Validation and Uncertainty Characterization for Energy Simulation (#1530)

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Co-PI’s:
Ron Judkoff (NREL), Joshua New (ORNL), Ralph Muehleisen (ANL)

BTO Merit Review - April 16/17, 2015
Problem Statement

Sources of differences:

- **Uncertainty:**
  - model algorithms
  - input parameters
  - modeler decisions

- **Variability:**
  - weather
  - occupancy
  - operation


Goals

Validation:
Enable substantial improvements in the energy performance of new construction and major retrofits by increasing the accuracy and credibility of all energy simulation tools.

Uncertainty:
Facilitate the management of risk associated with the procurement of high performance buildings by characterizing the uncertainty of energy performance predictions.
ASHRAE Standard 140 *Method of Test for Evaluation of Building Energy Analysis Computer Programs* is based on IEA BESTEST procedures:

- **Standard 140 tests & partially validates energy calculations**
  - Analytical tests – idealized cases → partial validation
  - Comparative tests - no ‘ground truth’

- **The Standard 140 framework accommodates** empirical tests but does not include any

- **We now have facilities to** make cost-effective empirical testing possible:
  - LBNL FLEXLAB
  - ORNL FRP
  - NREL HVAC

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**Doesn’t BESTEST Validate Energy Calculations?**

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**Standard 140-2007 Cooling Load Comparison**

- ESP
- Blast
- DOE2.1D
- DOE2.1E
- TRNSYS
- EnergyPlus
Objectives

- Generate sets of measured data for simulation model validation:
  - Set priorities based on Validation Roadmap and input from TAG
  - Conventional systems (↔ existing Standard 140 cases)
  - Low energy systems
  - Control of multi-zone systems
  - HVAC performance maps
  - EnergyPlus and commercial programs

- Implement a framework for estimating the uncertainty of simulation results:
  - Develop a representation of ‘model form’ uncertainty driven by validation data
  - Extend the implementation of the input parameter uncertainty framework in OpenStudio
Experimental Facilities - LBNL

LBNL: FLEXLAB

- 4 matched pairs of 20’x30’ test cells
- 1 pair of cells rotates
- Reconfigurable south façade
- Radiant slab and panels
Experimental Facilities – NREL

NREL: HVAC test facility

- Performance maps of HVAC components ≤ 10 tons
- Uncertainty < 5%
Experimental Facilities – ORNL

ORNL: Flexible Research Platforms (FRP)

- Two buildings:
  - Two story, 5 zones per floor
  - Single story, large zone
Work Plan

Planning and Experiment Design
Review by TAG and TDM

Model Uncertainty Framework

FLEXLAB Conventional
FRP Multi-zone

FLEXLAB Low Energy
NREL HVAC

Testing & Validating EnergyPlus

Standard 140
Deployment Paths

- Submit measured data sets for inclusion in **ASHRAE Standard 140** – used by:
  - IRS tax incentives qualified software procedure (20 tools qualified)
  - ASHRAE 90.1, Commercial Building Energy Standard
  - International Energy Conservation Code (IECC)
  - ASHRAE 189, Green Building Design Standard
  - International Green Construction Code (IGCC)

- **Technical Advisory Group:**
  - Simulation software developers/vendors, members of SSPC-140
  - Users: design practitioners, ESCO’s, utilities, manufacturers, policy analysts
  - Experimental researchers

- **IBPSA**
IRS & RESNET Qualified Software BESTEST’ed with Standard 140

179D Commercial Building Tax Credits (13 Simulation Tools)

- EnergyPlus
- EDSL Tas
- EnergyGauge®
- DesignBuilder
- TRNSYS 17
- DOE-2
- CoolTool
- Carrier
- EnergyPro
- Autodesk® Green Building Studio®
- EnerSim
- Hourly Analysis Program (HAP)

RESNET (HERS, IECC, Tax Credits)(7 Tools)

- ekotrope
- IC3
- EnergyGauge®
- APOGEE InterActive
- EnergyPro
- EnergyInsights™
- REM/Design™
- REM/Rate™

Energy Technologies Area
Benefits to EERE

◆ Impact:
  
  - **Designer confidence**: direct energy savings from greater user of advanced low-energy systems and improved integrated design
  
  - **Investor confidence**: management of risk → scaling up of high performance building projects

  **2030 savings**: target NC and EB > 50,000 sf, increase savings by 10% in 50% of target population → **0.5 quads/yr**

◆ **Additionality**: No empirical validation work in the US and little elsewhere

◆ **Proper Role of Government**:
  
  - Private sector does not have the technical resources to collect validation data
  
  - Validation data need to be generated by objective, respected organizations
### Project Schedule

**Project Start:** 10/1/2015

**Projected End:** 9/30/2018

#### Future Work (Lead Org.)

<table>
<thead>
<tr>
<th>Task</th>
<th>FY2016</th>
<th>FY2017</th>
<th>FY2018</th>
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<tbody>
<tr>
<td>Task 1: Planning, experiment design (LBNL)</td>
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<td>Task 2: Model uncertainty framework (ANL)</td>
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<td>Task 3: FLEXLAB I: conventional systems</td>
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<td>Task 4: HVAC performance maps (NREL)</td>
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<td>Task 5: Multi-zone measurements (ORNL)</td>
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<td>Task 6: FLEXLAB II: low-energy systems</td>
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<td>Task 7: EnergyPlus validation (LBNL)</td>
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<td>Task 8: ASHRAE Standard 140 (NREL)</td>
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Budget

◆ Synergies with other FLEXLAB projects – instrumentation and set-up:
  - PG&E: Comparison of radiant cooling and VAV
  - SCE: compare HVAC loads predicted by EnergyPlus, DOE-2.1e and DOE-2.2 (eQuest) with FLEXLAB measurements
  - CEC: UC Berkeley testing performance, sizing and control of radiant systems
  - Cost share calculable once project plan is established (Task 1)
Key Personnel

- Philip Haves (LBNL): simulation applications, model development, instrumentation
- Ron Judkoff (NREL): validation, Standard 140, IEA Operating Agent
- Joshua New (ORNL): software development, calibration, supercomputing
- Ralph Muehleisen (ANL): uncertainty analysis, algorithms, agent-based modeling
Questions?
## Milestones

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Date</th>
<th>Go / No-go</th>
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<tbody>
<tr>
<td>Draft project plan and first experiment designs reviewed by TAG</td>
<td>12/15/2015</td>
<td>Approval by TAG and TDM</td>
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<tr>
<td>First EnergyPlus validation with FLEXLAB data</td>
<td>6/15/2016</td>
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<tr>
<td>First EnergyPlus validation with NREL data</td>
<td>6/15/2016</td>
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<tr>
<td>Updated project plan for Year 2 approved</td>
<td>8/31/2016</td>
<td>Approval by TAG and TDM</td>
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<tr>
<td>First EnergyPlus validation with FRP data</td>
<td>9/15/2016</td>
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<td>First uncertainty model form characterization with measured data</td>
<td>9/15/2016</td>
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<tr>
<td>First EnergyPlus validation of alternative zone models</td>
<td>3/15/2017</td>
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<tr>
<td>First submission to SSPC 140</td>
<td>5/31/2017</td>
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<tr>
<td>Updated project plan for Year 3 approved</td>
<td>8/31/2017</td>
<td>Approval by TAG and TDM</td>
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<tr>
<td>Final submission to SSPC 140</td>
<td>5/31/2018</td>
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## Deliverables - I

<table>
<thead>
<tr>
<th>Deliverables</th>
<th>Date</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>D1.1. Project plan for Years 1–3 and detailed plan for Year 1</td>
<td>1/31/2016</td>
<td>Prioritized test list and testing schedule approved by TAG</td>
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<tr>
<td>D7.1. Tables of EnergyPlus model input uncertainties, EnergyPlus model output uncertainties, and experimental measurement uncertainties for selected experiments</td>
<td>1/31/2016</td>
<td>For internal team use and subsequent use by other validation researchers</td>
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<tr>
<td>D1.2. Updated project plan for Years 2–3 and detailed plan for Year 2</td>
<td>8/15/2016</td>
<td>Prioritized test list and testing schedule approved by TAG</td>
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<td>D2.1. Estimates of EnergyPlus model discrepancies for selected experiments</td>
<td>9/15/2016</td>
<td>EnergyPlus measurement comparisons for FLEXLAB, NREL, and FRP experiments</td>
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<td>D2.3. Report on extension of model form framework methodology to quasi-real-time models</td>
<td>3/15/2017</td>
<td>Eliminate need for Monte Carlo model analysis that would preclude use in quasi-real-time experiment analysis</td>
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<td>D8.1. First submission to SSPC 140 and report on SSPC response</td>
<td>7/31/2017</td>
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<tr>
<td>Deliverables</td>
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<td>Description</td>
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<tr>
<td>D1.3. Detailed plan for Year 3</td>
<td>8/15/2017</td>
<td>Prioritized test list and testing schedule approved by TAG</td>
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<tr>
<td>D8.1. Final submission to SSPC 140 and report on SSPC action</td>
<td>7/31/2018</td>
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