

CBERD Task 2.1 Simulation & Modeling

2015 Building Technologies Office Peer Review



U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy

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Project Summary

Timeline:

Start date: 1/1/2013

Planned end date: 9/30/2018

Key Milestones

1. Implementation of ECBC ruleset for code compliance; 9/30/15
2. Implementation of real-time MPC strategies in a building or tests-bed equipped with a low energy HVAC system; 9/30/2016

Budget:

Total DOE \$ to date: \$386k

Total future DOE \$: \$521k

Target Market/Audience:

- A&E design practitioners
- Code officials
- Control engineers
- Operators
- Researchers

Key Partners:

| | |
|----------------|--------------------|
| IIIT Hyderabad | Autodesk |
| CEPT | HOK Architects |
| UC Berkeley | Schneider Electric |

Project Goals:

- Improve building energy efficiency through the use of smart, integrated simulation tools for design and operation
- Develop new methods for reducing the energy consumption of existing and new buildings – controls, diagnostics

Purpose and Objectives

Problem Statement:

Simulation tools do not fully meet the needs of practitioners from early stage design to operation

Target Market and Audience:

- Architects, mechanical engineers, code officials, control engineers, operators.
- Existing and new commercial buildings in India and the US
- Enabling technologies, contributing to technical potential of 40% of 510 TWh/yr in India and 36% of 3200 TWh/yr in US by 2030

Impact of Project:

1. Products: Improved analysis tools for early design, rulesets for code compliance, control strategies for radiant slab systems, diagnostic tools
2. Impact metrics:
 - a. Near-term: Adoption
 - b. Intermediate-term: Case studies of benefits
 - c. Long-term: Impact on building stock

Approach

Approach: Identify needs/opportunities to improve tools and supporting data. Develop, implement and test new, high priority capabilities for existing tools and control systems. Leverage external R&D

Key Issues - selected for joint research interest and impact potential:

- early stage design analysis - optimization
- code compliance tools - extend ASHRAE 90.1 Appendix G capabilities to ECBC
- control of passive thermal storage to exploit diurnal swing and shift load - model predictive control
- automated diagnostics - test new and existing methods

Distinctive Characteristics:

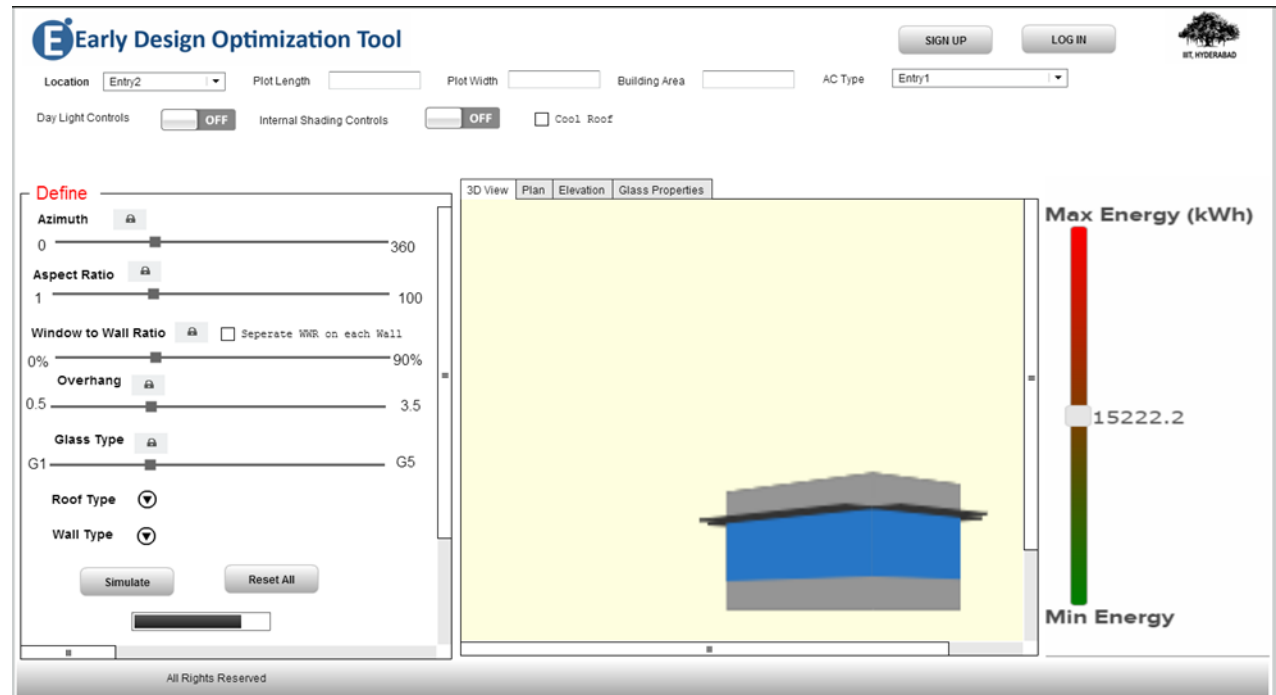
- adoption of rule-based representation of building energy codes and exploitation of similarities between ASHRAE 90.1 and ECBC
- collaboration on test facility design

Progress and Accomplishments – Early Design Optimization

Lessons Learned: Clients are requiring progressively more early stage design analysis

Accomplishments: Early Design Optimization Tool (eDOT)

- Based on survey of architects
- On-line tool
- Multi-parameter optimization:
 - 10 envelope parameters
- 4 HVAC system types
- Uses EnergyPlus and GenOpt



Market Impact:
(Too early for measurable impacts)

Awards/Recognition: (None as yet)

Progress and Accomplishments - ASHRAE 90.1/ECBC

Lessons Learned: Easier access to performance-based code compliance tools needed

Accomplishments: Tool for ASHRAE 90.1/ECBC base case parameters

- Generate base case parameters from as-designed /proposed case

Base/Standard Case Parameter Generator

Building Type: Climate Zone: VAVR:
 Skylight Roof ratio: No Of Floors: Condition Area:
 Heating Source: Apply Reset

- Useful stand-alone
- First step in mapping ECBC to Appendix G

| Component | Standard/Base Design Parameters | As-Designed/Proposed Parameters | ECM Check |
|--------------------|---------------------------------|---|-----------|
| Roof: | | U-Value <input type="text"/> $W/m^2 \cdot K$ Calculate | - |
| | | Minimum Insulation R-Value <input type="text"/> $m^2 \cdot K/W$ | |
| Roof Reflectivity: | | Actual Reflectivity <input type="text"/> | - |
| | | Actual Emissivity <input type="text"/> | |
| Above-Grade Walls: | | U-Value <input type="text"/> $W/m^2 \cdot K$ Calculate | - |
| | | Minimum Insulation R-Value <input type="text"/> $m^2 \cdot K/W$ | |

Market Impact:
(Too early for measurable impacts)

Awards/Recognition: (None as yet)

Progress and Accomplishments - Model Predictive Control

Lessons Learned:

Model predictive control can improve energy and comfort but needs integrated tools for practitioners

Accomplishments:

Development of tools for model identification and simulation

- Generate base case parameters from as-designed /proposed case
- Useful stand-alone
- First step in mapping ECBC to Appendix G

Market Impact:

(Too early for measurable impacts)

Awards/Recognition: (None as yet)

Model identification using EnergyPlus simulation



Automatically design predictive controller for simplified model



Run closed-loop simulation with EnergyPlus model using MLE+

Project Integration and Collaboration

Project Integration:

- Collaboration with Architectural Energy Corporation, 360 Analytics and Wrightsoft on development of code compliance rulesets
- Collaboration with Infosys and UC Berkeley CBE on measurement of radiant system performance

Partners, Subcontractors, and Collaborators:

- Collaboration with AutoDesk Research on real-time visualization of energy and IEQ performance
- Collaboration with IIT Hyderabad on ECBC ruleset development
- Collaboration with UC Berkeley on development of model predictive control for radiant slabs
- Collaboration with IIT Hyderabad on design and commissioning of diagnostics test facility

Communications:

(None as yet – key opportunity: Building Simulation 2015 in Hyderabad)

Next Steps and Future Plans - I

- Rule sets for performance-based code compliance:
 - Uses rule-based approach developed by CBERD partner CEC – rules as data
 - Builds on ASHRAE 90.1 ruleset recently developed by an Architectural Energy Corp team, funded by DOE
 - Development of ECBC ruleset by IIT-Hyderabad and LBNL, adapted from ASHRAE 90.1 ruleset (ECBC is based on ASHRAE 90.1)
- Continue development of model predictive control for thermal mass storage in low energy systems – radiant slab cooling, natural ventilation:
 - Specification of a graphical user interface for EnergyPlus users to access MPC tools and prototyping in OpenStudio
 - Characterization of effect of uncertainty in input data and model simplifications on actual quality of control
- Testing of eDOT at LBNL and HOK

Next Steps and Future Plans - II

- Collaboration with AutoDesk Research on visualization of energy and IEQ performance: Project Dasher + real-time EnergyPlus
 - Initial implementation in LBNL Building 90 (FLEXLAB)
- Develop model-based fault detection and diagnosis (FDD) tools for whole building, system and component levels:
 - IIIT-Hyderabad fault diagnostics test facility:
 - Matched pair of cells, each with its own air handling unit
 - Comparative testing of new and existing FDD methods
 - Next step: commissioning

REFERENCE SLIDES

Project Budget

Budget History

| 1/1/2013 - FY2014 (past) | | FY2015 (current) | | FY2016 – 12/31/2017 (planned) | |
|-----------------------------|------------|---------------------|------------|----------------------------------|------------|
| DOE | Cost-share | DOE | Cost-share | DOE | Cost-share |
| \$360k | ~\$80k | \$180k | ~\$1M | \$367k | ~\$1M |

Variances: No significant variances

Cost to Date: ~50%

Project Plan and Schedule

| Project Schedule | | | | | | | | | | | | |
|---|--|--------------|--------------|--------------|--------------|--------------|--|--------------|--------------|--------------|--------------|--------------|
| Project Start: 01/2013 | Completed Work | | | | | | | | | | | |
| Projected End: 9/30/17 | Active Task (in progress work) | | | | | | | | | | | |
| | ◆ Milestone/Deliverable (Originally Planned) | | | | | | | | | | | |
| | ◆ Milestone/Deliverable (Actual) | | | | | | | | | | | |
| | FY2013 | | | | FY2014 | | | | FY2015 | | | |
| Task 2.1: Simulation and Modeling | Q1 (Oct-Dec) | Q2 (Jan-Mar) | Q3 (Apr-Jun) | Q4 (Jul-Sep) | Q1 (Oct-Dec) | Q2 (Jan-Mar) | Q3 (Apr-Jun) | Q4 (Jul-Sep) | Q1 (Oct-Dec) | Q2 (Jan-Mar) | Q3 (Apr-Jun) | Q4 (Jul-Sep) |
| Past Work | | | | | | | | | | | | |
| FY2013 Q2 Milestone: Design specifications for Simergy low energy enhancements | | | ◆ | | | | | | | | | |
| FY2013 Q3 Milestone: Define early stage design workflow for GUI | | | | ◆ | ◆ | | | | | | | |
| FY2013 Q3 Milestone: Stochastic MPC design for low energy HVAC systems | | | | ◆ | ◆ | | | | | | | |
| FY2013 Q4 Milestone: Tool to extract MPC models from EnergyPlus | | | | | ◆ | | | | | | | |
| FY2014 Q1 Milestone: 90.1 and T-24 rule sets for CEC SDK | | | | | | ◆ | (n/a due to change of strategy - no development for Simergy) | | | | | |
| FY2014 Q1 Milestone: Tool to generate MPC design from reduced-order model | | | | | | ◆ | | | | | | |
| FY2014 Q2 Milestone: Simergy hybrid ventilation beta version | | | | | | | ◆ | | | | | |
| FY2014 Q3 Milestone: Compare sample-based and explicit methods for MPC | | | | | | | ◆ | | | | | |
| Current/Future Work | | | | | | | | | | | | |
| FY2015 Q3 Milestone: testing of ASHRAE 90.1 Appendix G rule set | | | | | | | | | | | | ◆ |
| FY2015 Q2 Milestone: EnergyPlus integration of MPC tools developed in Years 1 & 2 | | | | | | | | | | | | ◆ |
| FY2015 Q4 Milestone: testing of ECBC ruleset | | | | | | | | | | | | ◆ |
| FY2015 Q4 Milestone: Study: efficient MPC design for large number of coupled zones | | | | | | | | | | | | ◆ |
| FY2015 Q4 Milestone: Beta test version of ECBC ruleset | | | | | | | | | | | | ◆ |
| FY2015 Q4 Milestone: First test of automated FDD | | | | | | | | | | | | ◆ |
| FY2015 Q4 Milestone: Testing of eDOT with HOK | | | | | | | | | | | | ◆ |