

# **BOPTTEST Overview and Status**

BOPTTEST Workshop at IBPSA Building Simulation 2025

August 28, 2025



**David Blum**

Computational Research Scientist/Engineer  
Building Technology and Urban Systems Division  
Lawrence Berkeley National Laboratory (LBNL)  
Email: [dhblum@lbl.gov](mailto:dhblum@lbl.gov)

# **BOPTTEST Overview and Status**

- **BOPTTEST**
  - Motivation and Concept
  - Technical Approach
  - Example Usage
- **IBPSA Project 2**
- **Recent Update Highlights**

# Acknowledgements



This research was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Building Technologies of the U.S. Department of Energy, under Contract No. DE-AC02-05CH11231.



**IBPSA Project 2**

Thank you to IBPSA for support of BOPTEST and of IBPSA Project 2.

Thank you to all IBPSA Project 2 collaborators and BOPTEST contributors past and present!

**ARUP**

Recent improvements to BOPTEST's open-source BACnet interface were funded by Arup.

# Motivation

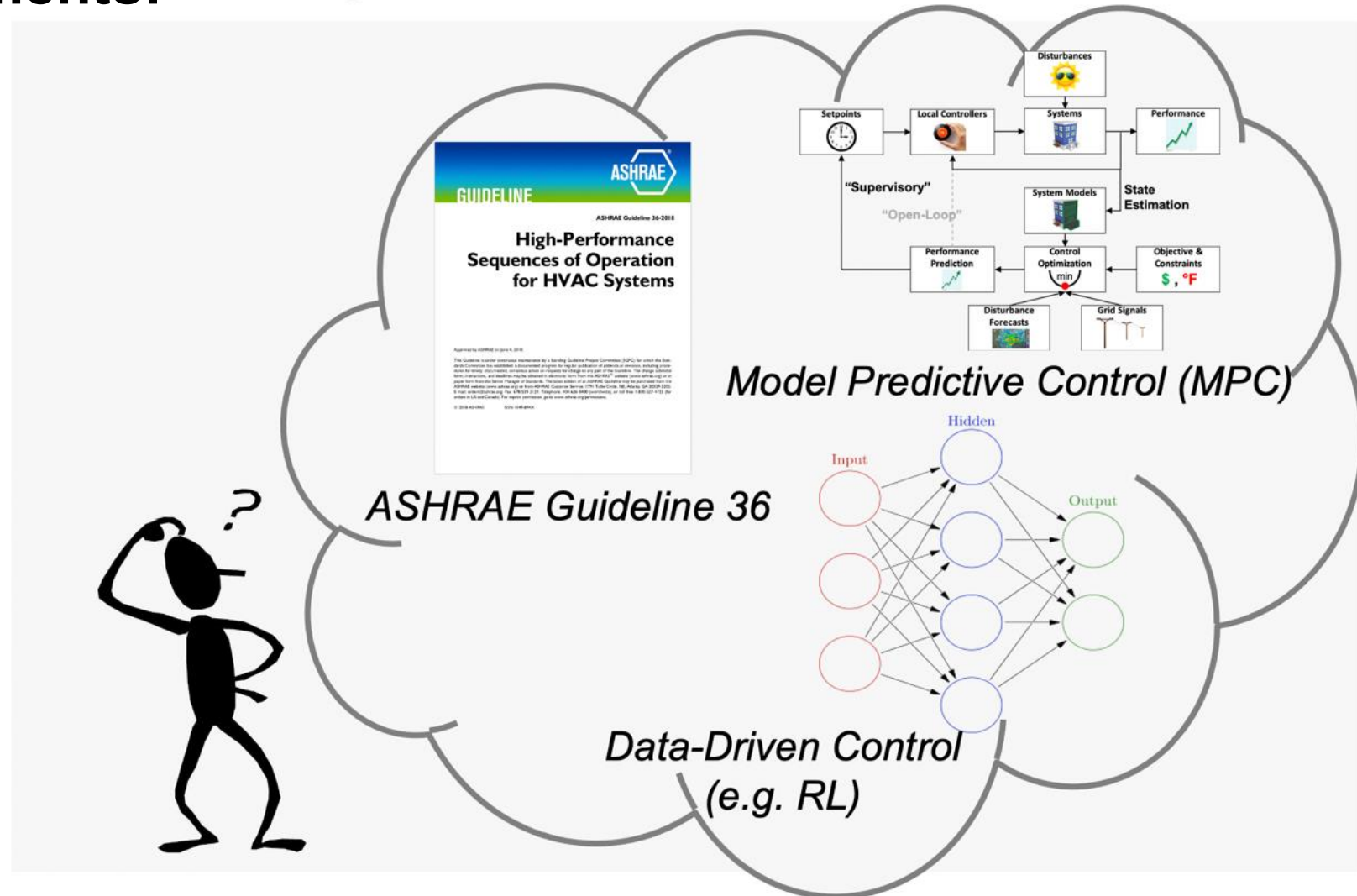
## There Are Many New Control Strategies

All have different requirements:

- Data
- Modeling
- Computation
- Expertise

How do they compare?

- Thermal comfort
- Energy management
- Implementation cost
- Reliability



# Motivation

## Current Approach: Testing with Individualized Case Studies

- Findings are specific to building, climate, metrics, comparative baseline
- Difficult to replicate and extend to new control strategies in future studies
- Effort and expertise to set up case study limits rapid prototyping and development by experts in fields outside traditional building industry

## Accelerate new control deployments

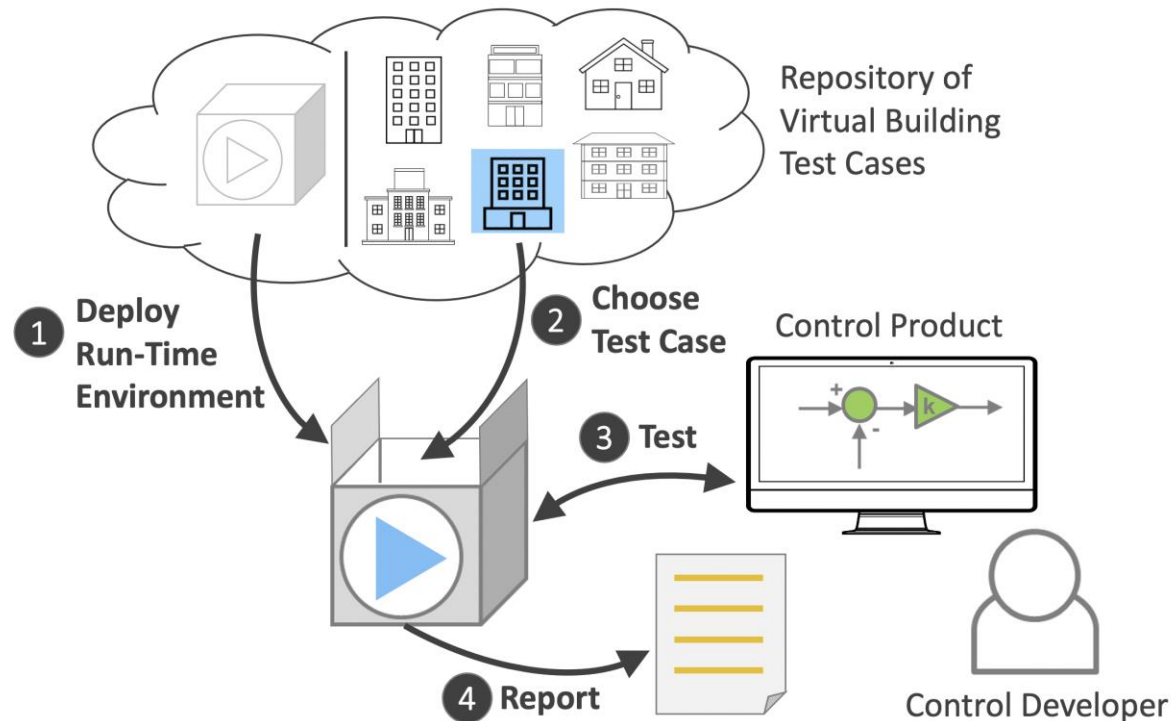
- **Control developers** want to streamline new control development, improve reliability, and reduce deployment costs
- **Building owners** want to see value and have trust in new control products
- **Educators** want to train students on performance expectations and commissioning

# Concept

## Building Optimization Testing Framework (BOPTEST)

A Simulation-Based Controls Testing and Benchmarking Environment

- Realistic virtual buildings that can be controlled by external test controllers
- Deployable software runtime environment: rapidly, repeatably, and at scale
- Standardized key performance indicators (KPI) that are auto-calculated



### Novelties

**Provides a level playing field** for control performance comparison.

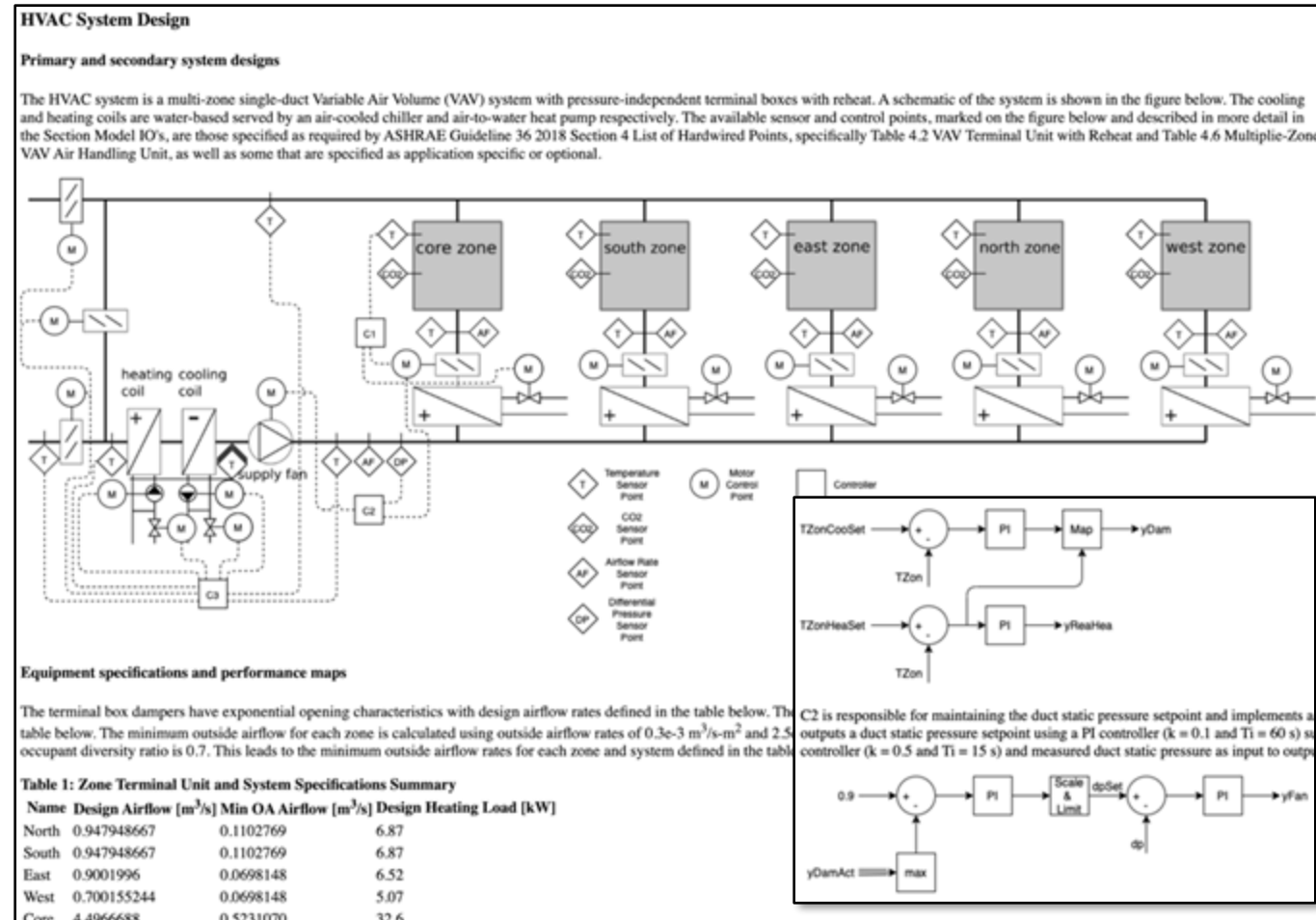
**Lowers the barrier** for access to realistic building simulations.

**Creates an international, open community** for controls testing and benchmarking.

# Approach

## Virtual Building Models ("Test Cases")

- High-fidelity models with embedded baseline control in Modelica, Spawn, and CDL
- Overwritable supervisory or local-loop control
- All boundary condition data (e.g. weather, schedules, energy prices)
- Documentation and peer review to ensure quality and usability



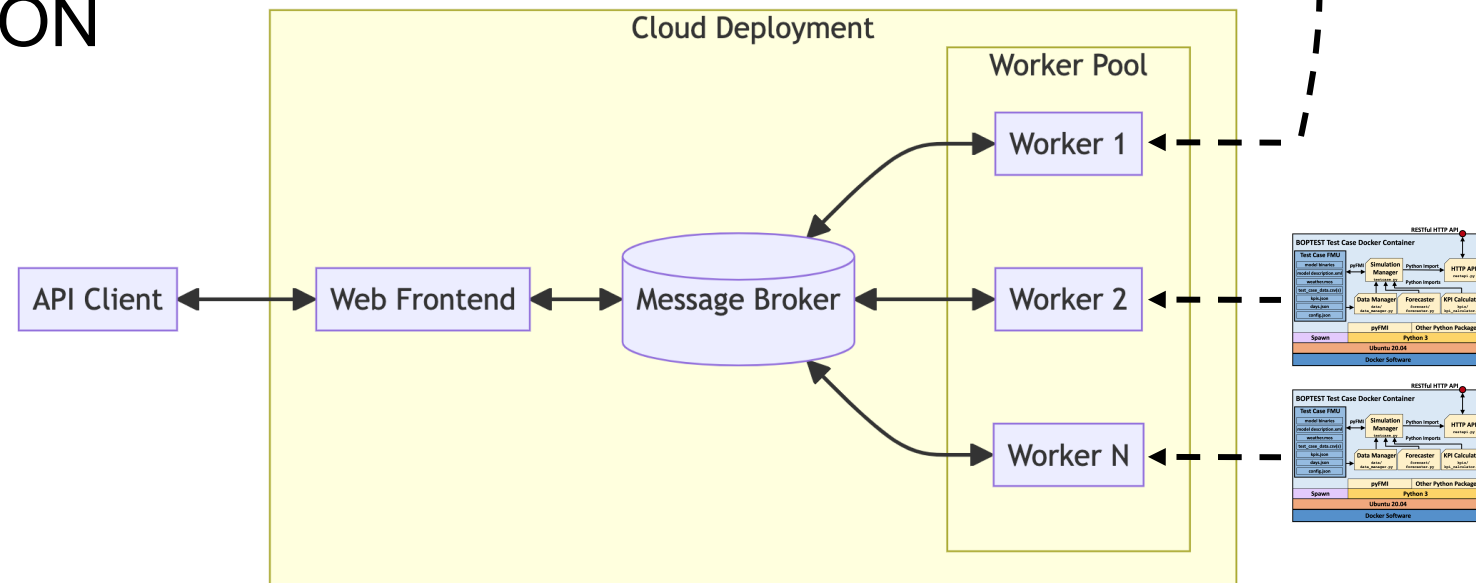
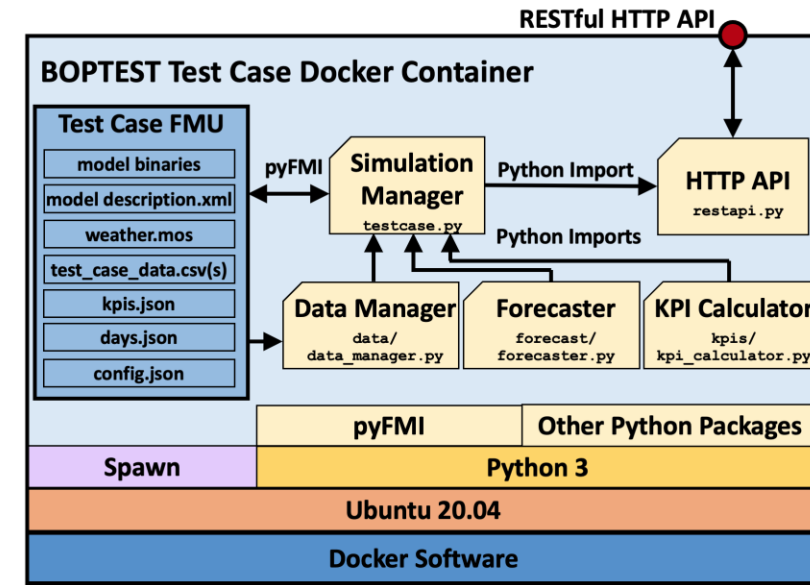
# Approach

## Run-Time Environment

- Rapid, repeatable deployment as a web-service using Docker
- “Native” HTTP RESTful API for test management and controller interaction
- Additional Interfaces:  
Gym, BACnet, Julia, VOLTTRON

| API Endpoint            | Description                           |
|-------------------------|---------------------------------------|
| GET <i>measurements</i> | Receive available measurements        |
| GET <i>inputs</i>       | Receive available inputs              |
| PUT <i>scenario</i>     | Set test scenario                     |
| PUT <i>initialize</i>   | Initialize simulation                 |
| PUT <i>step</i>         | Set control step                      |
| GET <i>forecast</i>     | Receive forecasts                     |
| POST <i>advance</i>     | Advance simulation with control input |
| PUT <i>results</i>      | Receive historic point trajectory     |
| GET <i>kpi</i>          | Receive KPI values                    |

Key API Requests



Web-service deployment architecture based on version of Alfalfa Virtual Building Service at <https://github.com/NREL/boptest-service>.

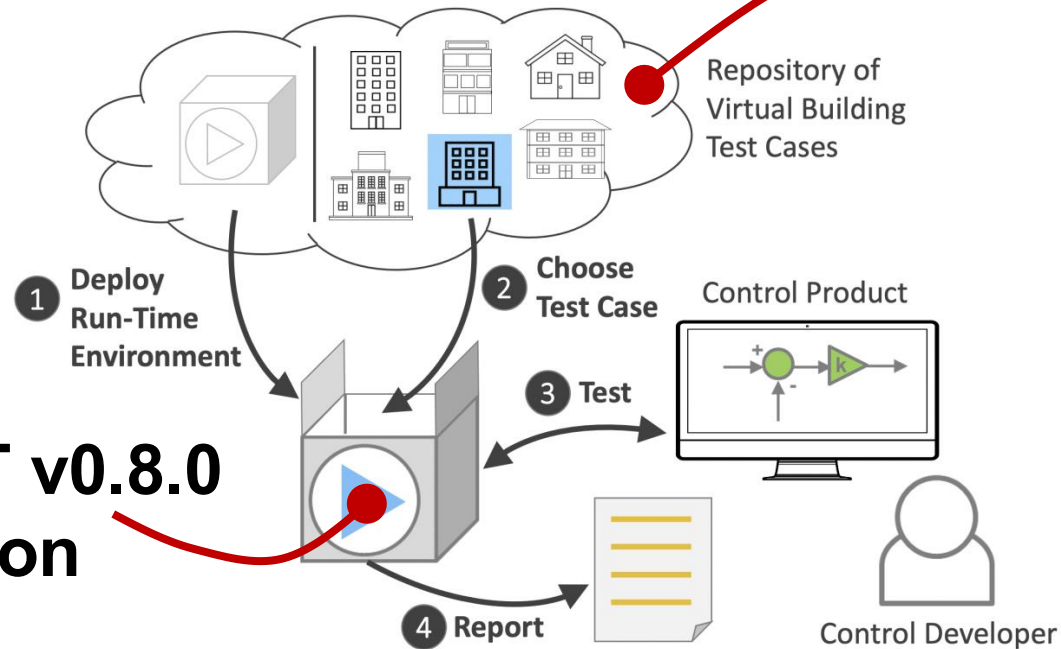


# Approach

## Progress

Home Page: <https://boptest.net>

**8 publicly available test cases**  
More under active development



**BOPTEST v0.8.0**  
available on  
**GitHub**

Available as a  
public web-service  
by sending API requests  
to <https://api.boptest.net>

| Hydronic                                       | Air                                     |
|--|---|
| 1 Zone, Radiator                               | 1 Zone, FCU                             |
| 1 Zone, Radiant Floor, Heat Pump               | 2 Zones, FCUs, AHUs Heat Pump, Chiller  |
| 2 Zones, Radiant Floor, Heat Pump              | 5 Zones, 1 VAV AHU, Heat Pump, Chiller  |
| 1 Zone, Radiator, AHU, CO <sub>2</sub> Control | 10 Zones, 1 VAV RTU, DX, Ele. Heat      |
| 8 Zones, Radiators, Boiler, Split Cooling      | 15 Zones, 3 VAV AHUs, Boiler, Chiller * |



Available



Implemented,  
but not yet available

\*Will be available in next release

# Example Usage

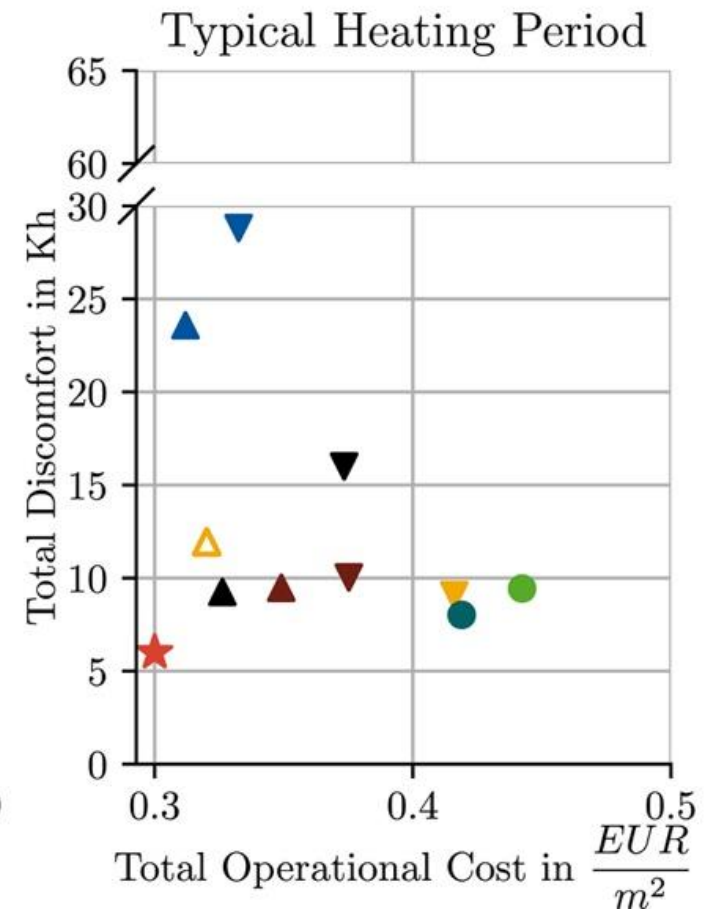
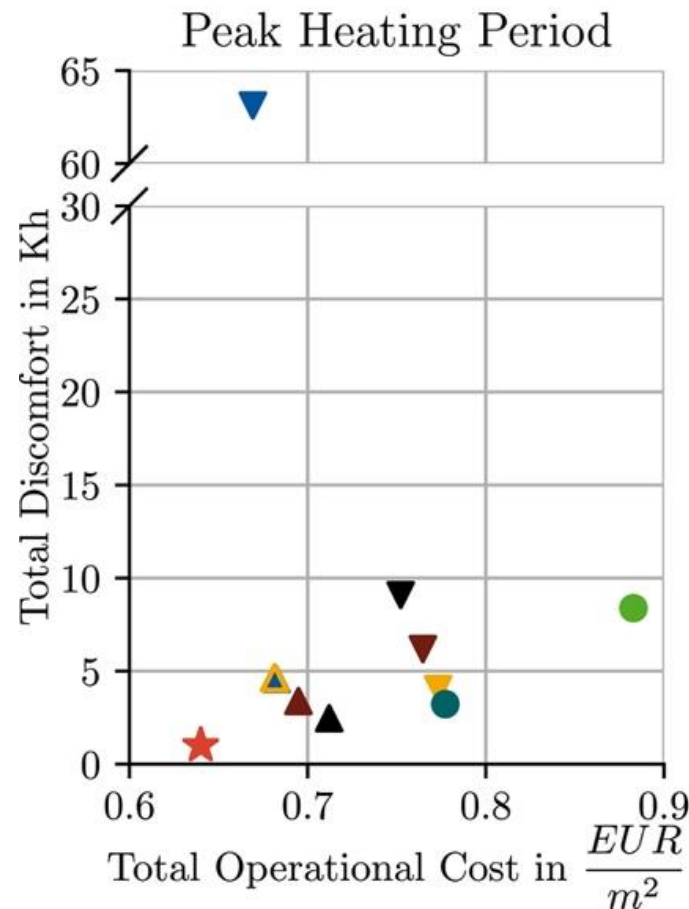
## Control Research

Stoffel et. al. (2024).

“Safe operation of online learning data driven model predictive control of building energy systems.” *Energy and AI*

<https://doi.org/10.1016/j.egyai.2023.100296>

“*The benchmark controller is a physics-based MPC from Arroyo et al. 2022 for comparison.*”

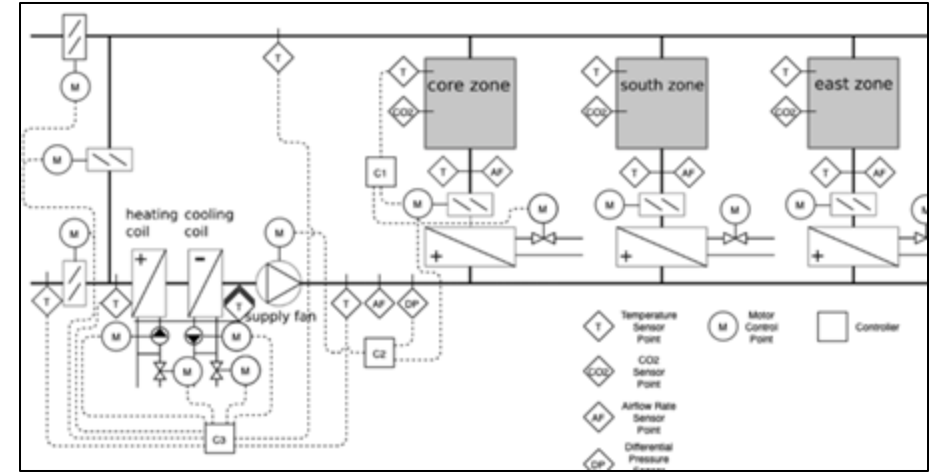


# Example Usage

## Control Product Development

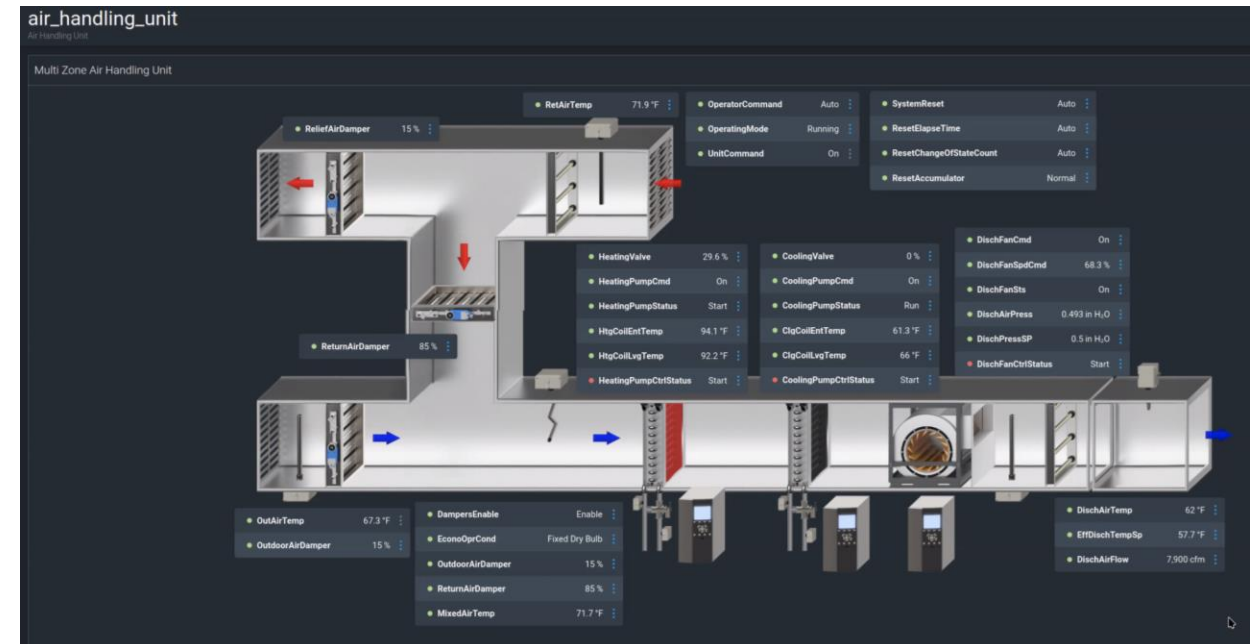


*Points from BOPTEST are read and written to Distech ECLYPSE Controller*



*BOPTEST's Multizone Office Simple Air Test Case*

- Testing Sequences of Operations
- Training customers on simulated data (e.g. PID loop tuning, dashboards)
- Testing RL algorithm performance and generating data for training
- Demonstrations for technical sales as well as sharing ideas internally

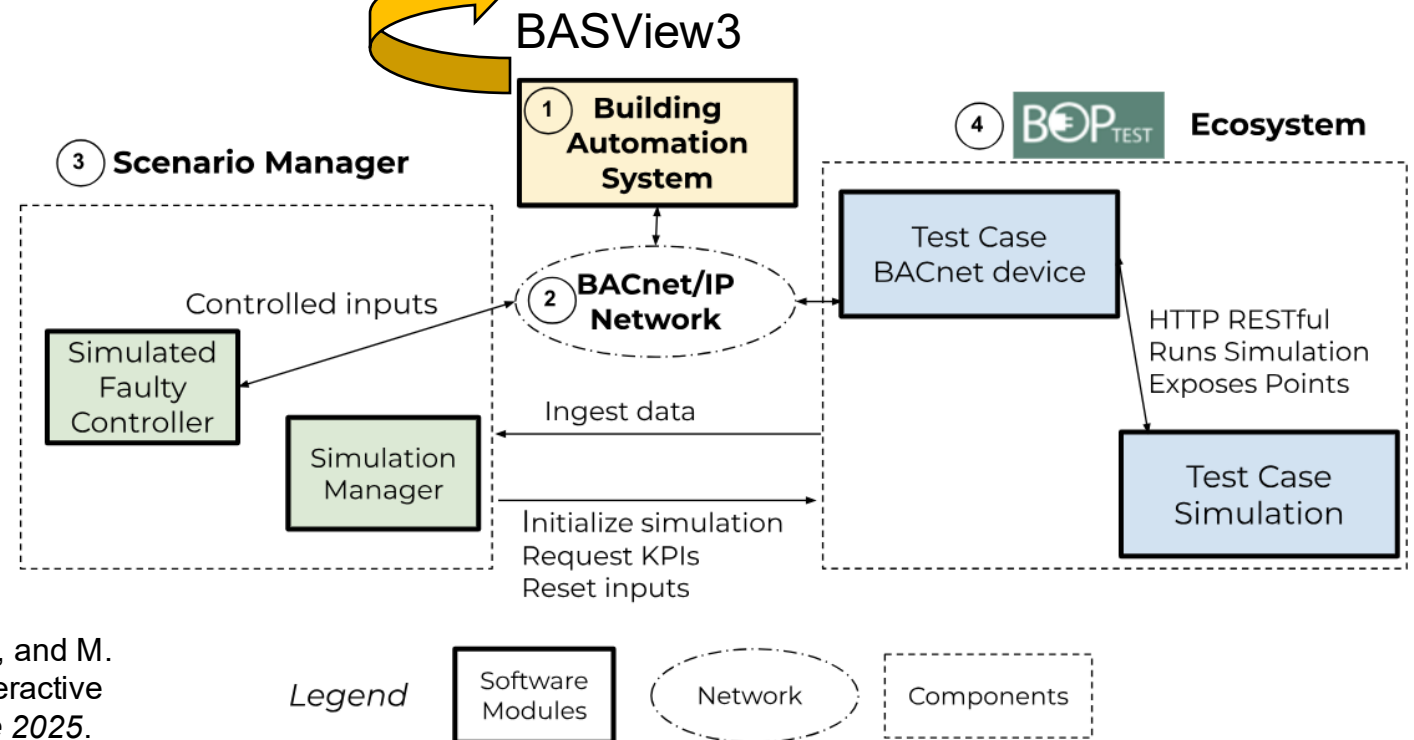
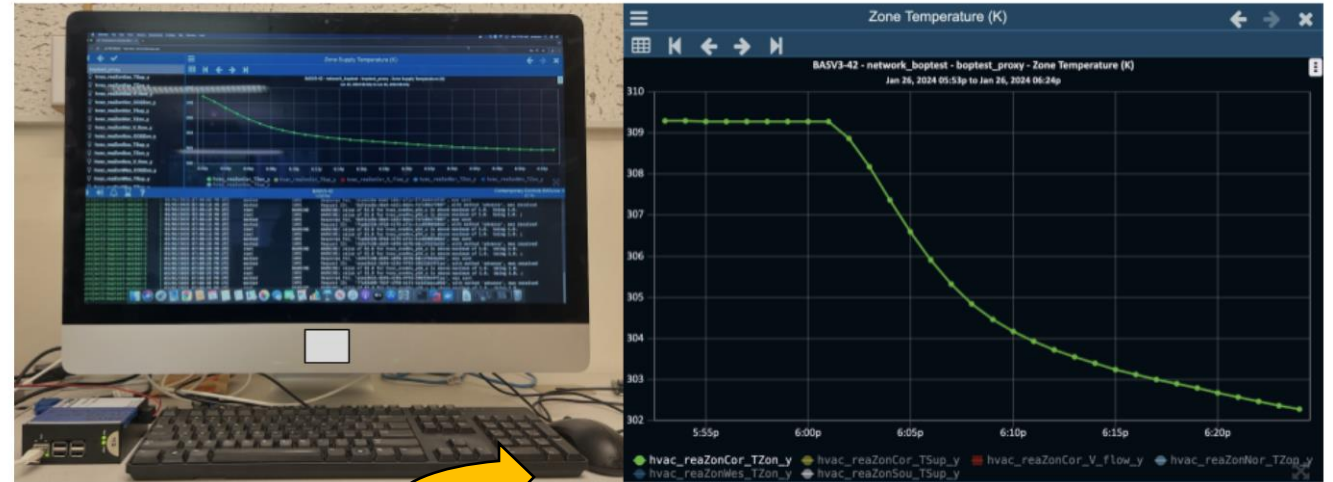


# Example Usage

## Workforce Development



- BEST Center National Institute used BOPTEST for HVAC operator and technician training



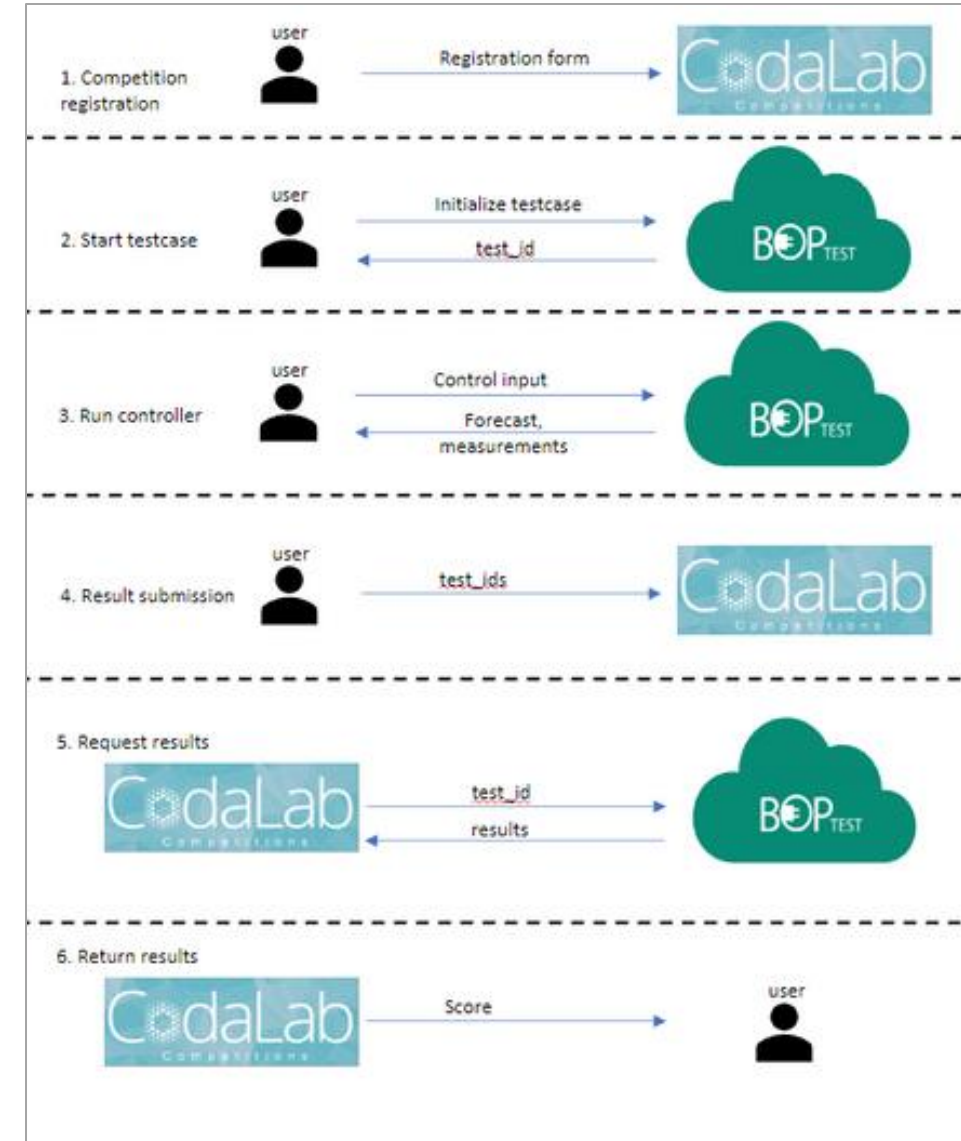
L. Paul, E. Zanetti, J. Liu, A. Casillas, A.K. Prakash, D. Blum, R. Nirenberg, and M. Pritoni (2025). "BOPTEST as a Platform for Building Controls and Grid-Interactive Buildings Workforce Training." *In Proc. of the ASHRAE Annual Conference 2025*. Phoenix, AZ. June 21-25.

# Example Usage

## Smart Building Control Competition ADRENALIN

<https://adrenalin.energy/BOPTEST-Challenge-Smart-building-HVAC-control>

- Led by SINTEF
- Best-performing solutions awarded prize money and chance to be implemented in real-life conditions
- Resulted in key lessons-learned for scaling usage of BOPTEST and using BOPTEST for competitive benchmarking





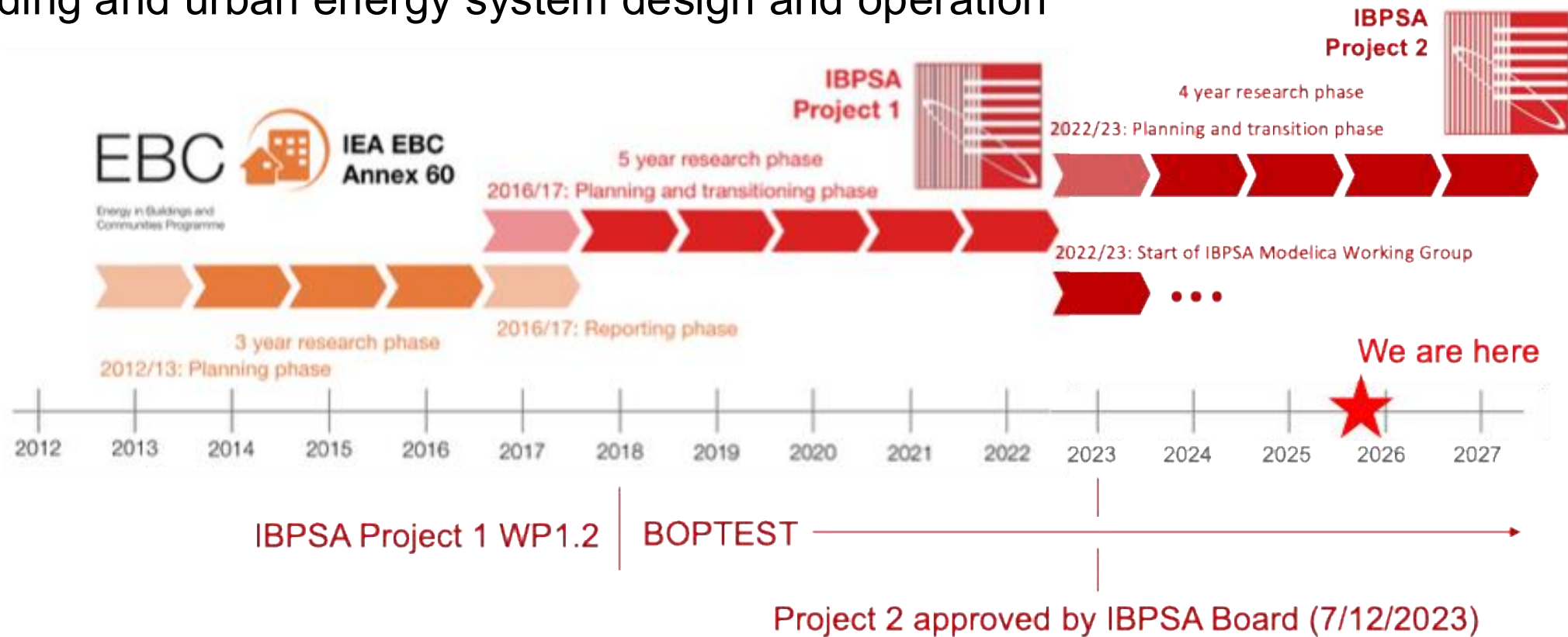
# IBPSA Project 2



## IBPSA Project 2

<https://ibpsa.github.io/project1-boptest/ibpsa/index.html>

- 23 Organizations, 12 Countries contributing to open-source BOPTEST development and dissemination
- Extends 10 years of international collaboration on Modelica and FMI-based modeling for building and urban energy system design and operation



# IBPSA Project 2

**Co-Operating Agents:** David Blum, LBNL and Lieve Helsen, KU Leuven - EnergyVille

**1. Task 1: Outreach and Community Building**

*Lead: Javier Arroyo, WEDOCO*

**2. Task 2: Methods and Infrastructure**

*Lead: David Blum, LBNL*

**3. Task 3: Test Cases**

*Lead: Ettore Zanetti, LBNL*

**4. Task 4: Controller Testing, IBPSA University Webinars, and Workshop**

*Leads: Esther Borkowski, DTU and Zhe (Walter) Wang, HKUST*

# Recent Update Highlights

## Software

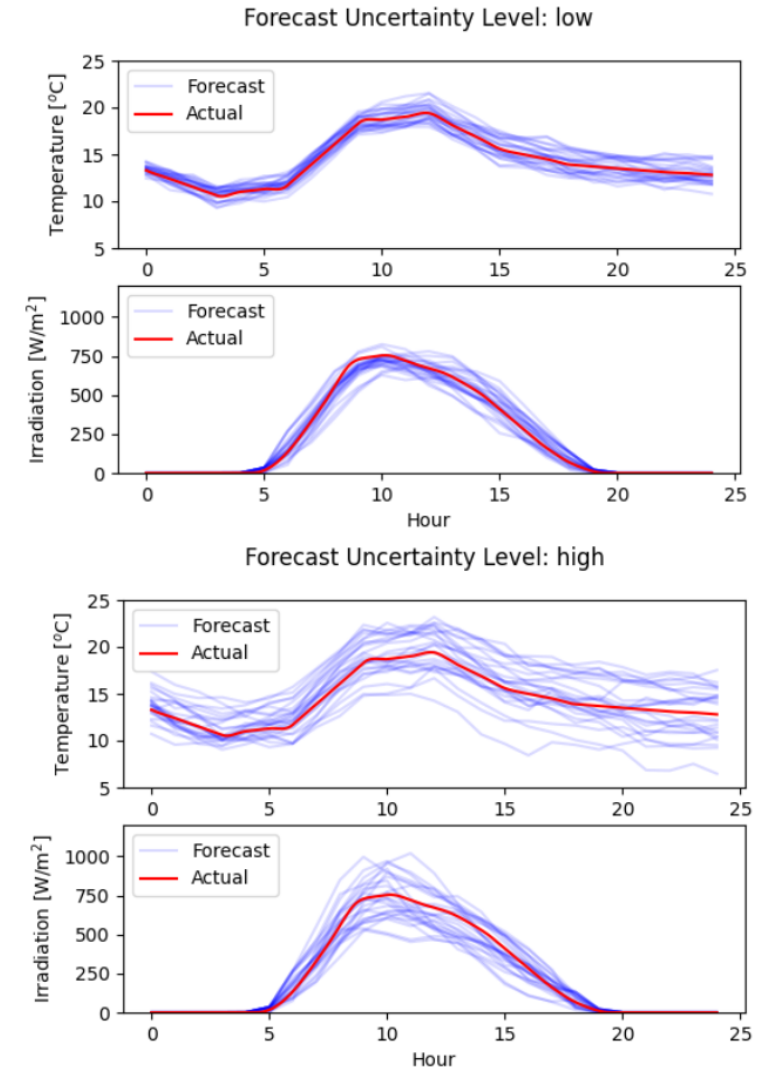
- Weather forecast uncertainty (in v0.8.0)  
(see Zheng et al. 2025: <https://doi.org/10.1080/19401493.2025.2453537>)
- BACnet interface time management options (expected next release)
- Actuator travel KPI under development

## Test Cases

- Support compilation by Dymola (in v0.8.0) and Impact (in v0.7.0)
- Updates to single\_zone\_commercial\_hydronic to improve HVAC system realism and simulation robustness (in v0.8.0)
- New test case multizone\_office\_complex\_air (expected next release)
- Updating dependent Modelica libraries for all test cases

## Dissemination

- (4) IBPSA University Webinars by BOPTEST users:  
<https://www.youtube.com/@IBPSAUniversity>



*Example uncertain forecasts (25 count) generated for levels of low and high for OAT and GHI.*



# BOPTTEST Overview and Status

Thank you!

Enjoy the workshop!



**David Blum**

Computational Research Scientist/Engineer  
Building Technology and Urban Systems Division  
Lawrence Berkeley National Laboratory (LBNL)  
Email: [dhblum@lbl.gov](mailto:dhblum@lbl.gov)



**IBPSA Project 2**

<https://ibpsa.github.io/project1-boptest/ibpsa/index.html>