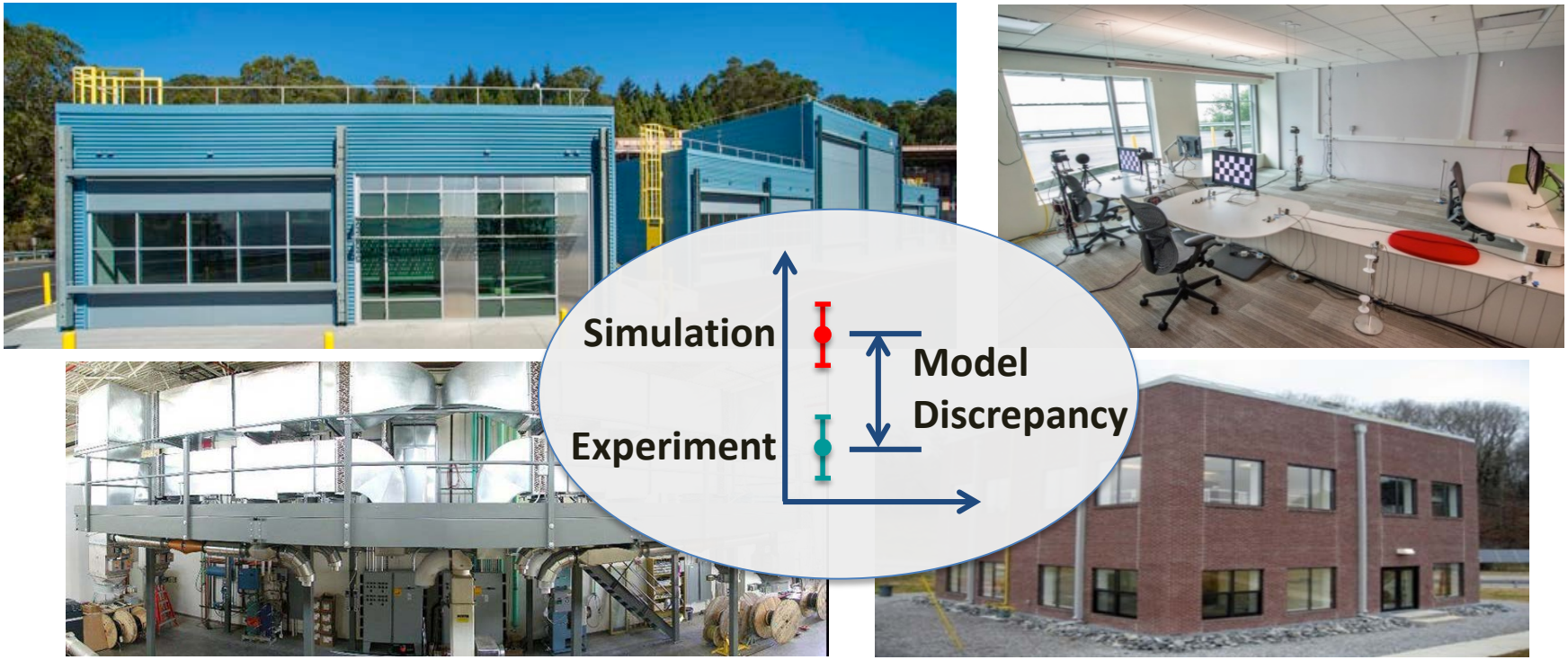
Validation and Uncertainty Characterization for Energy Simulation (#1530)

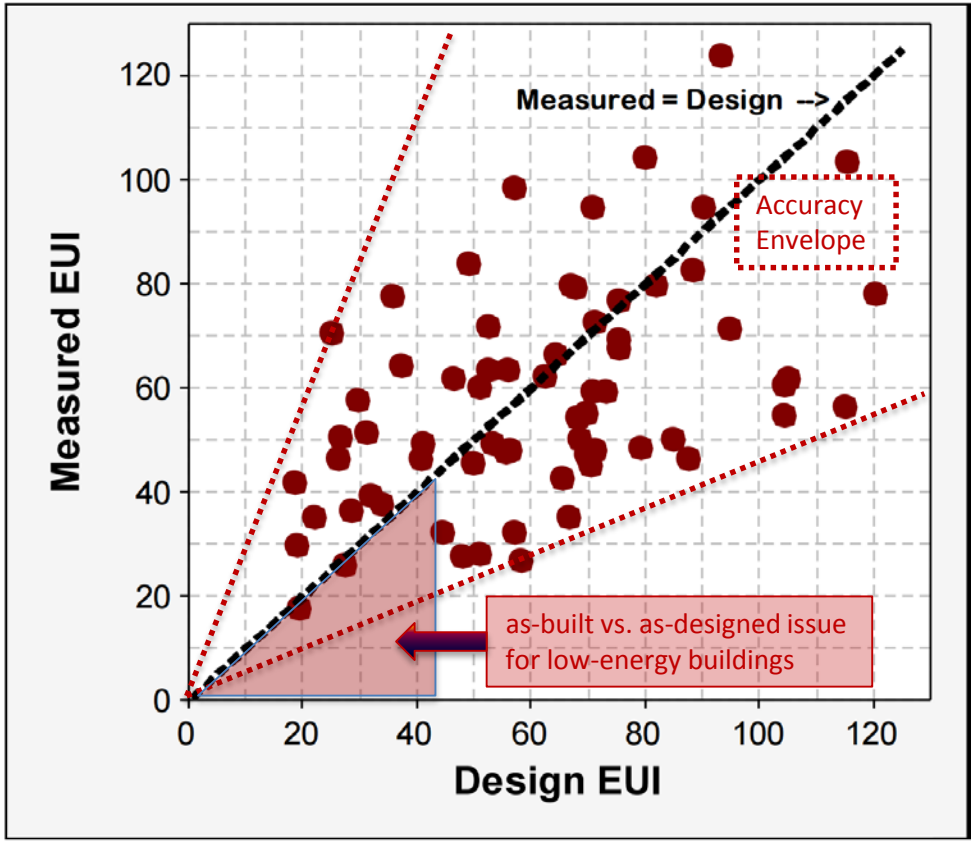


Philip Haves (LBNL)

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

BTO Merit Review - April 16/17, 2015

Problem Statement



Source: Energy performance of LEED-NC buildings, NBI, 2008

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.

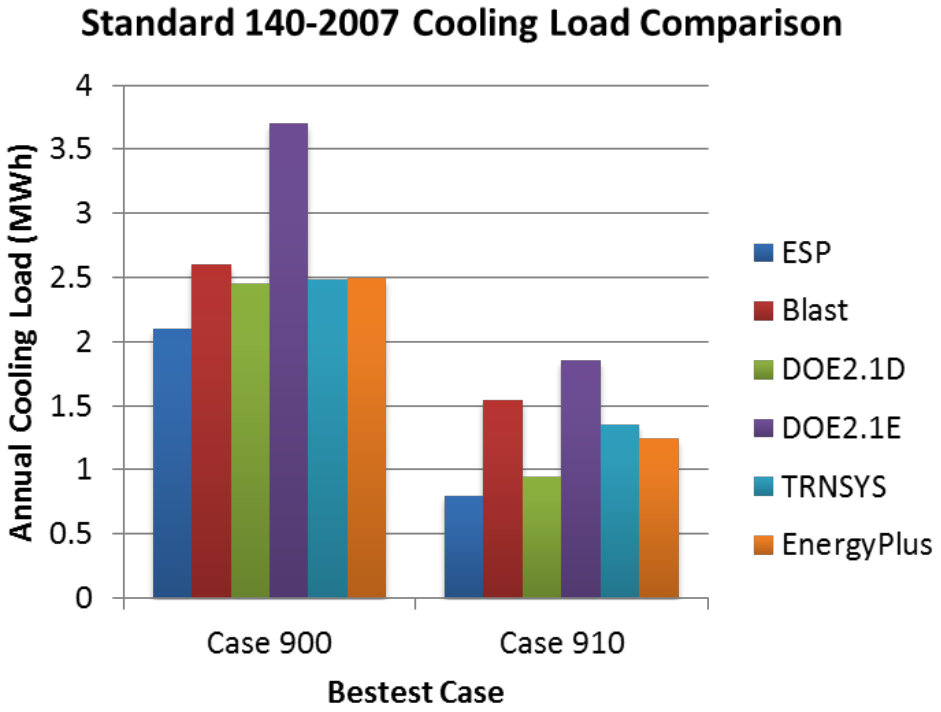
Uncertainty:

Facilitate the management of risk associated with the procurement of high performance buildings by characterizing the uncertainty of energy performance predictions.

Doesn't BESTEST Validate Energy Calculations?

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



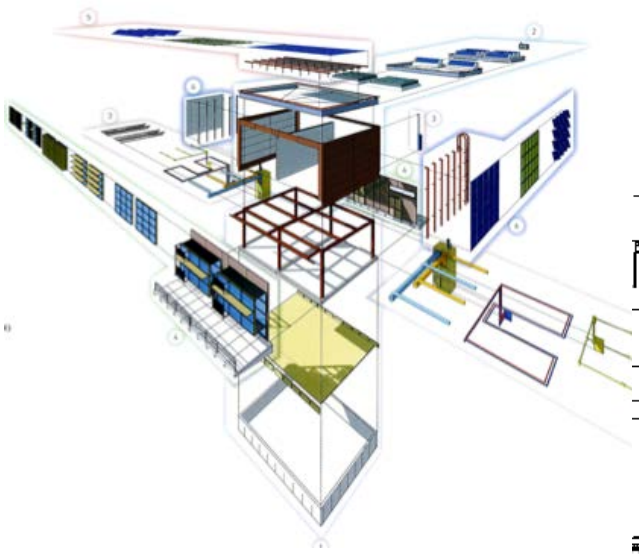
Objectives

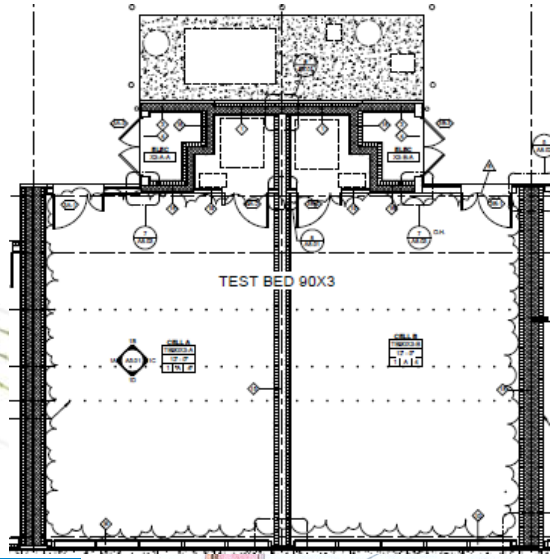
- Generate sets of measured data for simulation model validation:
  - Set priorities based on Validation Roadmap and input from TAG
  - Conventional systems (↔ existing Standard 140 cases)
  - Low energy systems
  - Control of multi-zone systems
  - HVAC performance maps
  - EnergyPlus and commercial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

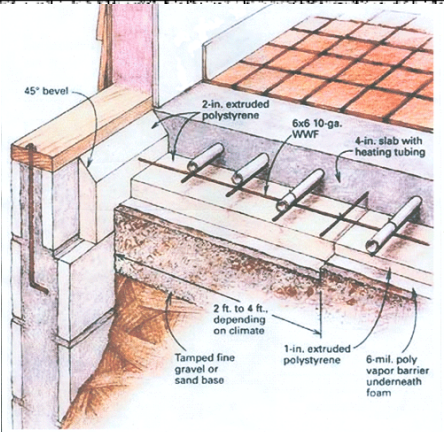
Experimental Facilities - LBNL

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

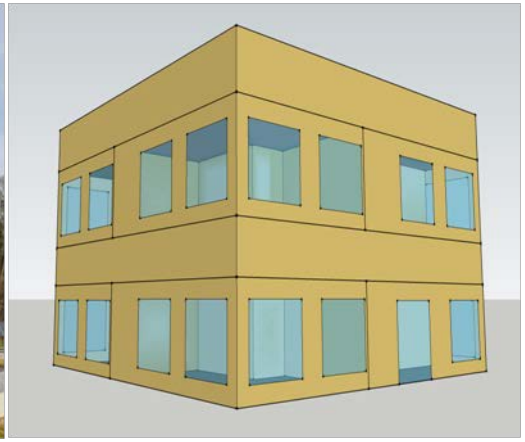
NREL: HVAC test facility

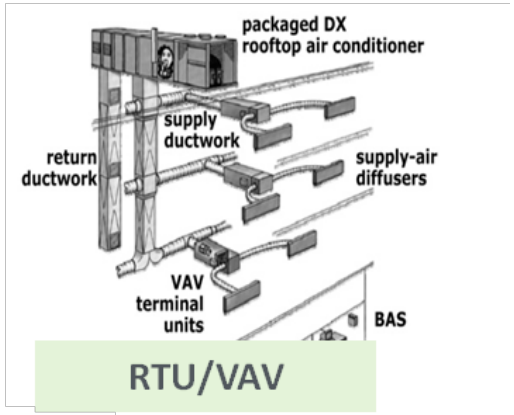
- Performance maps of HVAC components ≤ 10 tons
- Uncertainty < 5%

Experimental Facilities – ORNL

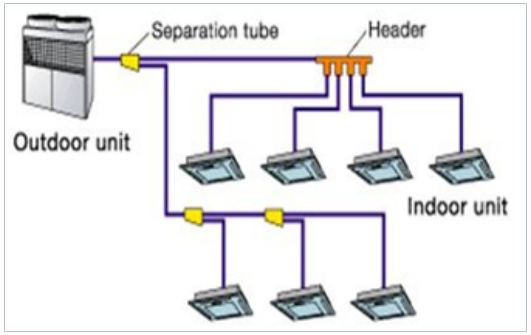
ORNL: Flexible Research Platforms (FRP)

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



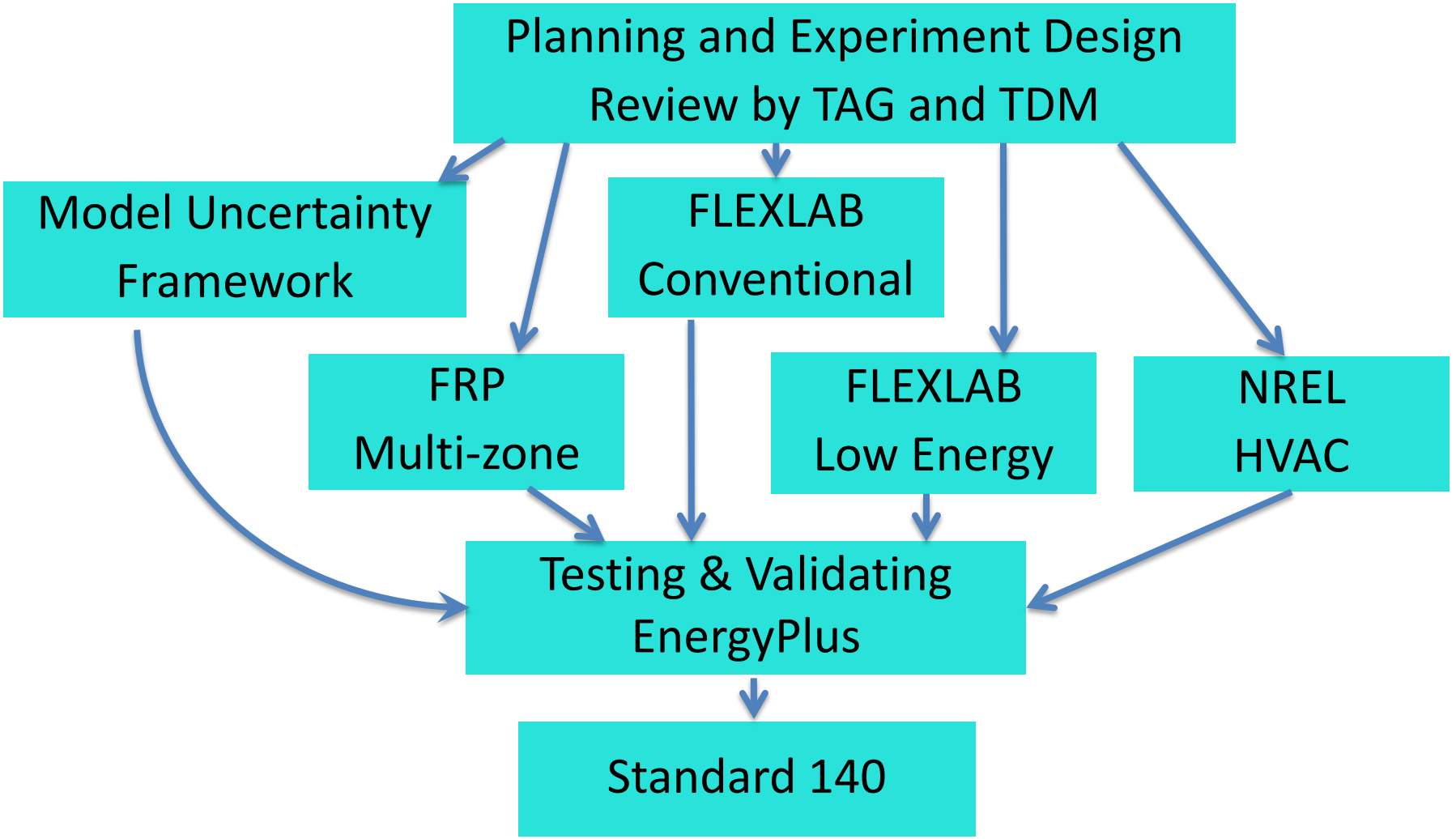


RTU/VAV



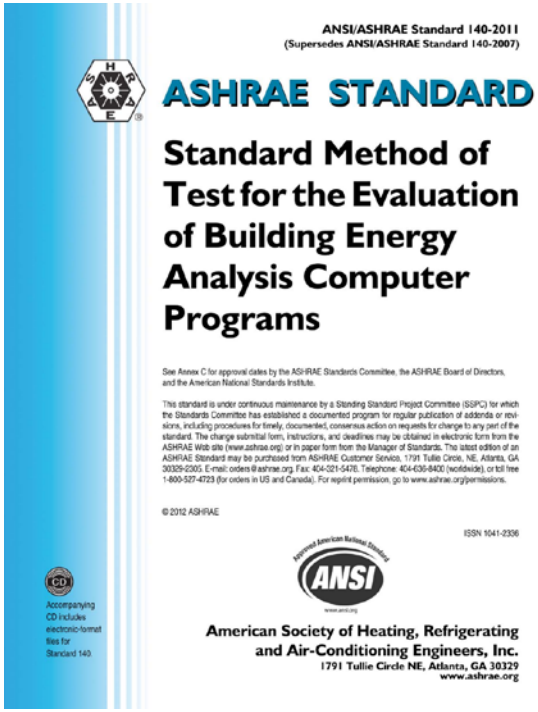
VRF

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)
  - European Union Energy Performance of Buildings Directive



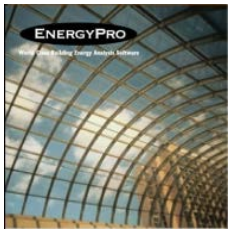
- **Technical Advisory Group:**
  - Simulation software developers/vendors, members of SSPC-140
  - Users: design practitioners, ESCO's, utilities, manufacturers, policy analysts
  - Experimental researchers
- **IBPSA**

IRS & RESNET Qualified Software BESTEST'ed with Standard 140

179D Commercial Building Tax Credits (13 Simulation Tools)

EnerSim

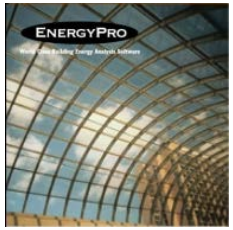
Hourly Analysis Program (HAP)



EnergyPro

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

EnergyInsights™



EnergyPro

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 Schedule													
Project Start: 10/1/2015		Planned Task											
Projected End: 9/30/2018		Milestone/Deliverable (Planned)											
		Go / No-go											
		FY2016				FY2017				FY2018			
Task	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)	
Future Work (Lead Org.)													
Task 1: Planning, experiment design (LBNL)													
Task 2: Model uncertainty framework (ANL)													
Task 3: FLEXLAB I: conventional systems													
Task 4: HVAC performance maps (NREL)													
Task 5: Multi-zone measurements (ORNL)													
Task 6: FLEXLAB II: low-energy systems													
Task 7: EnergyPlus validation (LBNL)													
Task 8: ASHRAE Standard 140 (NREL)													

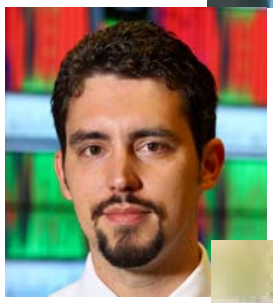
Budget

- 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

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

Deliverables - I

Deliverables	Date	Description
D1.1. Project plan for Years 1–3 and detailed plan for Year 1	1/31/2016	Prioritized test list and testing schedule approved by TAG
D7.1. Tables of EnergyPlus model input uncertainties, EnergyPlus model output uncertainties, and experimental measurement uncertainties for selected experiments	1/31/2016	For internal team use and subsequent use by other validation researchers
D1.2. Updated project plan for Years 2–3 and detailed plan for Year 2	8/15/2016	Prioritized test list and testing schedule approved by TAG
D2.1. Estimates of EnergyPlus model discrepancies for selected experiments	9/15/2016	EnergyPlus measurement comparisons for FLEXLAB, NREL, and FRP experiments
D2.3. Report on extension of model form framework methodology to quasi-real-time models	3/15/2017	Eliminate need for Monte Carlo model analysis that would preclude use in quasi-real-time experiment analysis
D3.1. Report and paper on validation of mixing ventilation zone models	3/15/2017	Report and technical paper for Building Simulation 2017 – data sets and EnergyPlus
D8.1. First submission to SSPC 140 and report on SSPC response	7/31/2017	

Deliverables - II

Deliverables	Date	Description
D1.3. Detailed plan for Year 3	8/15/2017	Prioritized test list and testing schedule approved by TAG
D2.4. Report on extension of validation methodology to Modelica models	9/15/2017	Support validation of Modelica models for Spawn of EnergyPlus
D2.5. Report on risk analysis / assessment measures for use by industry	6/15/2018	Methodology and User Guide to use of uncertainty extensions in simulation for risk analysis and assessment
D4.1. Report and paper on performance maps and validation of small HVAC equipment models	6/15/2018	Report and technical paper for ASHRAE – data sets and EnergyPlus
D5.1. Report and paper on validation of multi-zone control simulation	6/15/2018	Report and technical paper for ASHRAE – data sets and EnergyPlus
D6.1. Report and paper on validation of alternative zone models	6/15/2018	Report and technical paper for ASHRAE – data sets and EnergyPlus
D8.1. Final submission to SSPC 140 and report on SSPC action	7/31/2018	