BS 2019 2-4 SEPT ROME
16th IBPSA INTERNATIONAL CONFERENCE AND EXHIBITION

INTERNATIONAL BUILDING PERFORMANCE SIMULATION ASSOCIATION

Empirical Validation of Building Energy Modeling using Flexible Research Platform

Speaker:

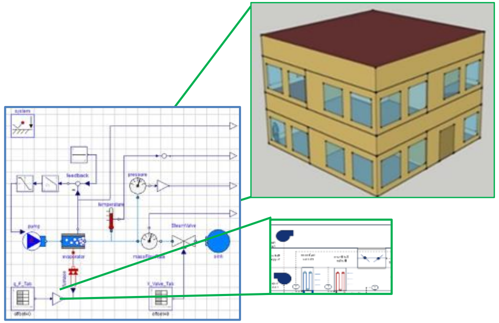
Piljae Im, Oak Ridge National Laboratory, USA

Authors:

Piljae Im, Joshua R. New, and Jaewan Joe, Oak Ridge National Laboratory, USA

Introduction/Background

- Use of building energy modeling (BEM)
  - Design new and existing buildings for energy efficiency
  - Code compliance
  - Green building certification
  - Real time building control



Piljae Im, Oak Ridge National Laboratory, USA

Introduction/Background

- Problem
  - Energy simulation cannot reliably predict actual energy performance (i.e., performance gap)

"The measured energy use can be as much as 2.5 times the predicted energy use"

  - Sources of the gap: model algorithm, model input parameters (occupant behavior, weather, building/HVAC properties), and modelers' decisions.

Introduction/Background

- 3 approaches for validation study

Comparative studies

- Analyzing the difference of BEM tools
- Improving the internal BEM code

Analytic verification

- Solving simple heat transfer problem to find the unique solution
- Compare the results with BEM that are solved numerically within internal code
- Improving the internal BEM code

Empirical validation

- Compares the simulation results to the measured data
- Highest potential to validate BEM tools
- Significant engineering cost

Introduction/Background

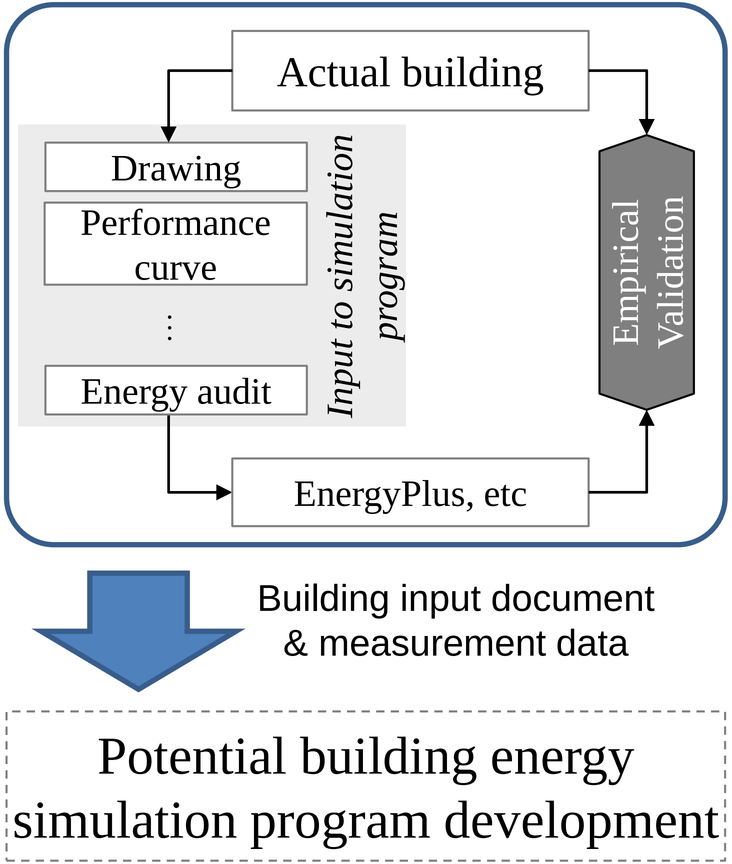
- Multiyear Multi-lab Empirical Validation Projects
  (FY16 through 19)
  - Work with ASHRAE Standard 140 “Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs”
  - Use highly instrumented test facilities to develop empirical data sets for SSPC140

ORNL FRP

LBNL FLEXLAB

Introduction/Background

- Expected impact
  - Make definitive quantitative statements about BEM engine accuracy
  - Improve BEM engine accuracy
  - Increase confidence in and use of BEM

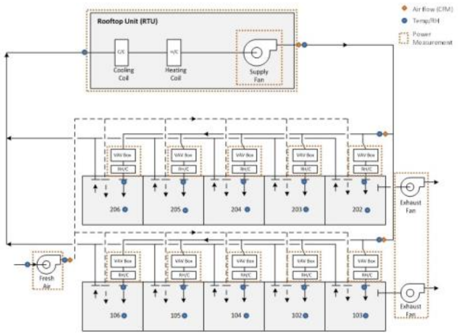


Objectives

- Project objectives
  - Document data sets for validating key functionality in different energy simulation tools
  - Identifying errors and inadequate assumptions in simulation engines
- This presentation focuses on:
  - Developing sub models
    - Infiltration model for building envelope
    - RTU DX cooling models
    - RTU supply fan model
  - Conducting cooling season validation

Test-bed – Flexible Research Platform (FRP)

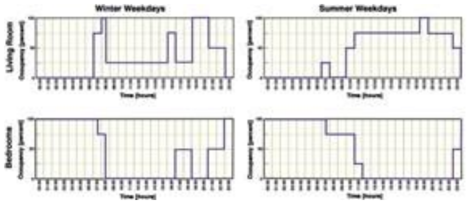
Multizone HVAC - RTU with VAV Reheating

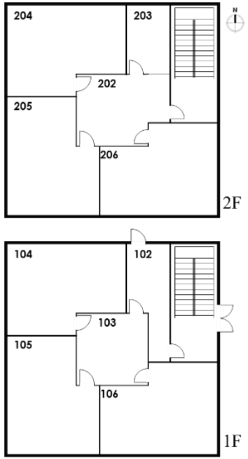


Weather Station

Flexible Research Platform (FRP)

Simulated Occupancy





Key input for the simulation model

- Infiltration model
  - Blower door test to estimate the I_{design}

$$I_{design} = (\alpha_{bldg} + 1) \cdot I_{75pa} (0.5 C_s \rho U_H^2 / 75)^n$$

Where:

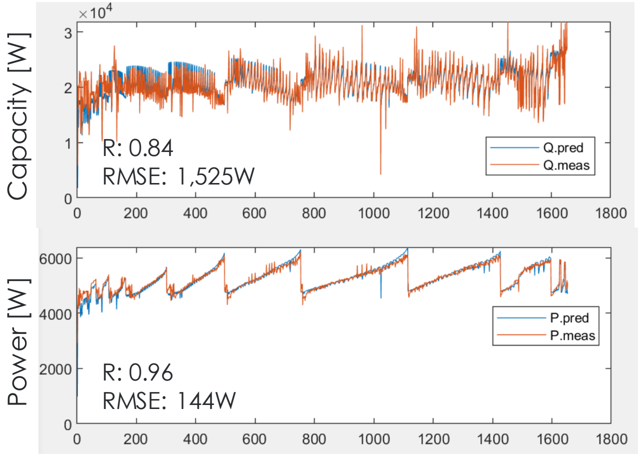
U_H: the wind speed at building height (4.47m/s)
ρ : the density of air (1.18 kg/m^3)
C_s: the average surface pressure coefficients (0.1617)
α_{bldg}: an urban terrain environment coefficients (0.22)
I_{75pa}: the building leakage rate at 75 Pa
n: coefficient (0.65)

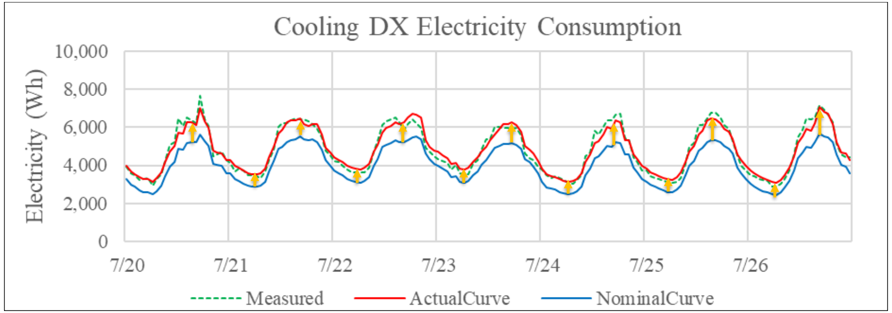
  - Tracer gas tests are ongoing to improve the model

Key input for the simulation model

- **Issue** - Initial model uses a generic RTU model, which cannot characterize the real system performance
- A real RTU performance curve was generated based on historical data.
- Demonstration in EnergyPlus
  - Improved NMBE and CV(RMSE)
    - 16.3% and 17.8% → −0.3% and 5.23%

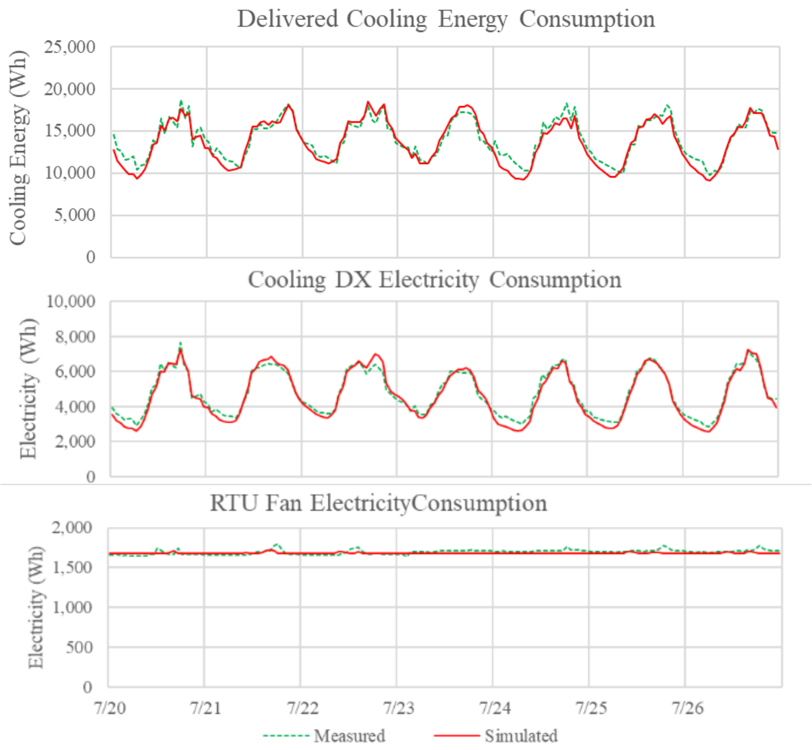
Stage1 (coil 1)





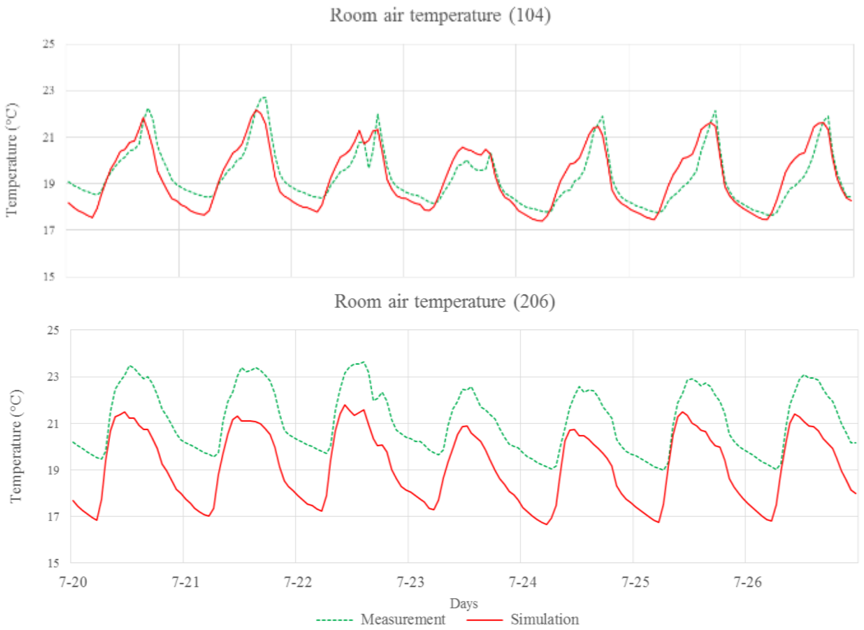
Empirical validation for cooling season

- **Test 1**
  - Baseline Case
  - 7/20/2017 ~ 7/26/2017
  - NMBE and CV(RMSE)
    - Delivered cooling: 2.6% & 5.9%
    - Cooling DX electricity: 2.4% & 5.8%
    - Fan electricity: 0.3% & 0.7%



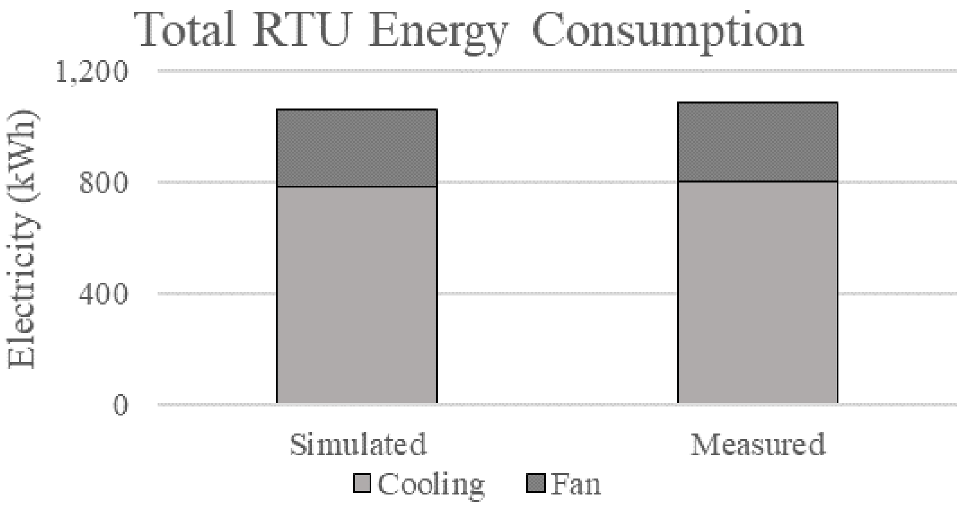
Empirical validation for cooling season

- **Test 1**
  - Baseline Case
  - 7/20/2017 ~ 7/26/2017
  - RMSE
    - Best room: 0.62℃
    - Worst room: 2.04℃
    - Weighted-average: 0.86℃



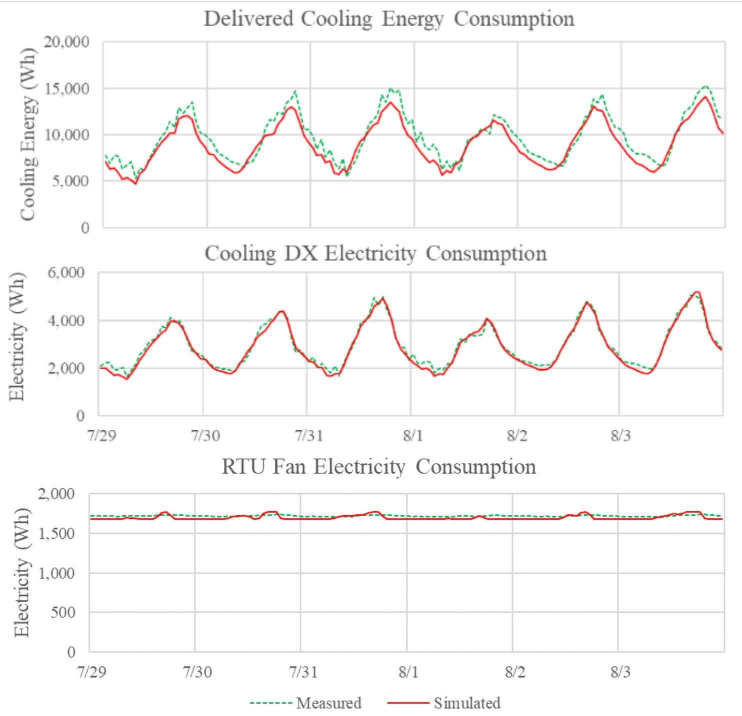
Empirical validation for cooling season

- **Test 1**
  - Baseline Case
  - 7/20/2017 ~ 7/26/2017
  - Total RTU energy
    - 2.0% higher in measurement



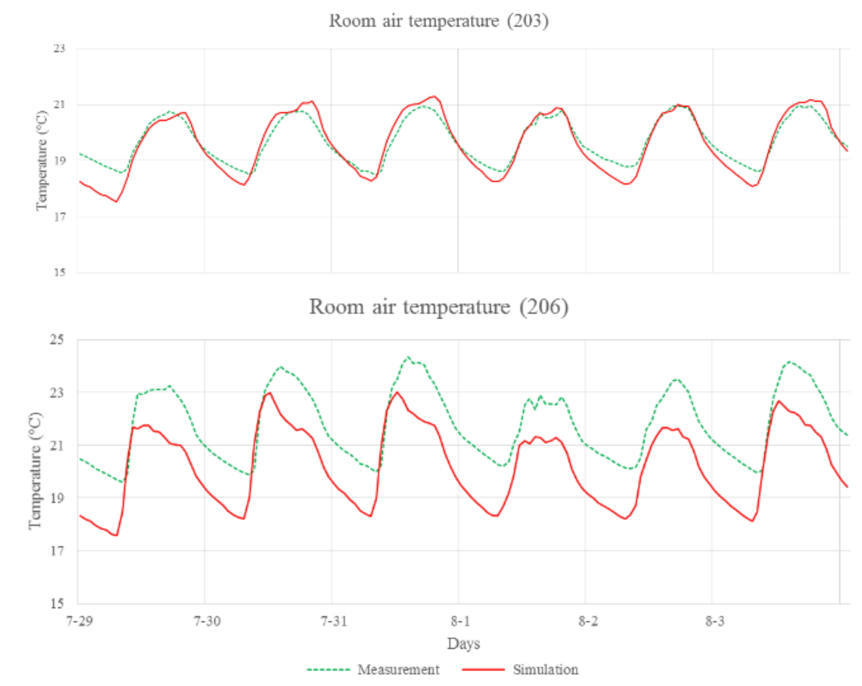
Empirical validation for cooling season

- **Test 2**
  - Increased supply air temperature
    - 12.7℃ → 15.6℃
  - 7/29/2017 ~ 8/3/2017
  - NMBE and CV(RMSE)
    - Delivered cooling: 7.9% & 10.9%
    - Cooling DX electricity: 2.5% & 5.3%
    - Fan electricity: 0.8% & 1.45%



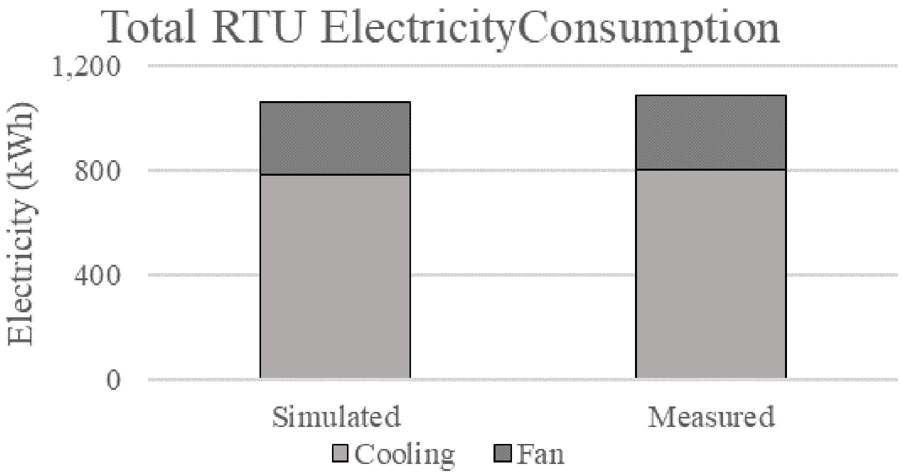
Empirical validation for cooling season

- **Test 2**
  - Increased supply air temperature
    - 12.7℃ → 15.6℃
  - 7/29/2017 ~ 8/3/2017
  - RMSE
    - Best room: 0.39℃
    - Worst room: 1.67℃
    - Weighted-average: 0.79℃



Empirical validation for cooling season

- **Test 2**
  - Increased supply air temperature
    - 12.7℃ → 15.6℃
  - 7/29/2017 ~ 8/3/2017
  - Total RTU energy
    - 2.1% higher in measurement



Conclusions

- EnergyPlus model from:
  - As-built drawings
  - Sub models with in-situ experimental data
    - Infiltration model (Blower door test)
    - RTU DX cooling
    - RTU supply fan
- Two sets of cooling season tests
- Comparison with the EnergyPlus simulations
  - Good agreement of energy / electricity consumption
  - Air temperature deviation in room level

Discussion and limitations

- **Infiltration**: Tracer gas test is going on for zone-level infiltration model
- **Duct leakage**: Individual VAV measurement is added and used for current analysis. Further duct leakage analysis is needed
- **Zone mixing**: The inter-zone air mixing can be investigated
- **Part load ratio**: Further investigation is needed for better modeling quality with PLR
- **Uncertainty quantification**: Parallel efforts in Argon National Lab for uncertainty analysis for measured data and simulation input

Empirical Validation of Building Energy Modeling using Flexible Research Platform

Questions and Comments

Speaker:

Piljae Im, Oak Ridge National Laboratory, USA

Contacts:

imp1@ornl.gov