NREL

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

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Objectives

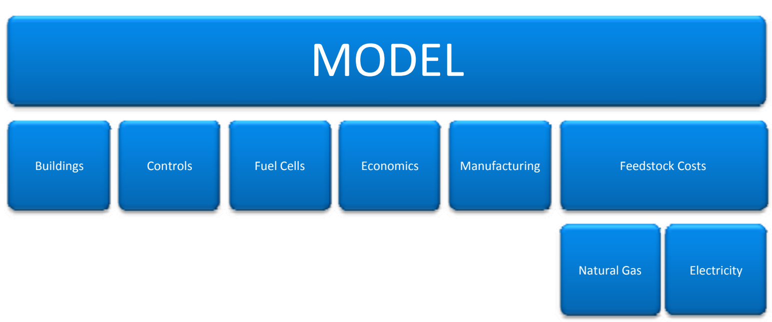
- Build a tool for optimizing fuel cell attributes, including control parameters, and system and component sizes for unique individual building characteristics. Tool will add flexibility for adding user-defined building, fuel cell, financial, control characteristics.
- Tool will be used to minimize lifecycle 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.

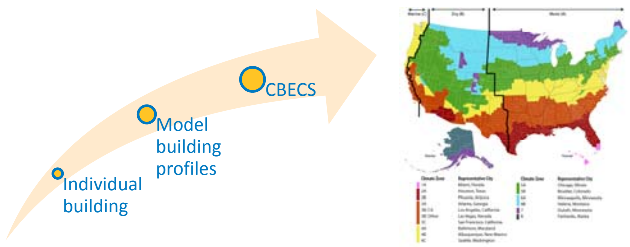
Approach: Buildings Module

- 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 90.1-2004)
Restaurant: quick-service (fast food)	Houston (ASHRAE 2A)	
School: primary school	Phoenix (ASHRAE 2B)	
School: secondary school	Atlanta (ASHRAE 3A)	•"Post-1980" construction (80s/90s, compliant with ASHRAE 90.1-1989)
Office: large office	Los Angeles (ASHRAE 3B-Coast)	
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

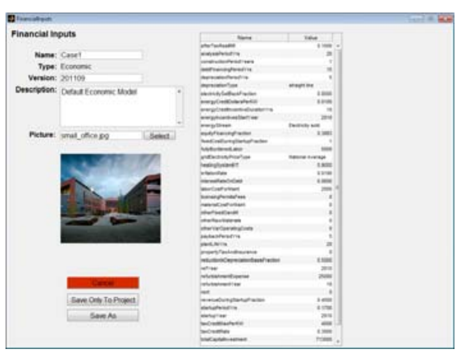
- Fuel cell characteristics such as min/max power, CHP temperature, and ramp rate determine the power and heat available for the next hour.
- Determine the marginal cost of electricity and value of CHP heat offset from grid and fuel pricing.
- Dispatch fuel cell to achieve the desired dispatch goal.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

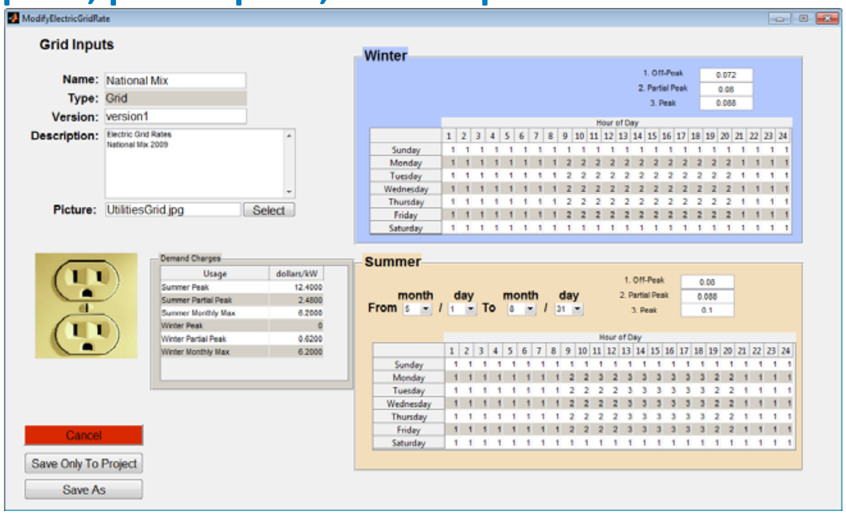
Approach: Economic Module

- 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.



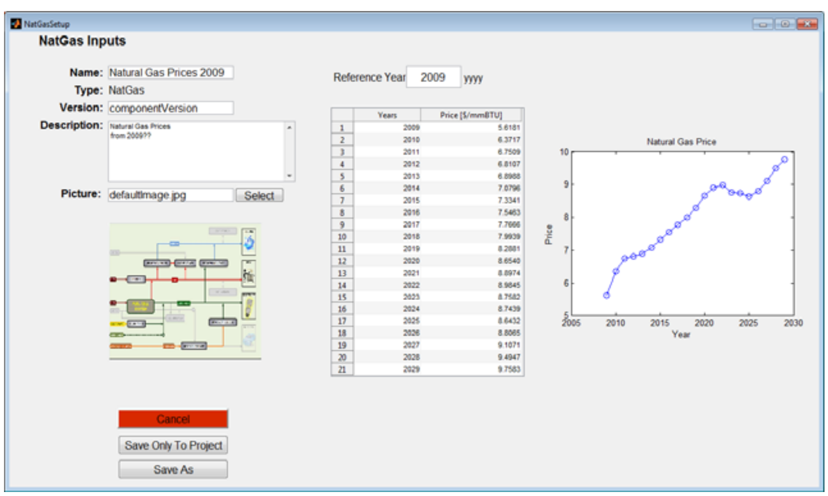
Approach: Grid Pricing Module

- Grid pricing specified as winter/summer peak, partial peak, and off-peak



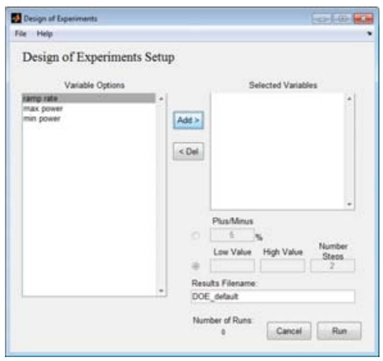
Approach: Natural Gas Pricing Module

- Gas pricing based on Energy Information Administration forecasts



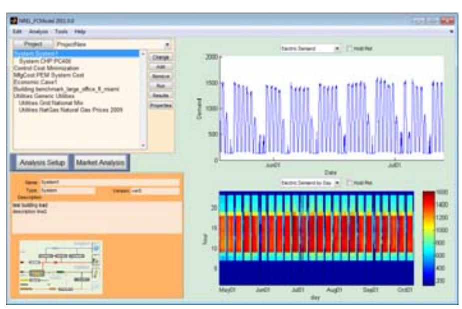
Approach: Optimization & DoE

- 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.



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



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

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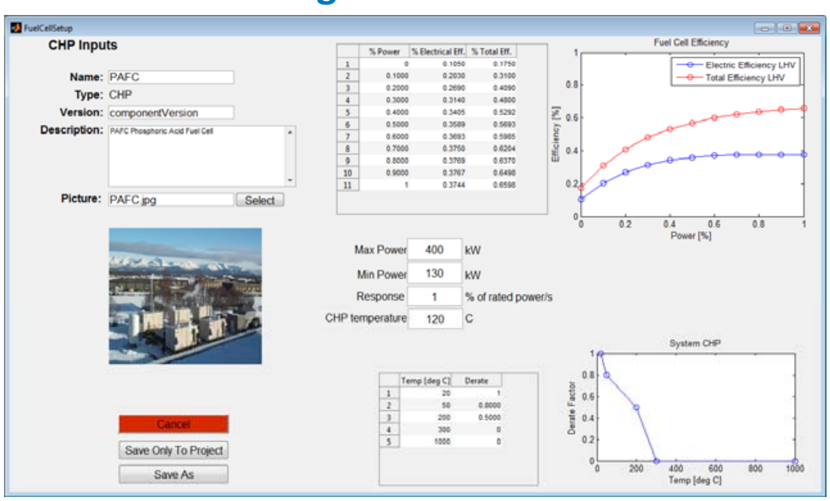
Accomplishments: Fuel Cell System Modules

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



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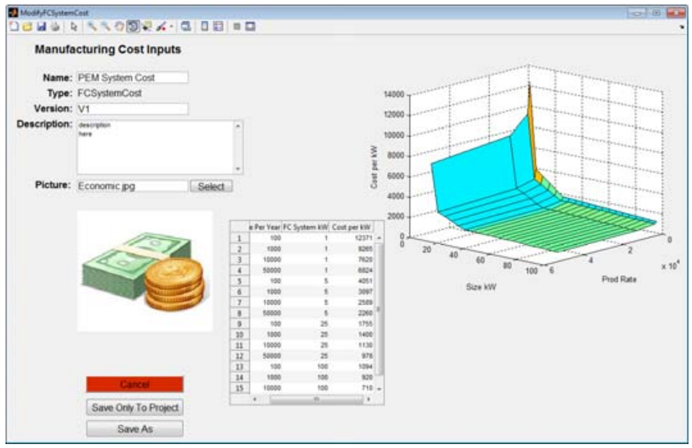
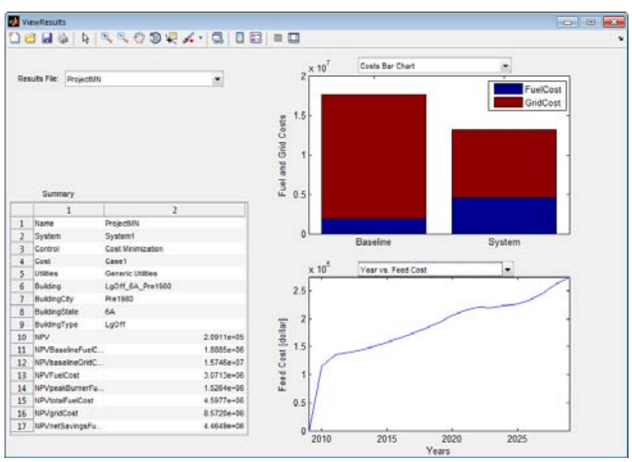
Accomplishments: Manufacturing Cost

- **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.
  - Provide input to CBECS 2012.
- FY13
  - Expand fuel cell types.
  - 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.