V.H.6 Stationery and Emerging Market Fuel Cell System Cost Analysis - Material Handling Equipment

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

DOE Managers
Donna Ho
Phone: (202) 586-8000
Email: Donna.Ho@ee.doe.gov
Reg Tyler
Phone: (720) 356-1805
Email: Reginald.Tyler@go.doe.gov

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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) 2013 Objectives

- Estimate cost of 1- and 5-kW solid oxide fuel cells (SOFCs) for auxiliary power unit applications at annual production volumes of 100 units, 1,000 units, and 10,000 units.
- Estimate cost of 1- and 5-kW PEM fuel cells for material handling equipment applications at annual production volumes of 100 units, 1,000 units, and 10,000 units.

Technical Barriers

This project addresses the following technical barriers from the Fuel Cell 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. The cost analyses will 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. The study will also provide insights into the optimization needed for use of off-the-shelf components in fuel cell systems to drive down system costs. Finally, the study will analyze the lifecycle costs of owning and operating a fuel cell to estimate primary costs drivers to the end user in applicable markets.

FY 2013 Accomplishments

- Completed manufacturing cost analysis of 10-kW and 25-kW direct hydrogen PEM fuel cell systems for material handling applications.
- Completed the market assessment for the auxiliary power unit and material handling equipment markets.
  - Defined the application requirements
  - Selected appropriate fuel cell technologies and system sizes to meet requirements
- Detailed performance specifications and system requirements and completed preliminary system design of:
  - 1-kW and 5-kW SOFC for auxiliary power units
  - 1-kW and 5-kW PEM fuel cell for material handling equipment, specifically forklifts

Next Steps

In FY 2014 Battelle will:

- Complete full cost assessment of 1-kW and 5-kW SOFC systems for auxiliary power applications
- Complete full cost assessment of 1-kW and 5-kW PEM fuel cell systems for material handling 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 [1-3]. 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 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. Both single-factor sensitivity analysis and Monte Carlo analysis will be performed. Single-factor sensitivity analysis helps determine the impact of individual parameters on system costs. The Monte Carlo analysis will help determine the impacts of cost variability. 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

A high level summary of the final costs is shown below and emphasizes that the balance of plant (BOP) dominates the final cost—at most it is estimated to account for 83% of the final cost before markup at high production volumes. In all sizes and production rates analyzed, the BOP was responsible for approximately 80% of the pre-markup price. Overall the final cost is analyzed in four distinct categories: the capital cost of manufacturing equipment, the direct cost of material and assembly of the stack, the expense of BOP hardware, and the final cost of complete system assembly and testing it. Anticipated scrap is also captured in the stack manufacturing cost.

A standard sales markup of 50% was integrated at the end and is called out separately in Tables 1 and 2. At high production volumes, the final ticket price is estimated to be $2,918 per kW for a 10-kW MHE PEM system. This price decreases nearly 33% per kW for a 25-kW system.

CONCLUSIONS AND FUTURE DIRECTIONS

The primary driver of overall MHE system cost is the cost of BOP hardware, with battery, direct current to direct current (DC/DC) converter, hydrogen tank, and humidification system making up around 75% of the total BOP cost. The stack costs are most sensitive to change in current density and platinum loading.

Production volume considered in this report has negligible effect on stack cost, due to the fact that

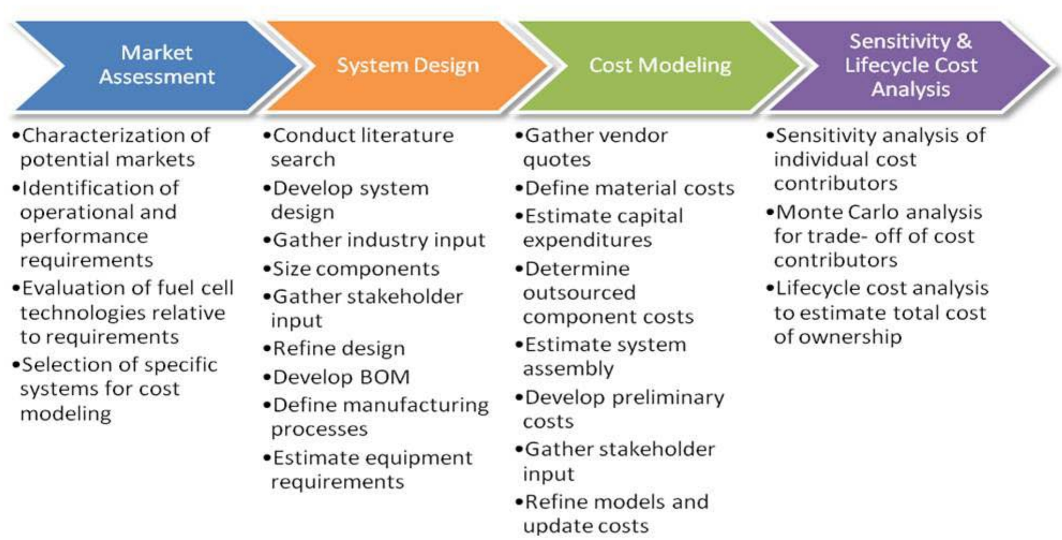

FIGURE 1. Battelle's Cost Analysis Methodology

TABLE 1. 10-kW MHE PEM Fuel Cell System per Unit Cost Summary

Description	100 Units	1,000 Units	10,000 Units
Total stack manufacturing cost, with scrap	$4,357	$3,974	$3,422
Stack manufacturing capital cost	$2,825	$283	$74
BOP	$27,272	$21,079	$17,856
System assembly, test, and conditioning	$279	$267	$266
Total system cost, pre-markup	**$34,733**	**$25,603**	**$21,618**
System cost per gross KW, pre-markup	**$3,158**	**$2,328**	**$1,965**
Sales markup	50.0%	50.0%	50.0%
Total system cost, with markup	**$52,100**	**$38,405**	**$32,427**
System cost per gross KW, with markup	$4,736	$3,491	$2,948

BOP – balance of plant

TABLE 2. 25-kW MHE PEM Fuel Cell System per Unit Cost Summary

Description	100 Units	1,000 Units	10,000 Units
Total stack manufacturing cost, with scrap	$8,815	$8,068	$6,851
Stack manufacturing capital cost	$2,825	$307	$121
BOP	$44,517	$34,571	$29,114
System assembly, test, and conditioning	$279	$267	$266
Total system cost, pre-markup	**$56,436**	**$43,213**	**$36,352**
System cost per gross KW, pre-markup	**$2,052**	**$1,571**	**$1,322**
Sales markup	50%	50%	50%
Total system cost, with markup	**$84,654**	**$64,820**	**$54,528**
System cost per gross KW, with markup	**$3,079**	**$2,357**	**$1,983**

platinum, graphite composite bipolar plate material, and commodity material costs are fairly constant across the range of purchased material quantities. Platinum is generally purchased at market spot price. Commodity material (e.g., aluminum, carbon black, methanol) markets are generally mature with price points fairly level over all but the smallest purchase quantities.

The manufacturing costs are also constrained to a lower cost bound by the material processing requirements, i.e., regardless of the volume being produced, the time required to produce each part is the same. For example, the bipolar plate material requires at least 120 seconds cure time in the mold, and another 15 minutes of post-bake time. This places an upper limit on throughput, and a corresponding lower limit on manufacturing cost, which is a function of the machine time required in producing each part. The same production time constraints are applicable to membrane electrode assembly hot pressing, and to a lesser extent, to catalyst application.

BOP component costs are driving total system cost and can potentially be reduced by:

- Eliminating DC/DC converter—requires invention/technical breakthrough
- Eliminating stack humidification
  - Required for operation at higher temperature and wider operating range

 – May require change of membrane material

- Using all steel hydrogen storage tank—also could help with ballast

FY 2013 PUBLICATIONS/PRESENTATIONS

1. F. Eubanks, V. Contini, Mahadevan, K,G. Stout, M. Jansen, J. Smith. November 2012. Manufacturing Cost Analysis of Fuel Cells for Forklift Applications. Fuel Cell Seminar, Uncasville, CT.

2. V. Contini, Mahadevan, K, F. Eubanks, M. Jansen, J. Smith. May 2013. Stationary and Emerging Market Fuel Cell System Cost Analysis – Material Handling Equipment. 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. Available at http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/pemfc_econ_2006_report_final_0407.pdf.

3. H. Stone, K. Mahadevan, K. Judd, H. Stein, V. Contini, J. Myers, J. Sanford, J. Amaya, and D. Paul. 2006. Economics of Stationary Proton Exchange Membrane Fuel Cells, Interim Report. Contract No. DE-FC36GO13110.