V.F.1 Optimal Stationary Fuel Cell Integration and Control

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Project Start Date: January 2011
Project End Date: Project continuation and direction determined annually by DOE

Overall Objectives

Build an open source tool (Distributed Generation Build-out Economic Assessment Tool [DG-BEAT]) and simplified web tool (Fuel Cell Tool for Assessing Costs [FCTAC]) that help combined heat and power (CHP) fuel cell developers, end users, and other stakeholders to do the following for their systems, helping to drive economies of scale and cost reduction.

- Determine the appropriate sizing to reduce cost
- Integrate to commercial building control and heating, ventilating, and air conditioning systems to maximize durability
- Compare performance relative to incumbent technologies
- Determine optimum system configuration
- Evaluate potential market penetration

Fiscal Year (FY) 2015 Objectives

- DG-BEAT is undergoing a revision of project scope and vision after being moved under Technology Validation. This revision includes a realignment to focus on grid integration activities. A three-year project plan is in progress.
- FCTAC will have revisions to better represent currently available fuel cell sizes and distinguish between electric only and CHP systems. The modifications will not compromise the ease of use while increasing its validity.

Technical Barriers

This project addresses the following technical barriers from the Technology Validation section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

(B) Lack of Data on Stationary Fuel Cells in Real World Operation

(E) Codes and Standards

Technical Targets

This project is providing a tool to fuel cell manufacturers, end users, and other stakeholders to help them reduce the cost of fuel cell CHP installations by optimizing their sizing, combining them with hybridizing technologies such as thermal energy storage and batteries, dispatching them in cost-optimal ways, and investigating the fuel cell sizes and features to best address the national market. Relevant DOE targets (2020) are:

- Installed cost, natural gas: $1,500/kW
- Operating lifetime: 40,000–80,000 h
- Electrical efficiency at rated power: >50%
- CHP energy efficiency: 90%.

FY 2015 Accomplishments

- DG-BEAT model features:
  - Component library for three types of fuel cells (phosphoric acid fuel cell [PAFC], molten carbonate fuel cell [MCFC], and polymer electrolyte membrane [PEM] fuel cell), two chillers (absorption and electric), thermal storage (heat and cold), batteries, and renewable generation (solar and wind)
  - A total of 1,280 model building profiles covering 16 American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) climate regions, 16 building types, and five vintages
  - Utility rate structures for time-of-use (TOU) demand and usage charges, including 20 preloaded rates and state averages; utility rates include options for net metering, fixed sellback, and TOU sellback of electricity
  - Natural gas rates that are forecasted from historical data by state with seasonal variation
  - Geospatially resolved by state emissions data with daily and seasonal variation, which are summed annually

- Five fuel cell dispatch strategies (baseload, weekend dip, diurnal peaking, load following, and emissions control)
- Four fuel cell sizing options (fixed size, 100% based on building load, net present value cost minimization, and annual emissions minimization)

- FCTAC accomplishments:
  - Initially released May 2014; has received 437 pages views between September 1, 2014, and April 2015
  - Narrowed the scope of DG-BEAT to be a first step toward making a decision about going forward with a stationary fuel cell installation
  - Reduced inputs to the 12 with the most impact, and carefully chose default values
  - Chose three outputs for FCTAC: net present value cost analysis, greenhouse gas emissions analysis, and criteria pollutant emissions analysis, which are displayed visually and compared to a baseline building performance

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INTRODUCTION

This project aims to create an open source software tool that allows fuel cell developers, their potential customers, and other stakeholders to evaluate the ability of fuel cell installations to save money relative to the grid/natural gas paradigm. The model includes 1,280 model building profiles covering the major ASHRAE climate zones in the United States.

The model can perform design optimizations on single fuel cells and building combinations or campuses of multiple buildings. In addition to fuel cells technologies that can be included in the buildings systems are chillers, energy storage technologies, and onsite renewables such as solar and wind.

APPROACH

The approach taken by the research team is to build a flexible, configurable model that allows users to create modules for the various components that make up a project scenario (fuel cells, energy storage, chillers, buildings, and campuses). NREL has teamed with the University of California, Irvine as a sub-contractor to leverage its extensive expertise in this area. Cost and sizing optimization can now be done for different control strategies utilizing the modules built. In addition, NREL is working cross-center within the laboratory, drawing extensively on the expertise of the Commercial Building group within NREL, to provide model building profiles.

RESULTS

The DG-BEAT project is a full feature tool for analyzing fuel cell integrated building systems (Figure 1). The code is modular and open source by invitation currently. Results include net present value cost analysis that is geospatially resolved with regional data for building profiles, utilities, and natural gas costs. It has a library of building components that include three types of fuel cells (PAFC, MCFC, and PEM), two types of chillers (absorption and electric), hot and cold

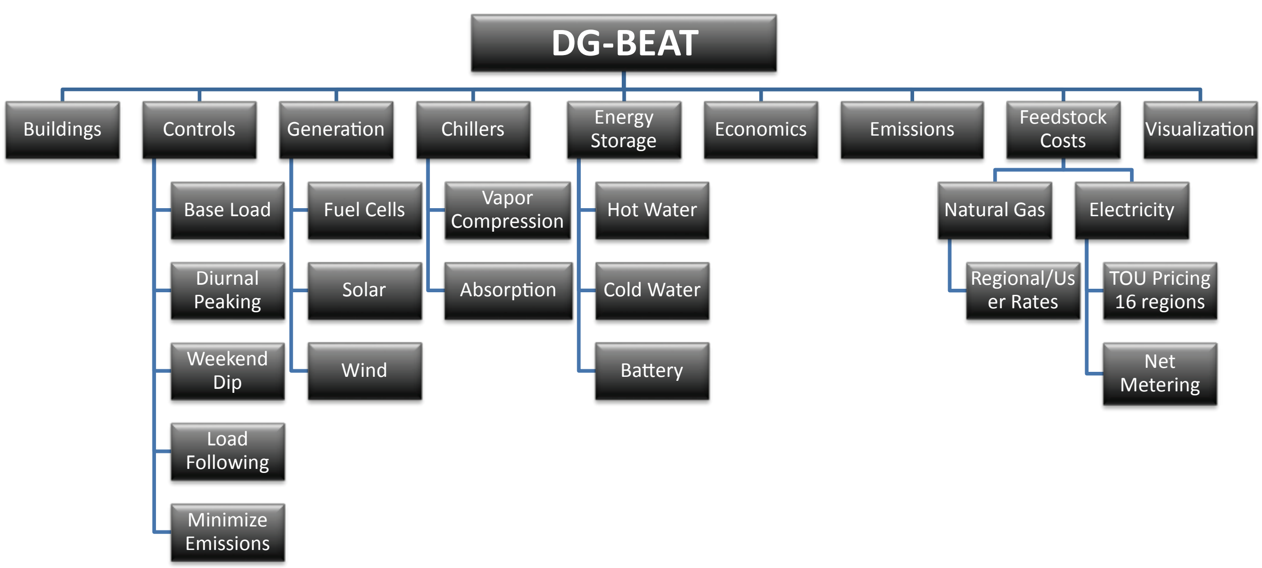


FIGURE 1. Construction of DG-BEAT

thermal storage, batteries, solar, and wind. The building components can be configured with appropriate performance profiles and cost. This year the project has been moved from the DOE Fuel Cell Annual Operating Plan to the Technology Validation section. This move serves to better align the project activities. The project is undergoing a major revision in scope and vision to better align it with grid integration activities. The main activity has been to work on a three-year project plan.

FCTAC had its inaugural year, and after receiving feedback, is undergoing several modifications. The results were revised to better represent currently available fuel cells and to distinguish between electric and CHP systems. The main objective of the web tool is to simplify the complexity of the DG-BEAT model and provide an initial assessment of a fuel cell integrated building (Figure 2). It was originally intended for federal building managers, but the tool is freely accessible at fctac.nrel.gov.

CONCLUSIONS AND FUTURE DIRECTIONS

A strong model foundation is now in place for implementing optimized component sizing optimization. The model can now manage integration of fuel cells into building systems that can include chillers, energy storage technologies, and renewable energy systems. A number of sizing and control strategies are implemented.

Future work includes:

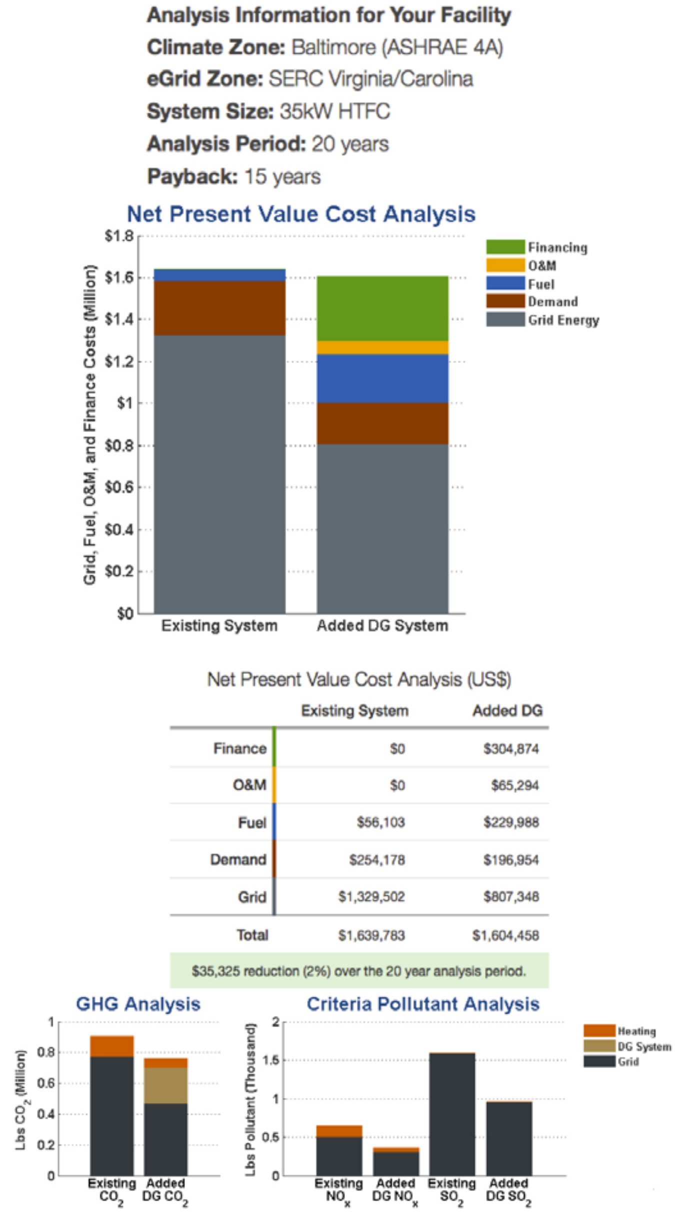
- Real-time optimal dispatch controller.
- Optimum component sizing for use in grid services markets.
- New building interface for communicating with buildings and sending optimized dispatch control schedules, as well as transacting in grid services markets.
- New graphical interface for use by building managers and planners.

FY 2015 PUBLICATIONS/PRESENTATIONS

1. Saur, G., Ainscough, C., Post, M., Kurtz, J., and Sprik, S. "Optimal Stationary Fuel Cell Integration and Control." (June 2015) 2015 DOE Annual Merit Review meeting.

2. Saur, G., and Post, M. "DG-BEAT: Distributed Generation Build-out Economic Analysis Tool, a Stationary Fuel Cell Model." Paper presented at Fuel Cell Seminar, November 2014.

3. Saur, G., Ainscough, C., Kurtz, J., Sprik, S., Post, M., Brouwer, J., McLarty, D., Sullivan, R., Field, K., and Bonnema, E. "Enlarging Potential National Penetration for Stationary Fuel Cell through System Design Optimization." (November 2014) 2014 DOE Annual Progress Report.



Net Present Value Cost Analysis (US$)

	Existing System	Added DG
Finance	$0	$304,874
O&M	$0	$65,294
Fuel	$56,103	$229,988
Demand	$254,178	$196,954
Grid	$1,329,502	$807,348
Total	$1,639,783	$1,604,458

$35,325 reduction (2%) over the 20 year analysis period.

Annual GHG and Pollutant Production (lbs)

	CO_2		NO_x		SO_2	
	Existing	Added DG	Existing	Added DG	Existing	Added DG
Heating	125,184	53,375	134	57	1	0
DG System	0	233,297	0	3	0	0
Grid	776,901	471,769	510	310	1,590	965
Total	902,085	758,441	644	370	1,591	965

HTFC – High Temperature Fuel Cell; GHG – Greenhouse Gas; DG – Distributed Generation

FIGURE 2. FCTAC example results