	1,000 Units	10,000 Units	50,000 Units
Total stack manufacturing cost, with scrap	$1,476	$1,327	$1,267	$1,257
Stack manufacturing capital cost	$4,757	$495	$82	$73
BOP	$11,323	$9,802	$8,738	$8,738
System assembly, test, and conditioning	$481	$456	$454	$454
Total system cost, pre-markup	$18,037	$12,080	$10,541	$10,522
System cost per net KW, pre-markup	$3,608	$2,416	$2,108	$2,104
Sales markup	50.00%	50.00%	50.00%	50.00%
Total system cost, with markup	$27,056	$18,120	$15,812	$15,783
System cost per net KW, with markup	$5,411	$3,624	$3,162	$3,157

TABLE 3. 1-kW PEM MHE Fuel Cell System per Unit Cost Summary

Description	100 Units	1,000 Units	10,000 Units
Total stack manufacturing cost, with scrap	$985	$744	$628
Stack manufacturing capital cost	$4,337	$434	$62
BOP	$14,826	$11,859	$10,034
System assembly, test, and conditioning	$278	$255	$249
Total system cost, pre-markup	$20,426	$13,291	$10,973
System cost per net KW, pre-markup	$20,426	$13,291	$10,973
Sales markup	50.00%	50.00%	50.00%
Total system cost, with markup	$30,639	$19,937	$16,460
System cost per net KW, with markup	$30,639	$19,937	$16,460

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 $12,520 and $3,157 per kW respectively for 1- and 5-kW SOFC APU systems and $16,460 and $4,401 per kW for the 1- and 5-kW PEM material handling equipment (MHE) systems. This work provides a detailed cost breakdown that helps identify key cost drivers and offers insight at various value propositions through the lifecycle cost analyses.

TABLE 4. 5-kW PEM MHE Fuel Cell System per Unit Cost Summary

Description	100 Units	1,000 Units	10,000 Units
Total stack manufacturing cost, with scrap	$2,219	$1,651	$1,337
Stack manufacturing capital cost	$4,337	$434	$96
BOP	$19,683	$15,594	$12,983
System assembly, test, and conditioning	$298	$264	$253
Total system cost, pre-markup	$26,537	$17,943	$14,669
System cost per gross KW, pre-markup	$5,307	$3,589	$2,934
Sales markup	50.00%	50.00%	50.00%
Total system cost, with markup	$39,806	$26,914	$22,004
System cost per gross KW, with markup	$7,961	$5,383	$4,401

CONCLUSIONS AND FUTURE DIRECTIONS

- The primary driver of overall system costs in both analyses is the BOP hardware, accounting for 62-91% of total system costs across the production volumes analyzed.
- For the SOFC APU, the complex nature of onboard fuel reforming and the high temperature requirements for SOFC operation keep the part count and material costs high. The SOFC stack cost is most sensitive to change in metal components, as the quantity of high-temperature steel makes up the bulk of the stack cost. BOP costs are most sensitive to heat transfer and power conversion equipment; specifically, the amount of heat transfer required to heat fuel feed streams, cool reformate for desulfurization, and reheat upstream of the stack is significant.
- The MHE BOP hardware is dominated by the battery, direct current (DC)/DC converter, hydrogen tank, and humidification system making up around 75% of the total BOP cost. The stack cost is most sensitive to change in current density and platinum loading.

FY 2014 PUBLICATIONS/PRESENTATIONS

1. F. Eubanks, V. Contini, G. Stout, M. Jansen, J. Smith. October 2013. Manufacturing Cost Analysis of SOFC Fuel Cells for APU Applications. Fuel Cell Seminar. Columbus, OH.

2. F. Eubanks, V. Contini, M. Jansen, G. Stout. June 2014. Stationary and Emerging Market Fuel Cell System Cost Analysis – Auxiliary Power Units. DOE Annual Peer Review. Washington, D.C.