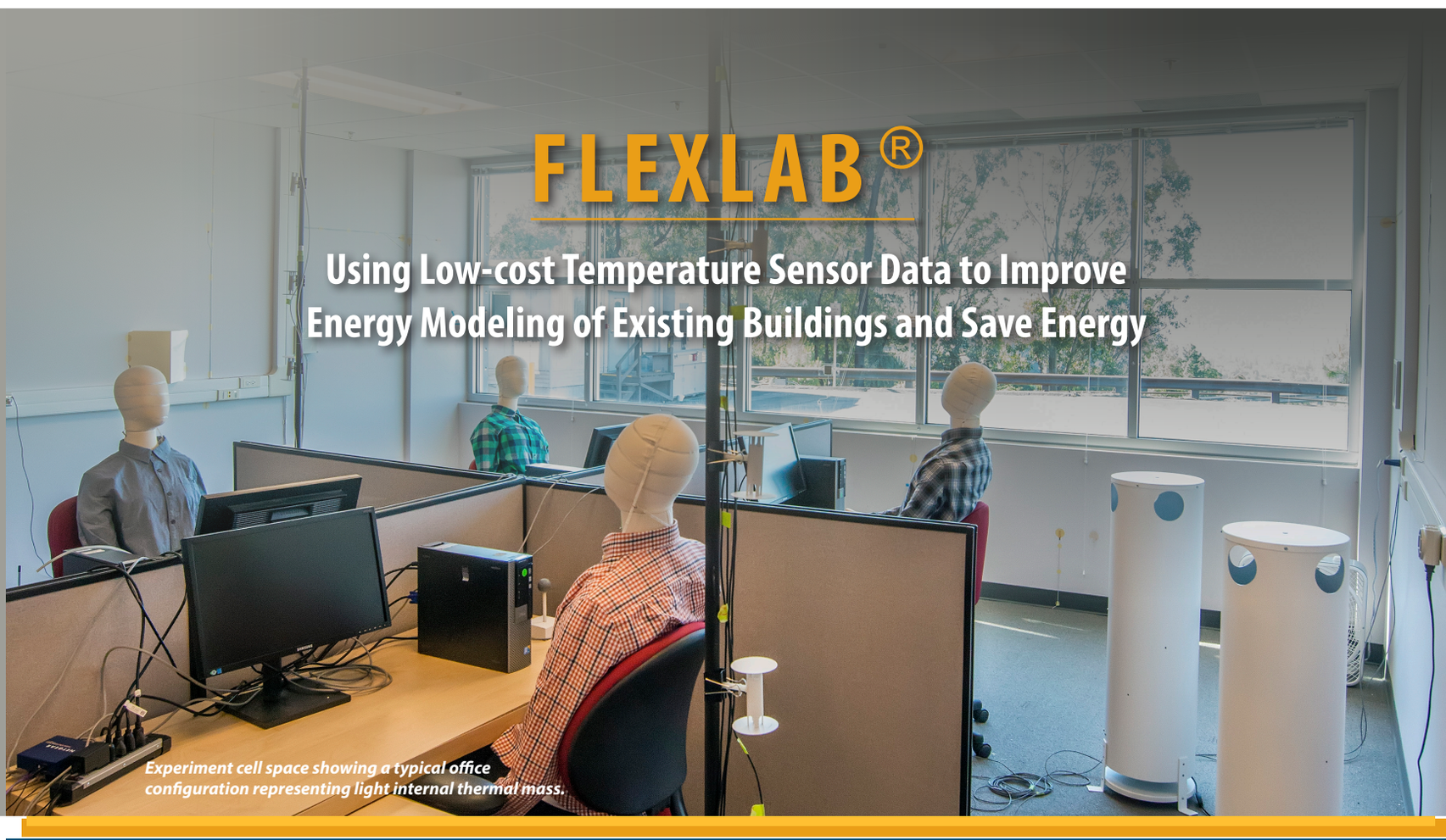
FLEXLAB®

Using Low-cost Temperature Sensor Data to Improve Energy Modeling of Existing Buildings and Save Energy



Experiment cell space showing a typical office configuration representing light internal thermal mass.

THE IMPACT

The FLEXLAB® experiment verified the hybrid models in EnergyPlus, which improves simulation usability and accuracy for existing buildings, providing more reliable performance assessment to support building retrofit decision-making. The hybrid model could improve the accuracy of simulated Heating, Ventilation, and Air Conditioning (HVAC) energy use by 10-30%. Assuming 16.5 Quad of the current existing building market size, and an estimate of 20% increase of the potential 30% retrofit savings, this leads to an incremental 1.0 Quad of energy savings annually.

THE CHALLENGE:

Most U.S. building stock consists of existing buildings. How can we improve their operation or retrofit with new energy-efficient technologies? The answer to that question is critical to reduce energy use in the building sector. Although building simulation has been widely used to support the design of new buildings, modeling the energy performance of existing buildings is challenging because model inputs that have significant impacts on simulation results, such as internal thermal mass and infiltration, are difficult to obtain. This leads to discrepancies between simulated and measured energy uses. A hybrid modeling approach for existing buildings is needed that uses measured data to reduce these uncertainties.

THE SOLUTION: MODELING TECHNIQUES VALIDATED USING MEASURED DATA FROM FLEXLAB

Department of Energy-funded research supported scientists Tianzhen Hong and Sang Hoon Lee who developed a new hybrid modeling approach to use zone air temperature to derive zone internal thermal mass and infiltration. Thermal mass—books, furniture, etc.—is an important component for stabilizing internal temperatures. Infiltration—uncontrolled outdoor air into a space—is another highly unknown parameter leading to uncertainties in heating or cooling load in buildings.

The researchers came up with a hybrid approach that is built upon the inverse model of the zone heat balance that keeps the virtues of physics-based modeling and also takes advantage of easily attainable measured data from low-cost sensors installed in buildings. Hybrid modeling enhances the accuracy of the building energy simulation for existing buildings by replacing highly unknown parameters of zone interior

thermal mass and air infiltration, with measured zone air temperature data as new inputs to energy modeling. They conducted FLEXLAB experiments to collect detailed data to validate the hybrid model. They measured zone air temperature under the controlled indoor environmental configurations with two levels of internal thermal mass and four levels of infiltration. They used the measured temperature to validate the hybrid model implemented in EnergyPlus, DOE's flagship whole-building energy simulation engine. The simulation results from the hybrid modeling showed good agreements with the measured data from the FLEXLAB experiments. Lessons and insights learned from the validation using the FLEXLAB experiments were used to refine the hybrid modeling algorithm and to provide a guideline on the use of the hybrid model in EnergyPlus.

THE EXPERIMENT

- Testing was conducted at FLEXLAB's testbed cell 3A for 50 days from April 4 to May 23, 2016.
- Measuring cell 3A's indoor air temperature under various configurations with two levels of internal mass and four levels of air infiltration rates.
- A total of 28 temperature sensors were used to measure indoor air temperature. Four stratification sensor trees, each with seven sensors, were located at each corner of the cell space.
- A variable speed fan was installed to control exhaust air-flow rates. The experiment designed the amount of exhaust air as the same amount of the outdoor air through a supply duct with an open damper and door and window gaps. The HVAC system was off during the whole experiment.
- An internal heat load of 1200 watts were added to create a thermal loading representative of typical offices.
- CO_2 tracer gas decay tests were used to accurately measure the air infiltration rates.
- One-minute interval sensor data were provided via the FLEXLAB data acquisition web interface.
- An EnergyPlus model of the test cell 3A and weather data were provided for experiment users. The EnergyPlus model was calibrated to the FLEXLAB experimental conditions and was used to validate the hybrid model approach.

"The hybrid modeling approach reformulates the space heat balance equations, based on the new set of inputs, to derive a more accurate estimate of the building energy performance by solving the partially inverse problem," said Hong. The approach will be implemented in EnergyPlus, DOE's flagship whole building energy simulation engine, and its results "will be verified in two ways by comparing to results from the current EnergyPlus simulations and to the measured results from Berkeley Lab's FLEXLAB."

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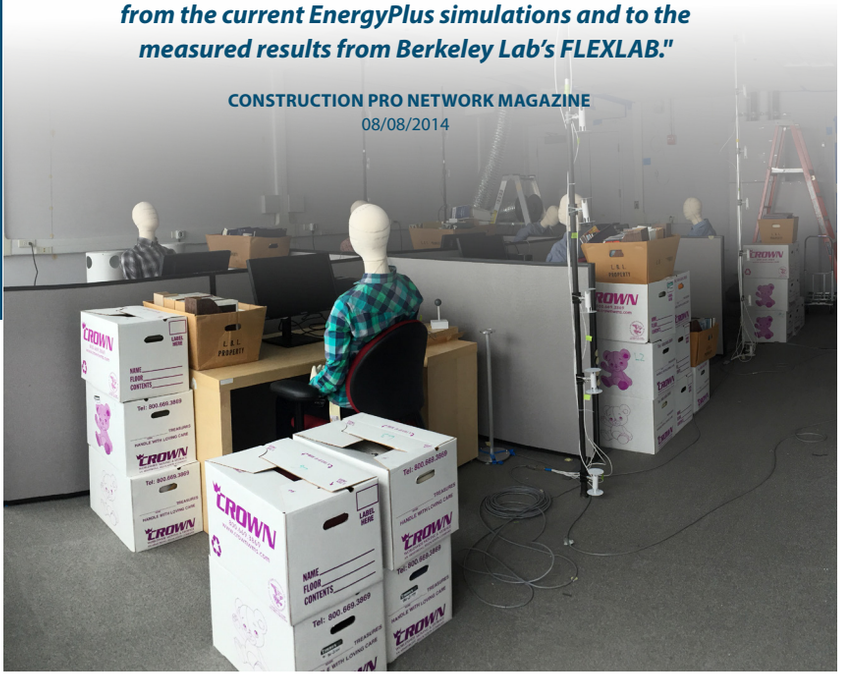

Experiment cell space showing an office configuration with added booksrepresenting heavy internal thermal mass.

THE RESULTS

- Detailed sensor and meter data collected and processed for temperatures and air infiltration.
- EnergyPlus model calibrated using the measured data.
- The hybrid model was validated using the simulated zone air temperature data and the user-specified infiltration rates from the calibrated EnergyPlus model.
- Further validation was done using the measured zone air temperature and infiltration data from the FLEXLAB experiments.
- Tests were run for at least seven days to ensure adequate measurement of the zone air temperature and to replicate indoor air temperatures.
- The experimental data helped to refine the hybrid modeling algorithm and to provide a guideline on the use of the hybrid model in EnergyPlus.

FOR MORE INFORMATION ABOUT THIS PROJECT, PLEASE VISIT:
energy.gov/eere/buildings/downloads/benefit-new-hybrid-approach-energy-modeling
FOR MORE INFORMATION ABOUT FLEXLAB, VISIT FLEXLAB.lbl.gov

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