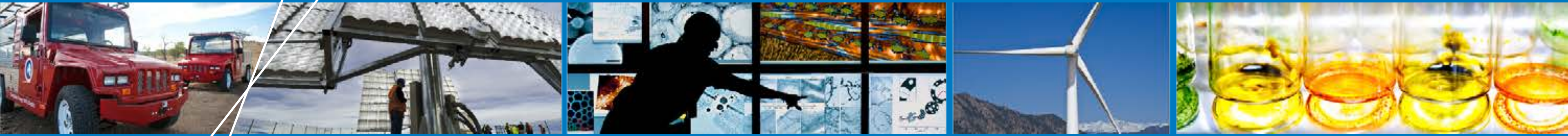
Enlarging Potential National Penetration for Stationary Fuel Cells through System Design Optimization



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National Renewable Energy Laboratory

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Project ID# FC083

Overview

Timeline

- Project start date: October 2011
- Project end date: October 2013*

Barriers Addressed

- Cost
- Durability
- Performance relative to incumbent

Budget

- Total project funding
  - DOE share: $650k
  - Contractor share: $0k
- Funding received in FY12: $300k
- Planned funding for FY13: $50k

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

Partners

- University of California, Irvine (UCI)
- Lawrence Berkeley National Lab (LBNL)**
- Strategic Analysis, Inc.**
- Battelle**
- Acumentrics, Ballard Power Systems, ClearEdge Power, and PNNL (User's group)

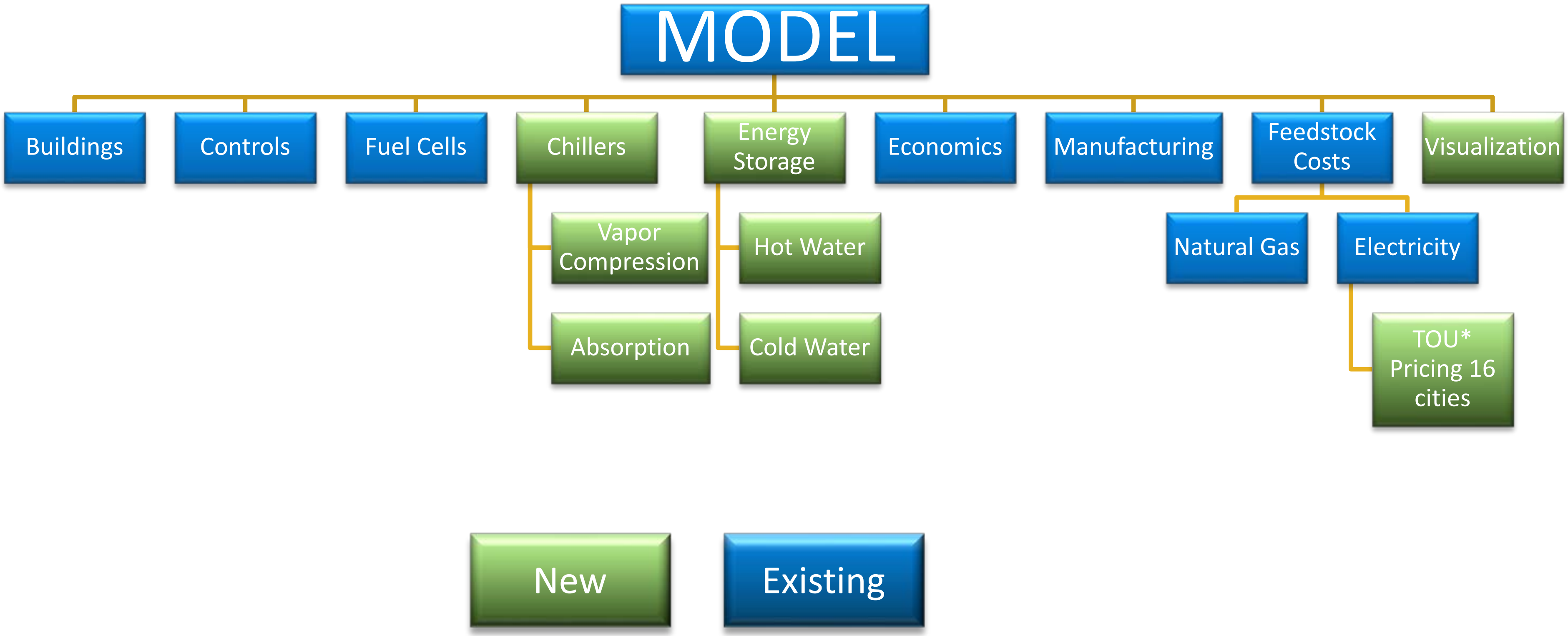
Relevance: Objectives

Technical Challenges	
• Cost • Durability • Performance relative to incumbent	
DOE Goal	**Project Goal**
By 2020, develop medium-scale CHP fuel cell systems (100 kW–3 MW) that achieve 50% electrical efficiency, 90% CHP efficiency, and 80,000 hours durability at a cost of $1,500/kW for operation on natural gas, and $2,100/kW when configured for operation on biogas	Build an open-source tool that helps 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 HVAC systems to maximize durability • Compare performance relative to incumbent technologies • Determine optimum system configuration • Evaluate potential market penetration

Approach: Milestones

02/13 (complete)	Implement updated strategies for cost-minimize, load follow, peak shave, and GHG-minimize dispatch and control into the Commercial Building Fuel Cell Model. UCI subcontract task 2.
4/13	Model verification against actual building/CHP installations
6/13	Scenario analysis
7/13	Demonstrate the fuel cell model to the fuel cell team. This demonstration will serve as the basis for a Go/No-Go decision on further work for the project.

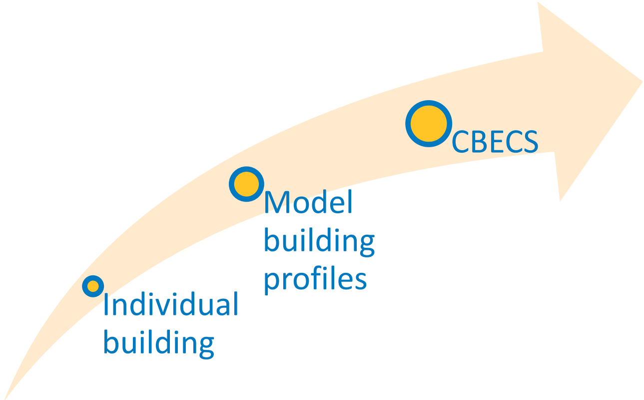
Approach: Construction of the Model



*Time-Of-Use

Accomplishment: Input to CBECS

- **Successfully lobbied for inclusion of relevant questions on building automation, controls, and onsite generation on the 2012 Commercial Building Energy Consumption Survey (CBECS), which is conducted usually every 3-5 years, but has not been updated in its entirety since 2003.**
- **CBECS 2012 will represents the energy usage data for >12,000 (2.3x the number in the 2003 survey) commercial buildings, with statistical extrapolations for the whole country.**
- **By integrating model building results with CBECS, national impact and potential market penetration can be estimated.**



Accomplishment: Building Modules

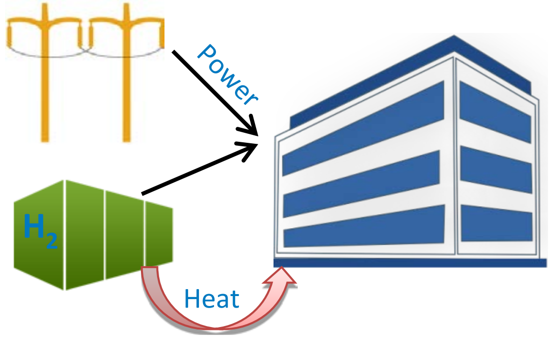
- **NREL's Electricity, Resources, and Building Systems Integration Center has updated energy use profiles for 16 model building types in 16 climate zones, for three different vintages**
- **Building modules were updated to 15-min time step, and building coil loads were added. This enabled modeling of energy storage systems.**
- **Represents about 67% of U.S. commercial inventory**
- **Total:**

  768 profiles

Building types	Locations	Vintages
Restaurant: full-service (sit down)	Miami (ASHRAE 1A)	•New construction (compliant with ASHRAE 90.1-2004)
Restaurant: quick-service	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 (3B-Coast)	
Office: medium office	Las Vegas (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	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)	

Accomplishment: New Control/Dispatch Cases

1



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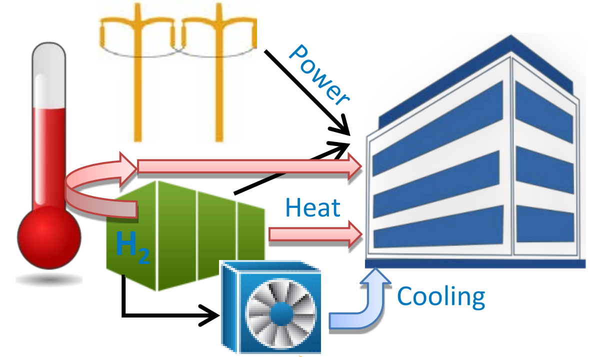

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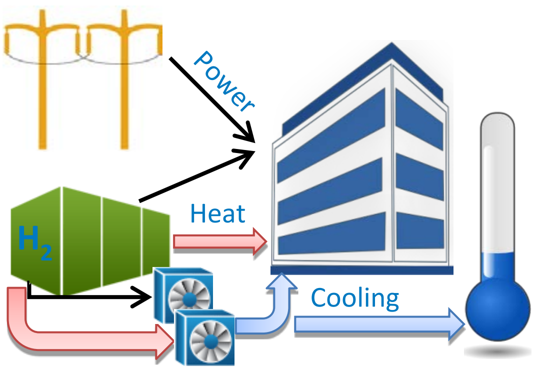

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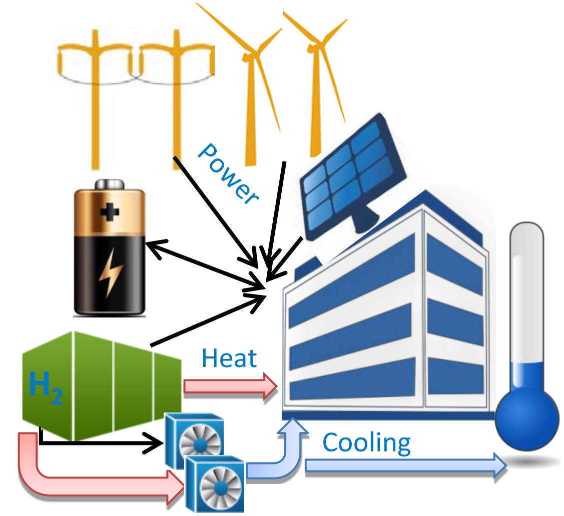


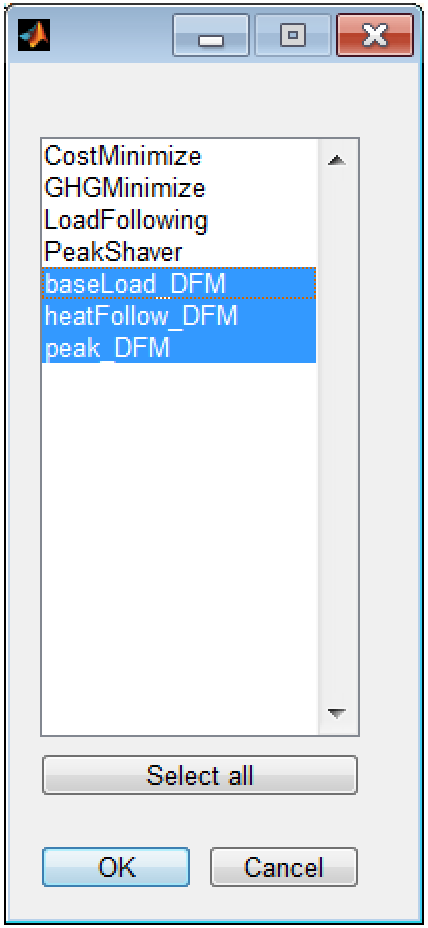
System	FC	Heat Recovery	Electric Chiller	Absorptive Chiller	Cold H_2O Storage	Hot H_2O Storage	Battery Storage	Renewable Generation
1	✓	✓						
2	✓	✓	✓			✓		
3	✓	✓	✓	✓	✓			
4	✓	✓	✓	✓	✓		✓	✓

New Elements to Model

Accomplishment: New Control/Dispatch Cases

UCI added the following control strategies:

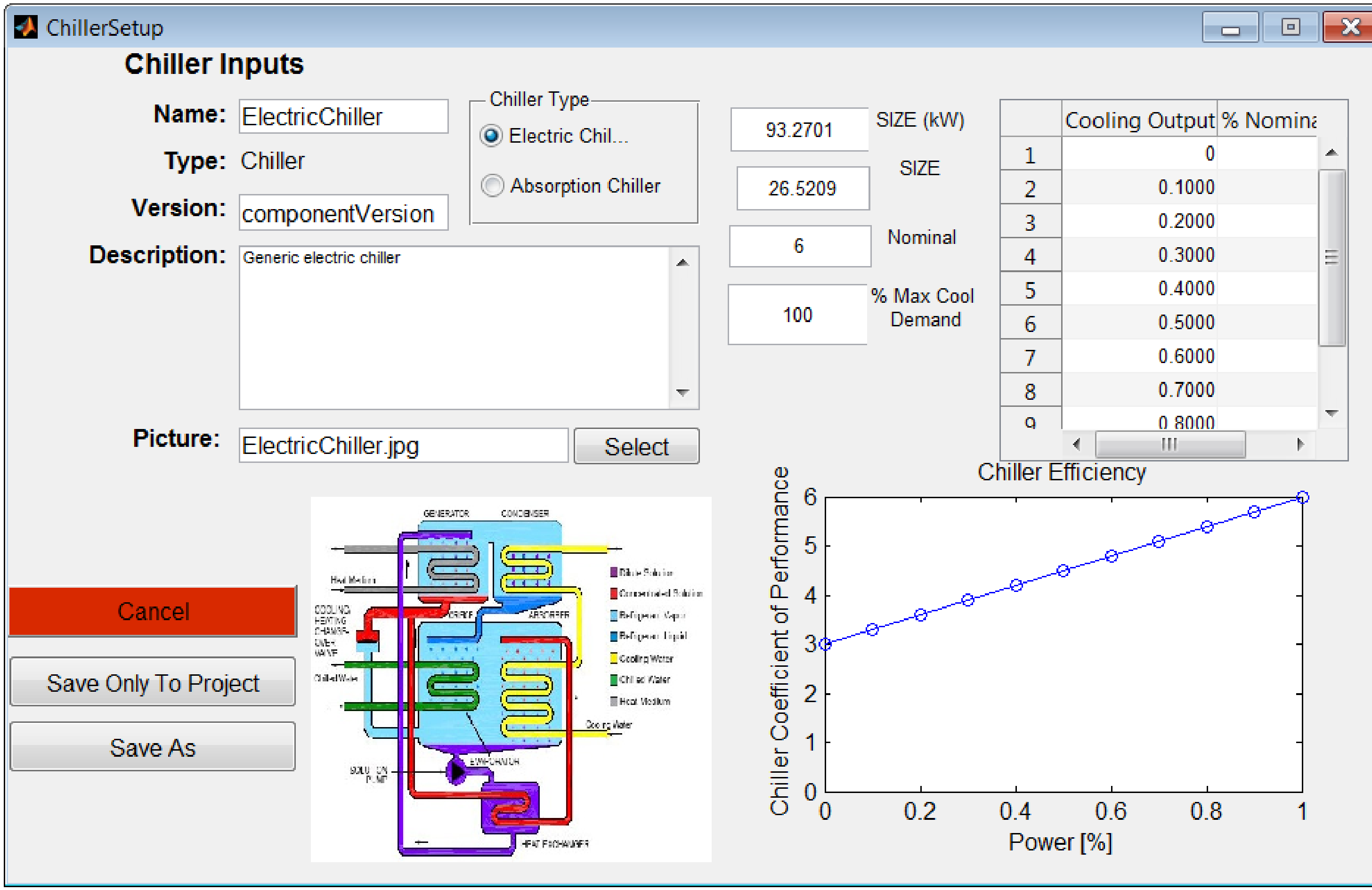
- Baseload
- Heat follow
- Peak, which follows the anticipated daily load in order to minimize system power cycling to help reduce related degradation



Accomplishment: Building Chiller Integration

New integration with building energy systems

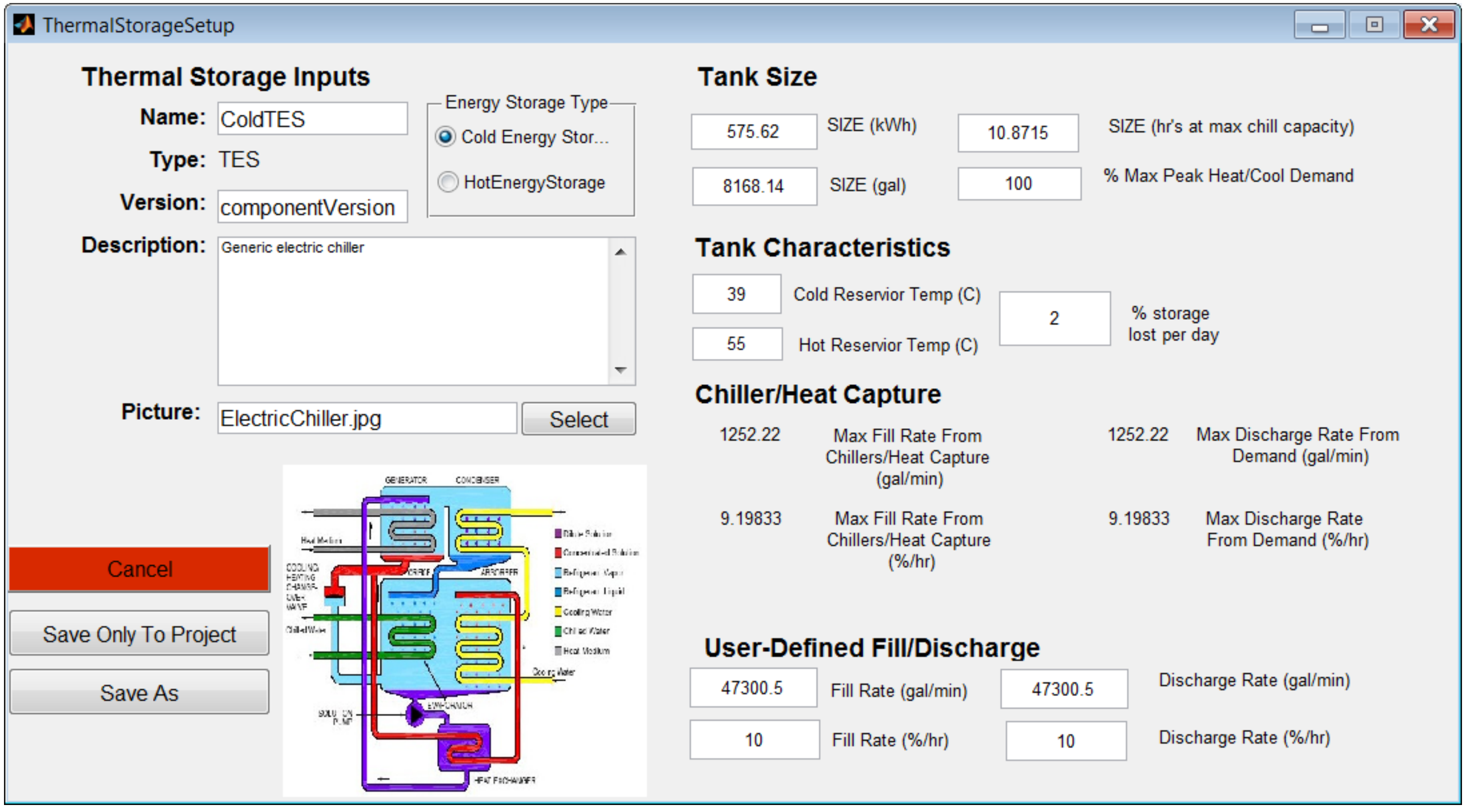
- Electric or absorption chillers



Accomplishment: Building Thermal Energy Storage

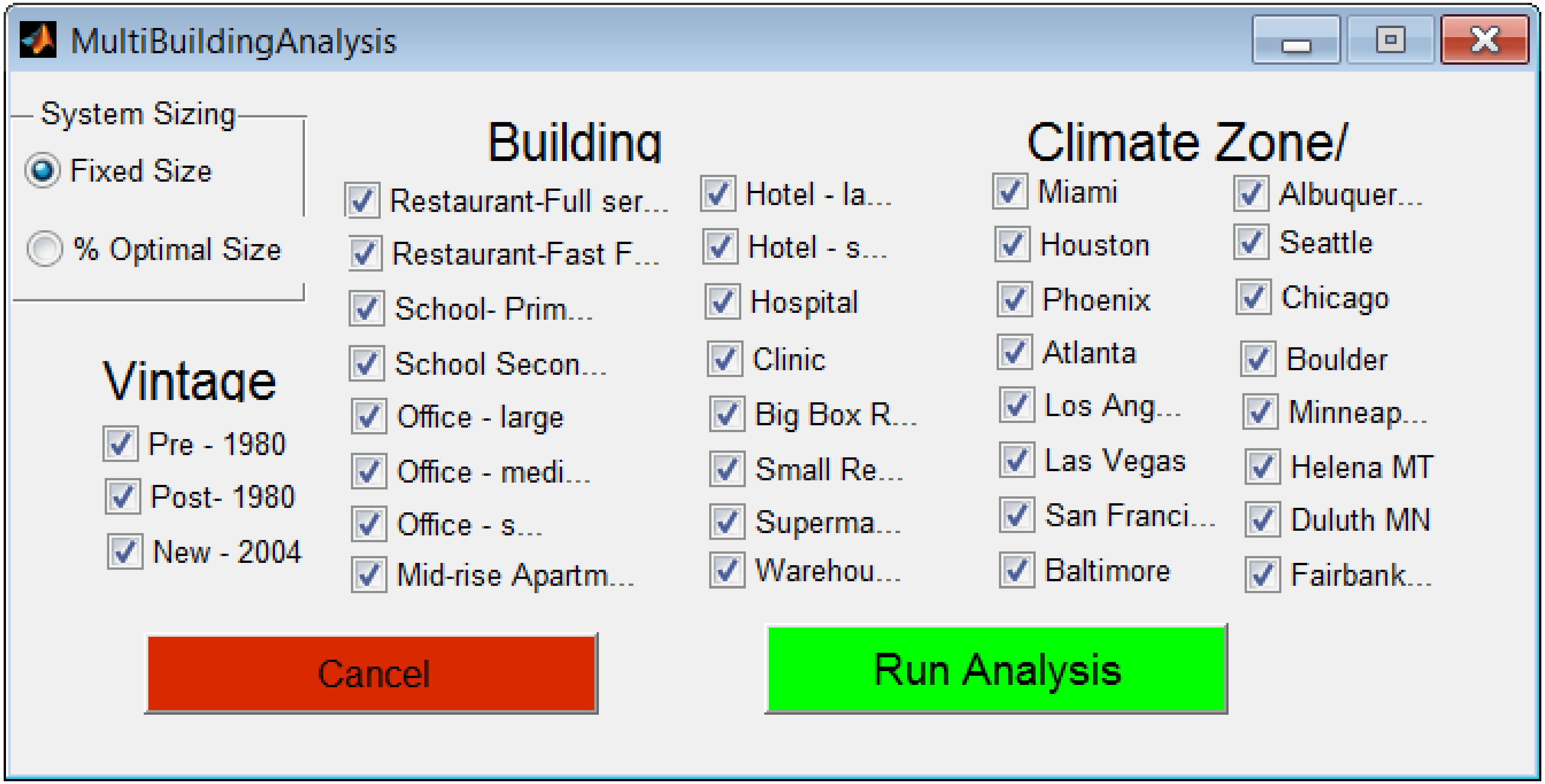
New integration with building energy systems

- Hot or cold water storage, the lowest cost energy storage currently available.



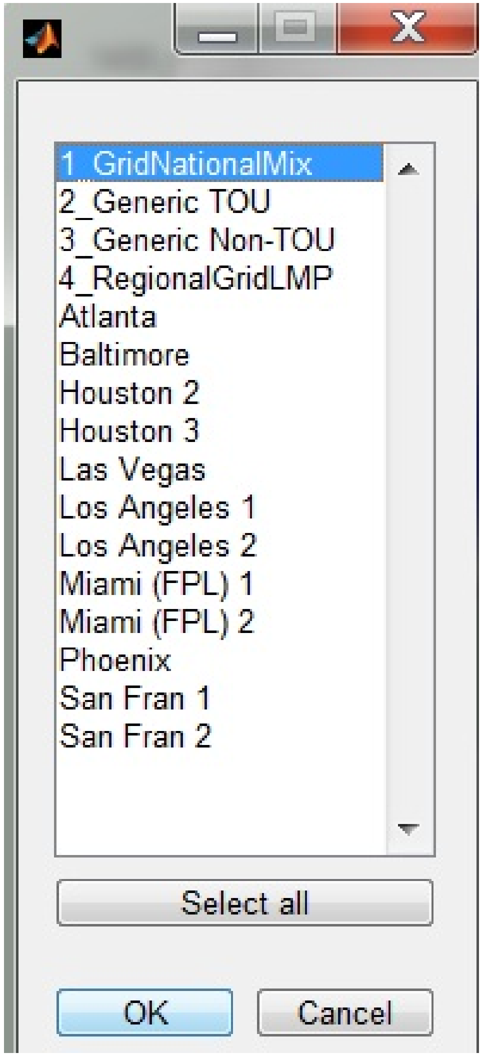
Accomplishment: Optimization of Systems

Ability to analyze all climate zones, building types, and vintages, with either fixed CHP system size or optimal size (lowest energy cost)



Accomplishment: Utility Pricing

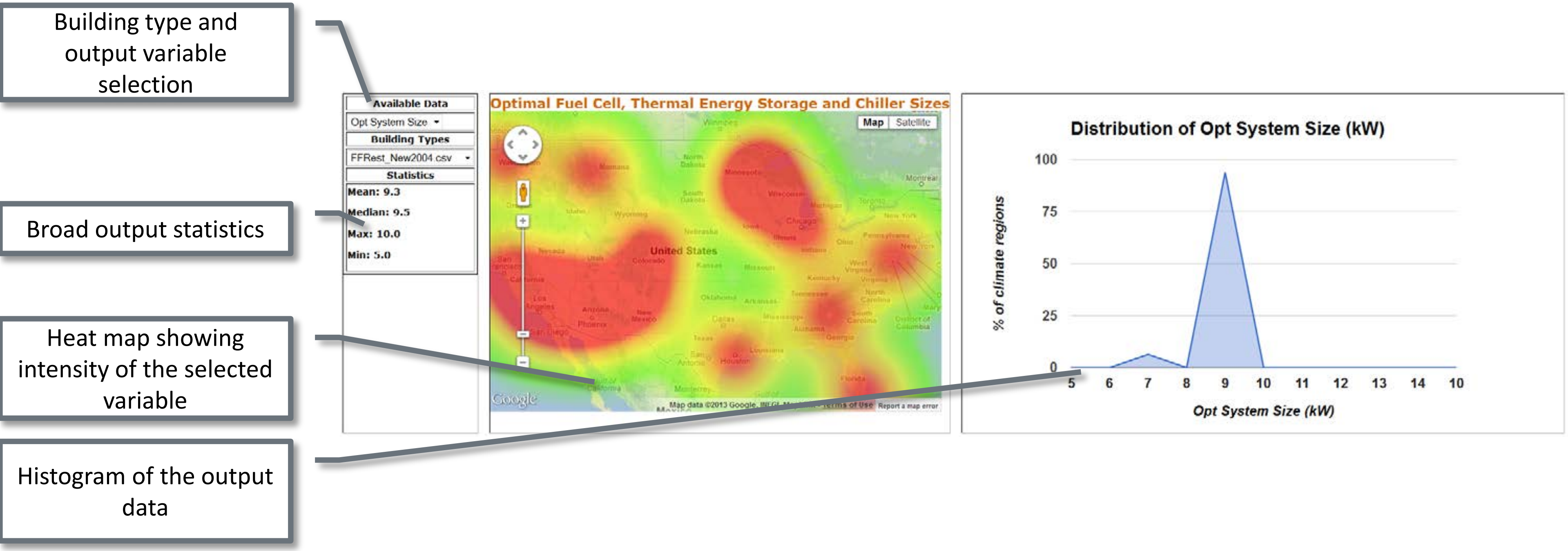
- **National average**
- **Generic TOU or non-TOU**
- **16 cities/climates**
  - Some with multiple rates for small/large users
- **EIA NG forecasts or $0.88/therm**



Accomplishment: Web-Based Visualization

Web-based visualization of an analysis case with a fuel cell system, chiller (vapor compression), and thermal energy (cold water) storage

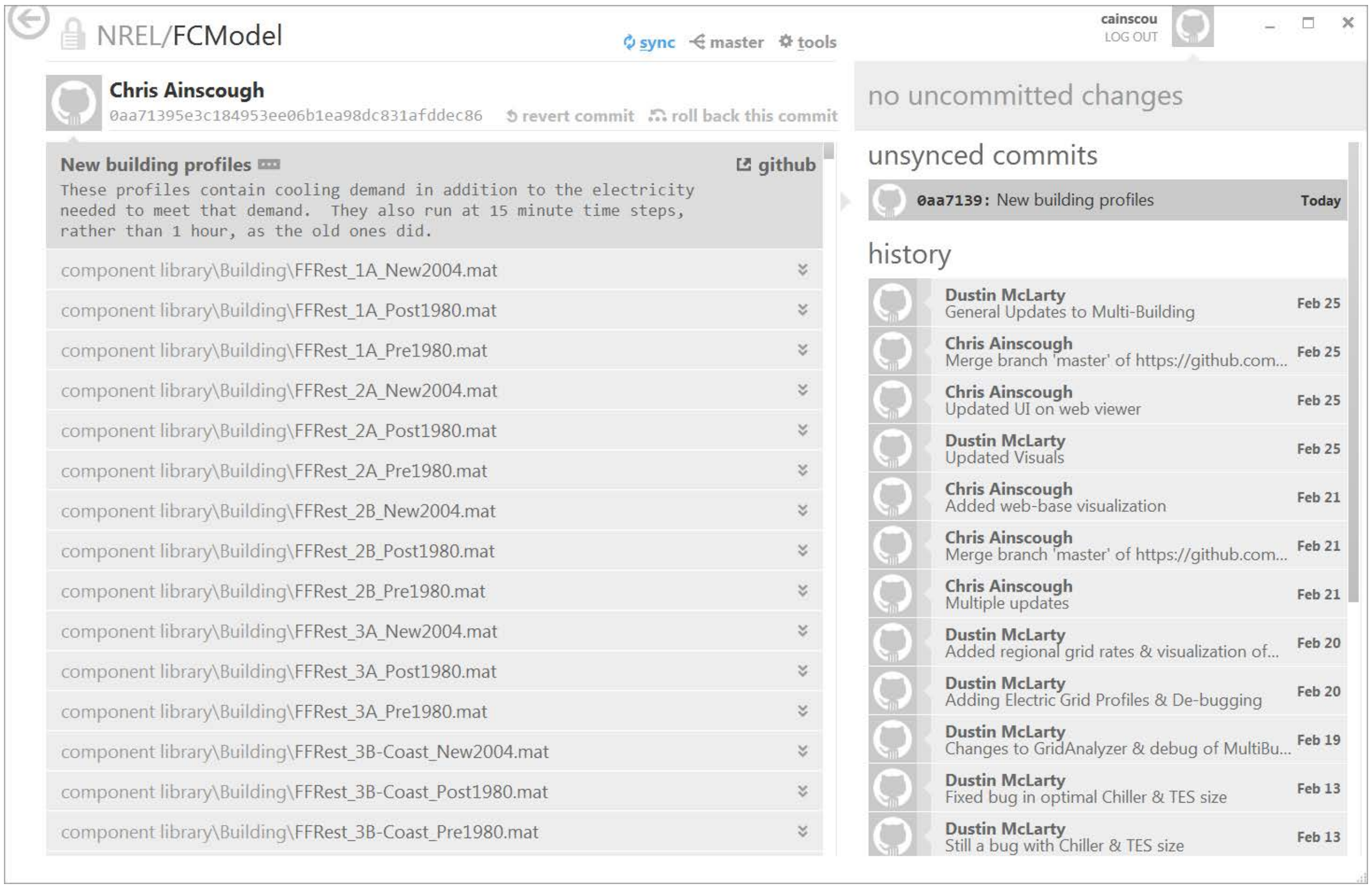
- Can show which applications/markets make sense for fuel cells
- Allows simple non-expert exploration of the analysis



Accomplishment: Open Source Collaboration

Codebase is hosted on GitHub (the largest code host in the world)

- Allows for distributed collaboration
- Open source, controlled access to fuel cell developers, NREL, UCI, and other stakeholders



Collaborations: User's Group

- **Formed a User's Group to guide further development of the model**
  - Currently includes Acumentrics, Ballard Power Systems, ClearEdge Power, and PNNL
  - Members have access to the model and building profiles for their own use, and will be able to contribute code and other modules to the effort
  - All industry stakeholders are invited to participate

Collaborations: Development

- **Controls and integration work**
  - UCI
- **Manufacturing cost analysis (separately funded projects)**
  - LBNL
  - Strategic Analysis, Inc.
  - Battelle
- **Building profiles and analysis**
  - NREL Electricity, Resources, and Building Systems Integration Center (ERBSIC)

Proposed Future Work

- **FY13/14**
  - Go/No-Go
  - Use the tool to evaluate/optimize CHP systems relative to output data from the output of the 2012 CBECS survey
  - Work with fuel cell OEMs on improvements and customizations to the tool
  - Validate model against real-world data

Summary

RELEVANCE This project addresses barriers of cost, durability, and performance relative to incumbent technologies.

APPROACH The approach includes an open source tool that fuel cell OEMs are invited to contribute to and use for their own purposes.

ACCOMPLISHMENTS We have expanded analysis capabilities and integration with commercial building control systems, developed visualizations, and made the code open source.

COLLABORATION Strong collaboration is occurring with industry, academia, and national labs. Open source code allows for contributions from other collaborators.

FUTURE WORK Future work is subject to a go/no-go decision.