NREL
NATIONAL RENEWABLE ENERGY LABORATORY

University of Colorado Boulder

Building Simulation Testbed Development for RLC

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IBPSA Project 1 - WP1.2 - BOPTEST and MPC

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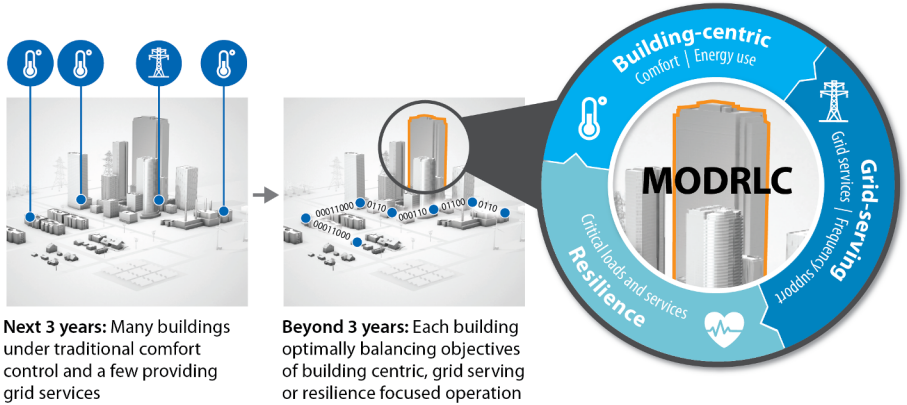
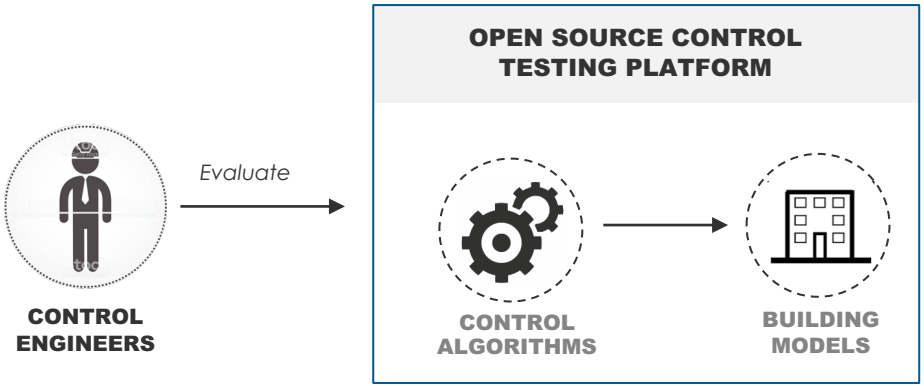
OBJECTIVES

- **DOE BTO Project:** Multi-Objective Deep Reinforcement Learning Control for GEB
- Build **testbed capabilities** using **open-source software** for long-term relevance and **benefit of building controls community**
- Develop **standard prototype building models** with realistic controls implemented in Spawn
- **Provide reproducible results** evaluated against accepted key performance indicators **(KPIs)**
- **Compare** conventional, enhanced rule based, and model predictive control (MPC) against reinforcement learning based **(RL) building control algorithms**
- **Validate transfer learning to arrive at recommendations** for most suitable control approaches for implementation at scale



Next 3 years: Many buildings under traditional comfort control and a few providing grid services

Beyond 3 years: Each building optimally balancing objectives of building centric, grid serving or resilience focused operation



DEVELOPMENT ROADMAP

1. ACTB DEVELOPMENT

- Development of Spawn models
- Test of Advanced Controls Testbed

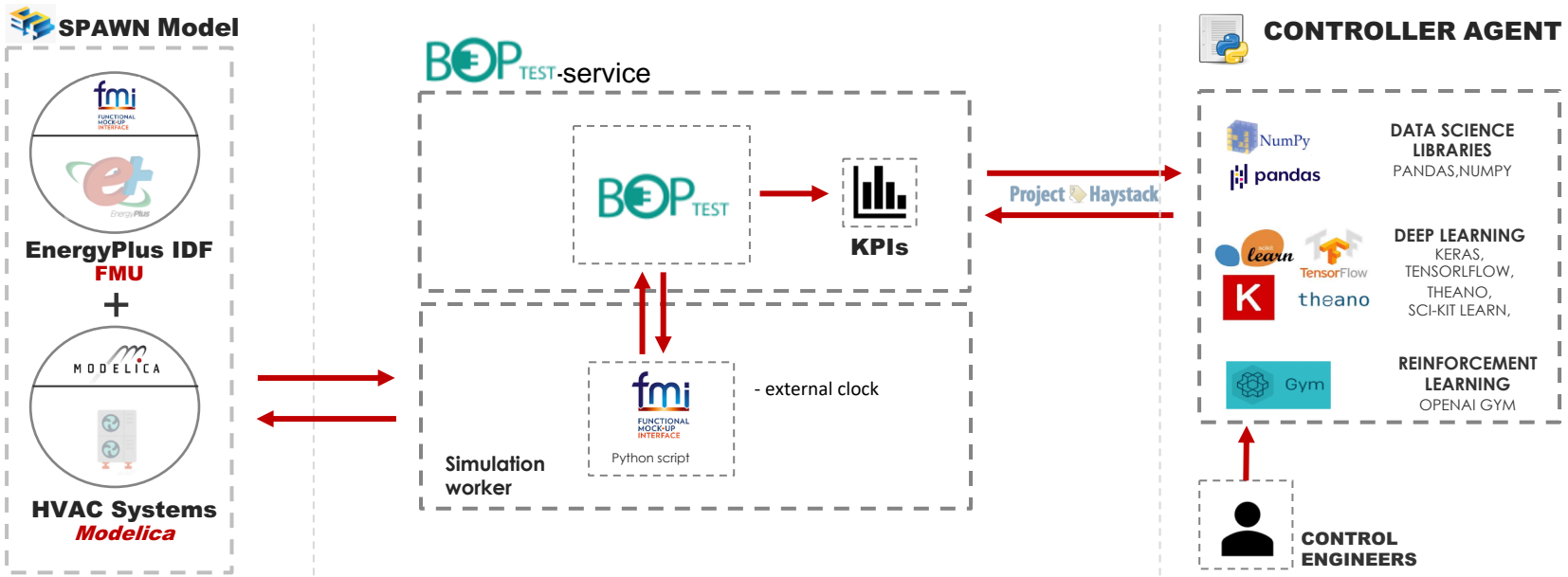
2. EVALUATION OF CONTROL STRATEGIES

- Development of rule-based, MPC and RL control
- Evaluation of KPIs with BOPTEST
- Evaluation of RL control strategies with ACTB

3. FIELD IMPLEMENTATION

- Identification of a suitable real building
- Development of a finely-granular Spawn model
- Application of RL control strategies and transfer learning

PROPOSED ARCHITECTURE



SPAWN OF ENERGYPLUS

- EnergyPlus thermal zone balance & load model
- Modelica HVAC and controls model using Modelica Buildings Library
- Bridges gap between BEM & control workflows

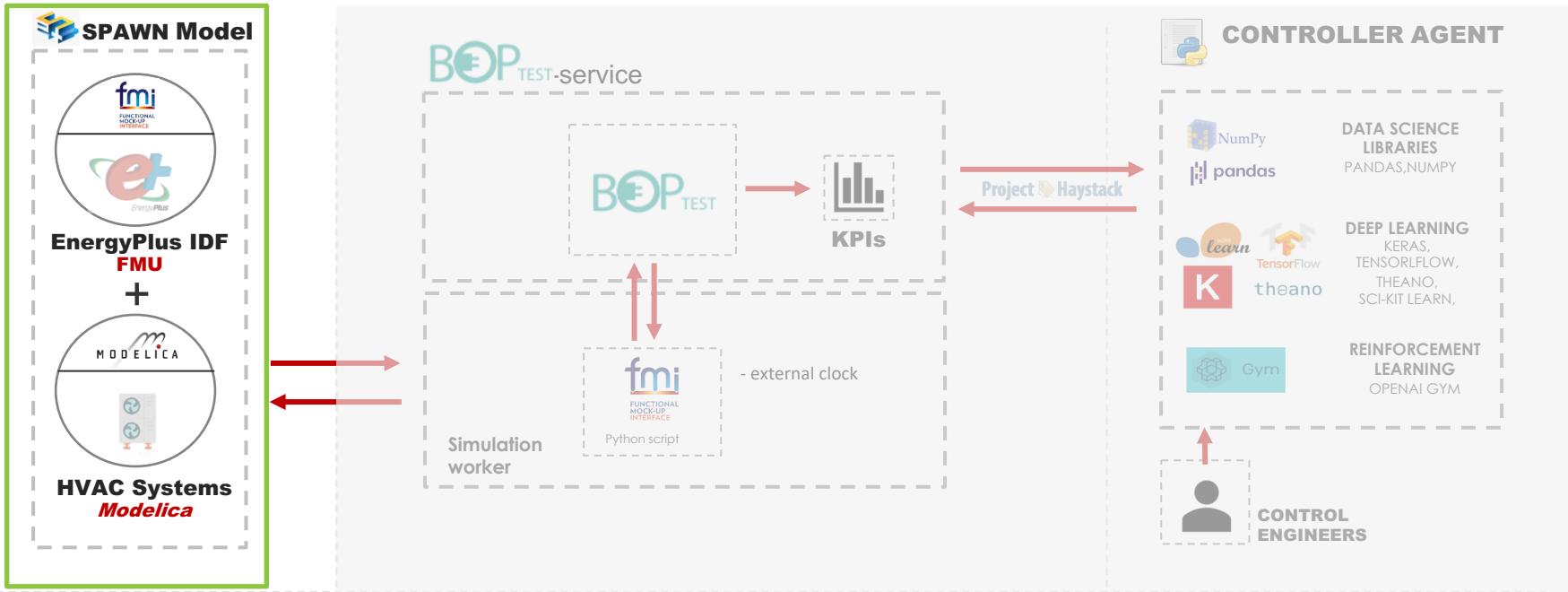
BOPTEST

- Signal override & measurement points
- Control of EnergyPlus & Modelica simulations
- Haystack API for point mapping
- Management of FMU simulations
- Python controller interface
- User-side client for control & KPIs output
- Parallel simulation of multiple BEM test-cases

PYTHON AGENT

- Implementation of control agents pursuing a variety of strategies
- Flexibility
- Availability of proven deep learning and RL libraries

PROPOSED WORKFLOW



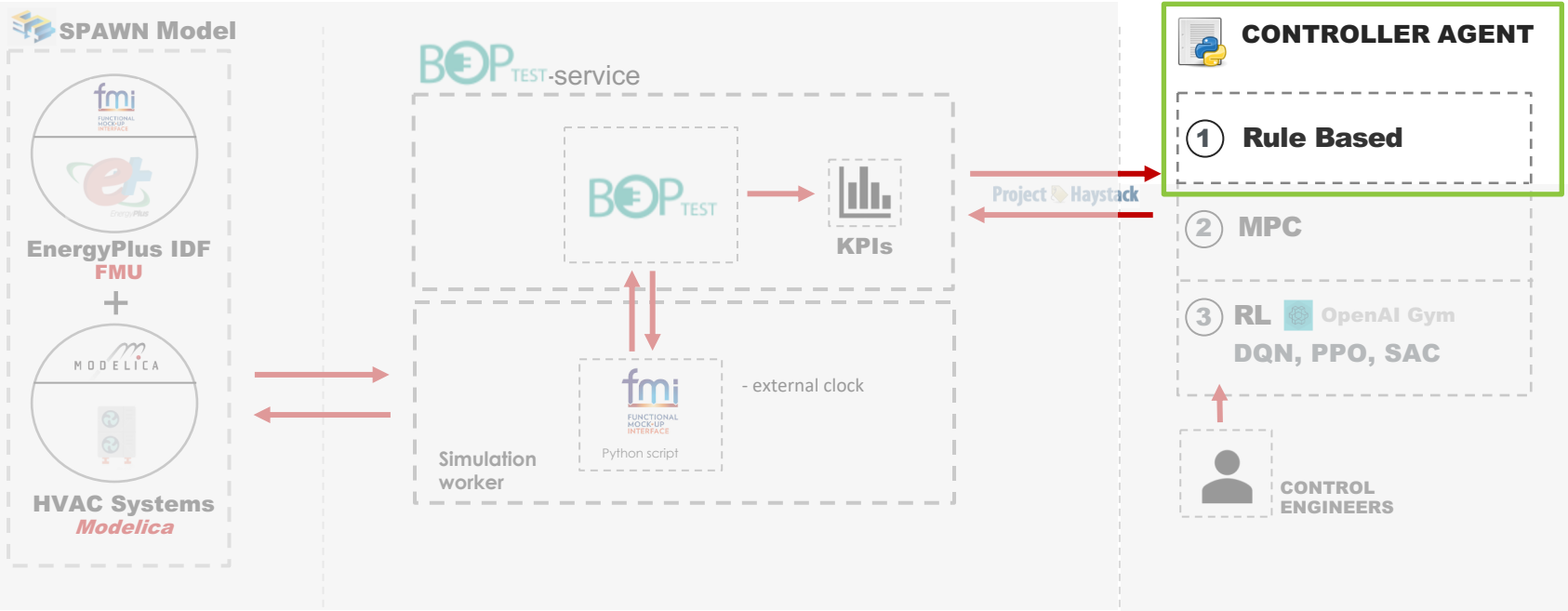
1. Development of a Spawn model

- A detailed building envelope model is developed in EnergyPlus
- A detailed HVAC model is developed in Modelica
- Envelope and HVAC models are packaged into a Spawn model

Advantages:

- Leverage EnergyPlus sensible and latent load modeling capabilities and Modelica's flexibility
- Decouple building envelope model from HVAC system models
- Enable the development of vendor-specific detailed HVAC models

PROPOSED WORKFLOW

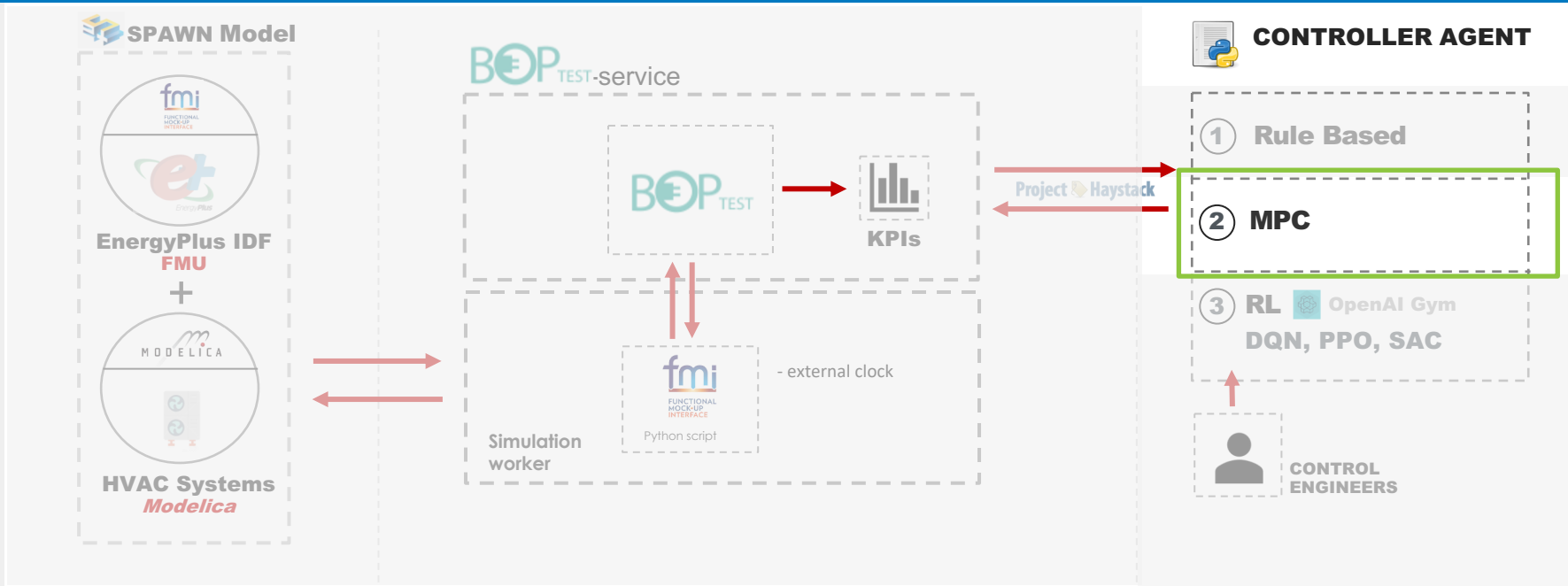


BOPTEST Python controller interface:

Development of three types of control strategies:

- Rule-based controls, to serve as a baseline

PROPOSED WORKFLOW



BOPTEST Python controller interface:

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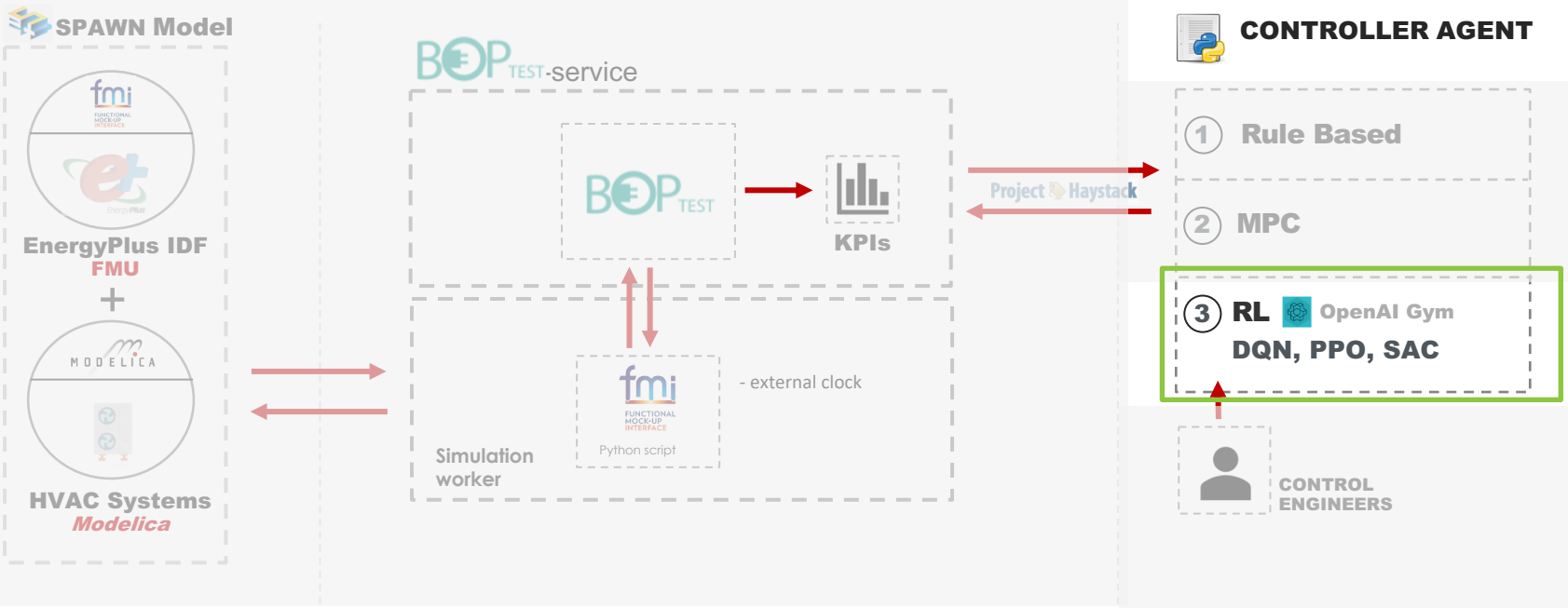
- MPC strategies

PROPOSED WORKFLOW

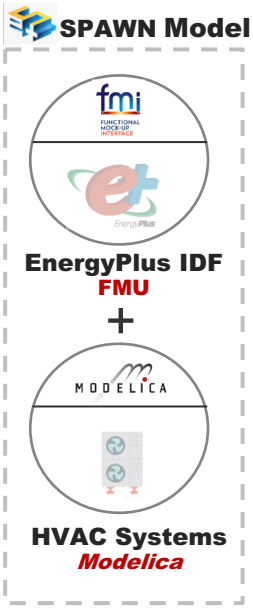


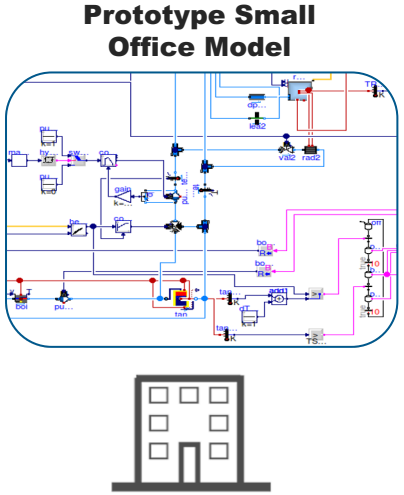
BOPTEST Python controller interface:

Development of three types of control strategies:

- Rule-based controls, to serve as a baseline
- MPC strategies
- Reinforcement Learning with OpenAI Gym: Deep Q Learning (DQN), Proximal Policy Optimization (PPO) and Soft Actor Critic (SAC)

PROPOSED TESTCASE



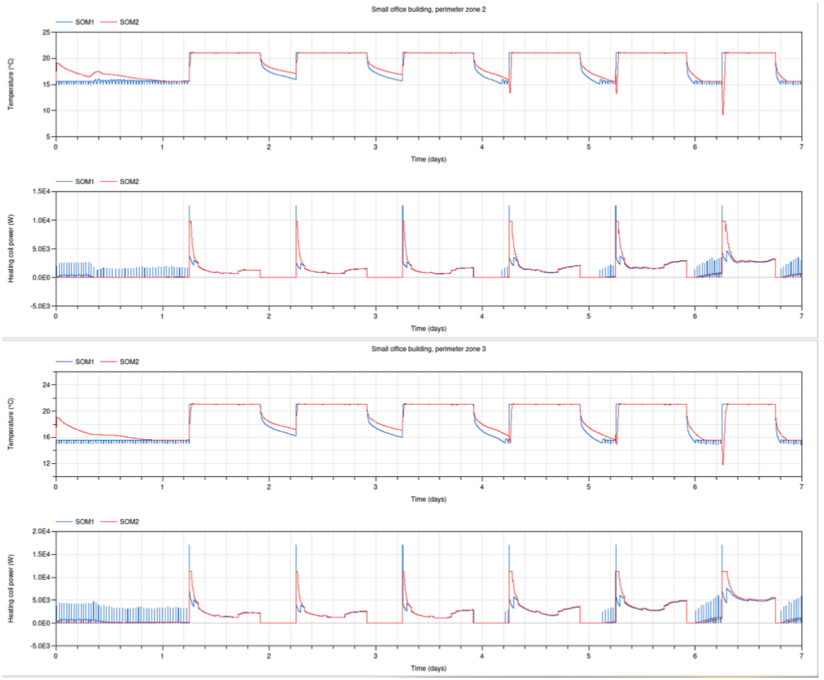


- **5 Zone** Building
- Single zone packaged RTU
- Control sequences (ASHRAE GL 36 where appropriate)
- HVAC – using **MBL** components
- HVAC – Derived from **DOE Small Office Prototype**
- Rule-based, MPC, and RL controls evaluation using BOPTEST KPIs

SUMMARY & FUTURE WORK

Work to date:

- **Verified** that EnergyPlus models and their FMU equivalent have the same performance characteristics.
- **Developed** a Spawn model of a DOE prototype small office building, embedded into an FMU.
- **Exposed** sensors and setpoints of the Spawn model in BOPTEST using the SignalExchange components.



Future work:

- **Test** Advanced Controls Testbed leveraging BOPTEST framework.
- **Debug** and **refine** the integration of the testbed tools.
- **Develop** and **evaluate** advanced control strategies.

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Thank you!

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