

Enlarging Potential National Penetration for Stationary Fuel Cells through System Design Optimization

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Overview

Timeline

- Project start date: October 2011
- Project end date: October 2012*

Barriers Addressed

- Cost
- Building Integration
- Manufacturing economies of scale

Budget

- Total project funding
 - DOE share: \$600k
 - Contractor share: \$0k
- Funding received in FY11: \$300k
- Planned funding for FY12: \$300k

*Project continuation is determined annually by DOE. **Funded under a separate project.

NATIONAL RENEWABLE ENERGY LABORATORY

Partners

- University of California, Irvine (UCI)
- Lawrence Berkeley National Lab (LBNL)**
- Stationary Fuel Cell OEMs

Relevance: Objectives

- Build a tool for optimizing fuel cell attributes, including control parameters, and system and component sizes for unique individual building characteristics. Tool will add flexibility for adding user-defined building, fuel cell, financial, control characteristics.
- Tool will be used to minimize lifecycle cost, lifetime GHG emissions, or installed capital costs of fuel cell installations.
- Characterize the largest segments of the U.S. building inventory for use in the tool, leveraging the CBECs building survey.
- Characterize building control systems and include in the tool, advanced control strategies for integrating fuel cell system and building control systems.
- Validate the model outputs against real-world data from stationary fuel cell installations.
- Exercise tool to determine the set of most-favorable system sizes and types to achieve national greenhouse gas (GHG) emissions and energy demand reductions.

Activity To Date

• FY11

- Set goals for the project.
- Developed a strategy to meet the objectives.
 - Develop an easy-to-use modular software tool that allows great flexibility and scalability for performing analysis.
- Developed capabilities list for the model.
- Developed GUI storyboard.
- Developed GUI.
- Developed Modules
 - Fuel Cell
 - Buildings
 - Controls
 - Economics & Costs
 - Feedstocks

Approach: Build a Tool to Enable Modeling

- Build a flexible, modular software framework which allows the addition of a wide variety of modules.
- This allows scalability and flexibility when tackling the extremely diverse population of commercial buildings in the US.



Approach: Buildings Module

- NREL is a nationally recognized leader in buildings research combining renewable energy with innovative technologies & strategies to significantly reduce energy consumption in buildings.
- The NREL Hydrogen Technology Systems Center is working closely with the NREL Electricity, Resources, and Building Systems Integration Center (ERBSIC) to enhance the depth and robustness of the model.



Approach: Buildings Module

- ERBSIC has developed hourly energy use profiles for 16 model building types in 16 climate zones, for three different vintages.
- Total: 768 building profiles.
- Represents about 67% of U.S. commercial inventory.

Building types	Locations	Vintages
Restaurant: full-service (sit down)	Miami (ASHRAE 1A)	•New construction (compliant with ASHRAE 90.1-
Restaurant: quick-service (fast food)	Houston (ASHRAE 2A)	2004)
School: primary school	Phoenix (ASHRAE 2B)	
School: secondary school	Atlanta (ASHRAE 3A)	 "Post-1980" construction (80s/90s, compliant
Office: large office	Los Angeles (ASHRAE 3B-Coast)	with ASHRAE 90.1-1989)
Office: medium office	Las Vegas (ASHRAE 3B-Inland)	
Office: small office	San Francisco (ASHRAE 3C)	• "Pre-1980" construction
Hospitality: large hotel	Baltimore (ASHRAE 4A)	
Hospitality: small hotel/motel	Albuquerque (ASHRAE 4B)	
Health care: large hospital	Seattle (ASHRAE 4C)	
Health care: outpatient facility	Chicago (ASHRAE 5A)	
Retail: big-box, standalone retail store	Boulder (ASHRAE 5B)	
Retail: retail strip mall	Minneapolis (ASHRAE 6A)	
Retail: supermarket	Helena, MT (ASHRAE 6B)	
Mid-rise apartment building	Duluth, MN (ASHRAE 7)	
Unrefrigerated warehouse	Fairbanks, AK (ASHRAE 8)	

Approach: U.S. Inventory CBECS

- The Commercial Building Energy Consumption Survey (CBECS 2003) represents the energy usage data for ~5,200 U.S. commercial buildings, with statistical extrapolations for the whole country.
- Take advantage of once-in-a decade opportunity to actively participate in a CBECS survey.
- By integrating model building results with CBECS, national impact can be estimated.



Approach: Control Strategies Module

- Fuel cell characteristics such as min/max power, CHP temperature, and ramp rate determine the power and heat available for the next hour.
- Determine the marginal cost of electricity and value of CHP heat offset from grid and fuel pricing.
- Dispatch fuel cell to achieve the desired dispatch goal.
- Partner UCI will help develop/refine/validate dispatch strategies.



Approach: Manufacturing Costs Module

- Synchronizing activity with DFMA[®] cost modeling performed by LBNL.
- Reviewing results from and working with Strategic Analysis (SA) (formerly DTI) and Battelle.
- Mapping cost vs. manufacturing volume vs. power.
- Initial targets: PEM, high temperature PEM (PBI), and SOFC in the 1–250-kW range.

Approach: Economic Module

- Model leverages the Fuel Cell Power Model and H2A method financial calculations.
- This makes it easy to compare analyses and results across different tools such as H2A and the POWER model.

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Approach: Grid Pricing Module

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Approach: Natural Gas Pricing Module

• Gas pricing based on Energy Information Administration forecasts

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Approach: Optimization & DoE

- Once the model can process one scenario, give it the ability to run multiple scenarios based on variations in the inputs, like a designed experiment.
- Add the ability to optimize a single parameter within a constrained solution space.

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Accomplishments: The Model

- Developed tool with a graphical interface capable of analyzing many different scenarios.
- It is important to build sufficient analysis depth for a single case before replicating to multivariate optimizations
- Incorporated 384 model buildings (50% completion)



Accomplishments: Fuel Cell System Modules

Currently have models for

- PAFC 400 kW
- MCFC 300 kW
- Natural Gas Genset (as a control)
- Developing models for
 - PEM 1, 5, 25, 100 kW
 - SOFC

Accomplishments: Fuel Cell System Modules

• Users can input custom fuel cell characteristics to generate a new module.

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Accomplishments: Manufacturing Cost

 Model is built to receive cost surfaces (cost vs. power and production volume) developed by LBNL, Battelle and SA.



Model Results

 Results page shows a variety of economic indicators to help evaluate the viability of such a project.



Collaborations

- NREL Electricity, Resources, and Building Systems Integration Center.
- UCI subcontracted for controls and integration work.
- LBNL- tie-in with their separate DOE project (FC098) for manufacturing cost surfaces.
- Strategic Analysis, Inc. and Battelle.
- Stationary Fuel Cell OEMs are providing product data sheets and supporting information.

Proposed Future Work

• FY12

- Expand control strategies with UCI.
- Develop a rough estimate for the range of FC sizes needed for the commercial building inventory to feed to the LBNL team, in order to focus their cost efforts.
- Expand building types to include remaining 384.
- Provide input to CBECS 2012.
- FY13
 - Expand fuel cell types.
 - Option to continue UCI work.
 - Implement Design of Experiments capability.
 - Implement speed improvements to dispatcher code.
 - Perform detailed optimizations.
 - Validate model against real-world data.
 - Provide input to CBECS 2012.

Summary

RELEVANCE Project addresses barriers of cost, market adoption, and electricity demand. Building integration sizes and shapes variability.

APPROACH Approach includes deep analysis that will be replicated to optimize stationary fuel cells for the U.S. commercial building inventory. Leveraging existing high value data sources.

ACCOMPLISHMENTS Have developed a detailed, scalable, multifaceted analysis tool that will allow for fast comparison of different options and sensitivities.

COLLABORATION Strong collaboration with academia, national labs (LBNL), and industry (Strategic Analysis, Fuel Cell OEMs).

FUTURE WORK Clear scope for future work.