

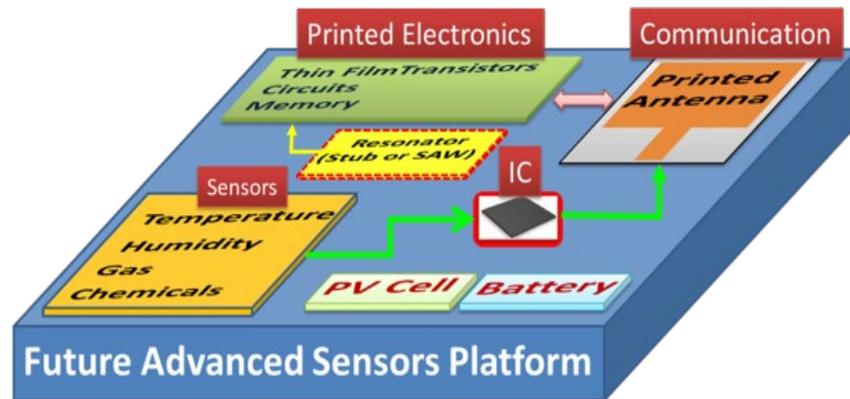
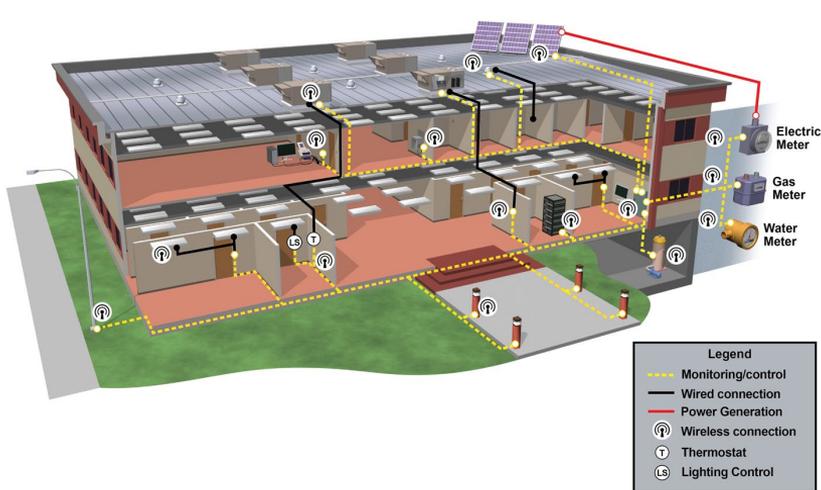
2024 PROJECT PEER REVIEW

U.S. DEPARTMENT OF ENERGY
BUILDING TECHNOLOGIES OFFICE

BTO Peer Review: Development and Validation of Low-Cost, Interoperable, User- Centric, Supervisory Controller Kit for Small and Medium Size Commercial Buildings (One Kit)



Development and Validation of Low-Cost, Interoperable, User-Centric, Supervisory Controller Kit for Small and Medium Size Commercial Buildings (One Kit)



Performing Organization(s): Pacific Northwest National Laboratory (PNNL) and Oak Ridge National Laboratory (ORNL)

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WBS #: PNNL - 3.2.6.205; ORNL - 3.2.6.204

Project Summary

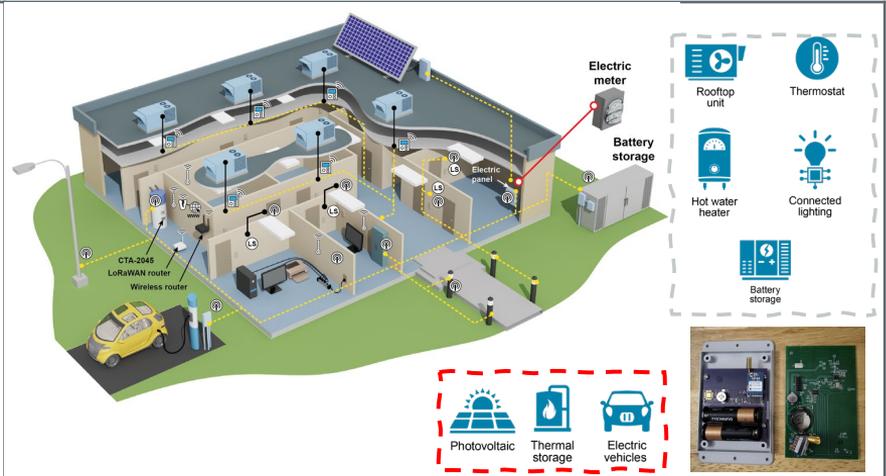
OBJECTIVE: Design, develop, test, and field validate a low-cost, interoperable, user-centric, retrofit supervisory controller kit (SC-SMB) that can be used to continuously optimize energy consumption and deliver demand flexibility of small- and medium-size commercial buildings (SMBs), including all-electric buildings, and provide a means for maximizing decarbonization benefits.

OUTCOME: A reference design for low-cost controls for SMBs at a target cost (material & labor) of \$0.6/sf to \$1/sf.

IMPACT: Widespread deployment of low-cost controls in SMBs will result in 10-30% reduction in energy consumption and 10-20% increase demand flexibility.

TEAM: PNNL and ORNL are the main Research, Development and Deployment team members

PARTNERS: Edo and Intellimation LLC, Technical Advisory Committee



Performance Period: 10/1/2022 – 9/30/2025

DOE Budget: \$1075.5K (PNNL), \$972.5K (ORNL);
Subcontract \$355K

Milestone 1: Development of [Requirements](#) and [Specification](#) for SC-SMB System complete – **5/31/2023**

Milestone 2: Development of the SC-SMB system and lab testing complete – **12/31/2024**

Milestone 3: Field Testing and Validation of the SC-SMB System complete – **9/30/2025**



Problem

- Based on CBECS 2018, less than 15% of SMBs (<50,000 sf) have a building automation system (BAS)
- Studies have shown that lack of control infrastructure results in 10% to 30% excess energy consumption (2,000 to 2,500 trillion Btu annually)
 - Lack of reference designs for a low-cost BAS that leverage interoperable connected thermostats and controllers
 - Building owners lack awareness of the benefits of a BAS
- Other issues not addressed by the project:
 - Split incentives (occupant not owner of the building), lack of utility incentives and lack of deployment experience (inadequate workforce)
- **A low-cost BAS system for SMBs that can be easily deployed will result in significant energy savings and emission reduction and increase demand flexibility by 10% to 20%**



Alignment



Contribute to reduction of U.S. building emissions of 60% by 2035 and 90% by 2050 vs. 2005 while enabling net-zero emissions economy-wide and centering equity and benefits to communities



- **Equity:** Controls solutions that will benefit disadvantage communities; and underserved building owners to address energy justice



- **Affordability:** Low-cost solution that will lower utility bills with less than a 3-year payback and, in some regions, it could range between 1- and 2-year payback



- **Resilience:** Advanced controls make building operations resilient against extreme weather events and support passive survivability



- **Energy Efficiency:** Solution provides 20% to 30% reduction in whole building energy consumption and equivalent emissions reductions



- **Accelerate Onsite Emissions Reduction:** Supports all electric buildings, minimizes energy consumption by coordinating operations across all DERs



- **Transform the Grid Edge:** Reduces electrical infrastructure cost and mitigates grid constraints from supply-demand imbalance by coordinating DERs to manage peak electricity consumption and provide automated demand flexibility between 20% (passive) to 50% (active storage)



Impact

- A field validated reference design for low-cost controls for SMBs at a target cost of \$0.6/sf to \$1/sf with less than 3-year payback that can be implemented in 85% of commercial building stock that do not have a BAS
- Deployment of this system in SMBs will result in 10% to 30% reduction in energy consumption and equivalent emissions and 10% to 20% increase in demand flexibility
- Opensource reference design and software to manage SMBs
 - Rooftop units (RTUs), water heaters, connected lighting, and storage systems; in the future, it can be extended to monitor solar and manage electric vehicle charging



Approach – Current State of SMBs Operations: Energy Efficiency (EE)

- Most SMBs use RTUs for heating, ventilation, and air-conditioning (HVAC) and are controlled by thermostats
 - Even if the thermostats are programmable, they are often programmed incorrectly; therefore, set points, setbacks, schedules, and optimal start are not properly configured or enforced
 - Buildings with multiple RTUs have no ability to coordinate RTU operation
- Many RTU economizers do not work as intended
- Interior lighting and exhaust fans are not controlled in an automated way; exterior lighting may be controlled by photocell or time clocks





Approach – Current State of SMBs Operations: Grid Services (GSs)

- Limited building-grid interaction, mostly through BYOD (bring your own device – connected thermostats)
- SMBs lack the ability to transact energy-related services with entities, including aggregators, independent system operators, or electric utilities
- Lack of scalable applications to meet the current and future market needs, which limits demand flexibility potential
 - Most non-BYOD deployments are one-off custom solutions, which are not cost-effective
 - Many BYOD programs do have an opt-out option
 - Building owners/occupants do not have full control – ability to override
- **Electrification of buildings by introducing RTU-heat pumps and decarbonization of the grid through increasing use of renewable generation will significantly disrupting the supply-demand imbalance**



Approach: Project Overview

- The solution approach was developed in consultation of project partners and members of the Technical Advisory Committee (TAC) and it is highly tailored to the current needs of the SMB market

1st Year

- Specify requirements for the SC-SMB system, draft an implementation plan, and identify reference implementation hardware for lab testing

2nd Year

- Extensive testing and characterization of the solution at PNNL and ORNL. Testing in real buildings or simulated lab environment

3rd Year

- Expected benefits to be demonstrated through field testing the SC-SMB system in 3 to 5 SMBs
- Develop a commercialization plan



Approach: Barriers, Technical Challenges, and Project Risks

- SMBs are first-cost sensitive and lack full-time operators; therefore, the solution must be:
 - Cost-effective (lower material cost)
 - Easy to deploy (lower labor cost) and
 - Minimal ongoing cost
- Primary risks are not being able to find an interoperable thermostat or water heater controller, or the solution might require significant time to deploy and configure in the field
- **The solution has been designed with 1) interoperable components that minimize the component costs, 2) easy to deploy, lowering the engineering costs and 3) autonomous operations**



Approach: Plan to Deliver

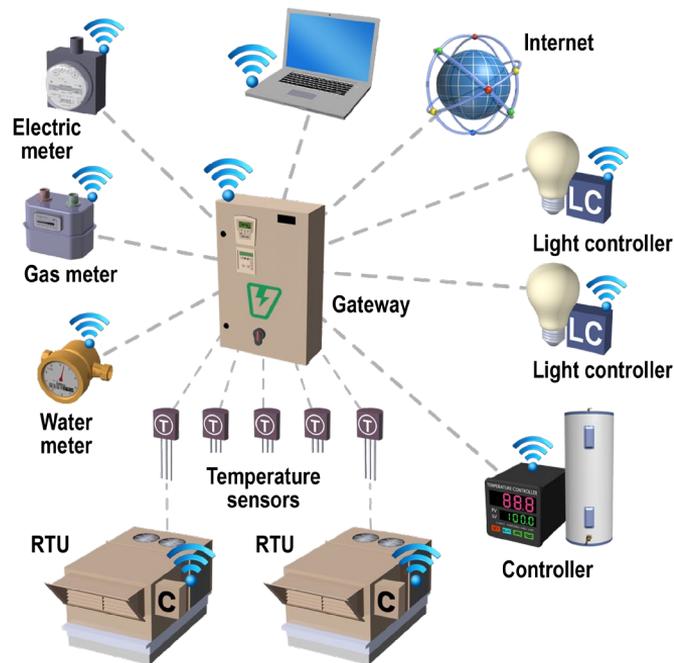
Assumptions

- Building size: 10,000 sf
- Energy use index of a building is 100 kBtu/sf/yr (55% electricity and 45% gas) – CBECS 2018 data
- Electricity price is 0.1 \$/kWh, natural gas price is \$5/MMBtu
- Anticipated savings from SC-SMB deployment is 10%, the annual normalized energy cost savings are approximately 0.2 \$/sf
- Anticipated annual savings will be approximately **\$2,000/yr**; not inclusive of savings from peak load reduction or grid services
- If the building owner is looking for a 3-year simple payback, the owner could afford to invest **\$6,000 (\$0.6/sf)** to install controls without any utility incentives
- If the utilities provide incentives through their demand side management program, the installed cost can be higher and still have a 3-year payback



Approach: Innovation

- To enable minimal integration, engineering, and ongoing operational cost:
 - Use standards-based WIFI thermostats and hot water heater controller
 - Fully automated and autonomous; user override capability
 - Reference design and related software will be released as opensource, so anyone can freely deploy it
- Interoperable and off-the-shelf equipment should achieve \$0.6/sf to \$1/sf cost target





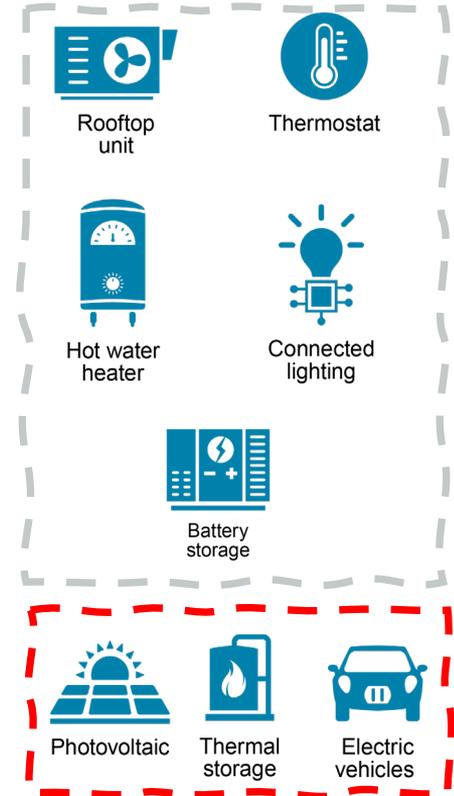
Progress: Commercialization and Market Transformation

- Clearly articulate benefits of automated controls to the building owners and stakeholders (utilities, cities, etc.)
- Conduct field validation to show the benefits of the technology and ease of deployment
 - Develop case studies and disseminate the results at major conferences
- Engage utilities to encourage them to incentivize building controls for SMBs
- Engage energy service providers, including those on the TAC, to promote the technology



Progress: SC-SMB

- Requirements and specification for SC-SMB system completed
- SC-SMB system development complete
 - Solution cost-effectively increases EE and demand flexibility of underserved SMB sector
 - Manages and controls diverse set of DERs
 - System is easy to deploy and configure, i.e., minimal integration, engineering, and ongoing operational costs
 - Wireless integration with devices reduces deployment cost
 - Supports increasing hosting capacity of renewables
 - Addresses the needs for all electric buildings





Progress: Development and Laboratory Testing of SC-SMB System



Thermostat

Evaluated and selected BACnet-WIFI thermostats: Schneider Electric SE8650U0B00 and Temco Controls Tstat10-W



Hot water heater

Hot water heater controller testing completed: CTA-2045 (SkyCentrics) and Non-CTA-2045 (Shifted Energy and Trickle Star)



Connected lighting

Whole building electricity meter integration completed: Dent (BACnet-WIFI) and Shark (Modbus WIFI)

Tested BACnet-based connected lighting fixtures (no proprietary systems tested)



Battery storage

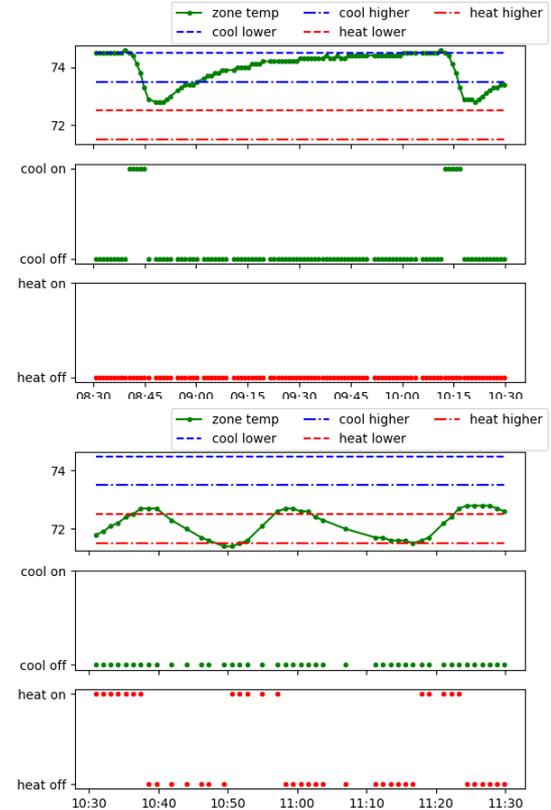
Tested Modbus-based inverters to control BESS (no proprietary)



Progress: Wireless Sensor and Control for Improving Building Energy Efficiency

Prototypes

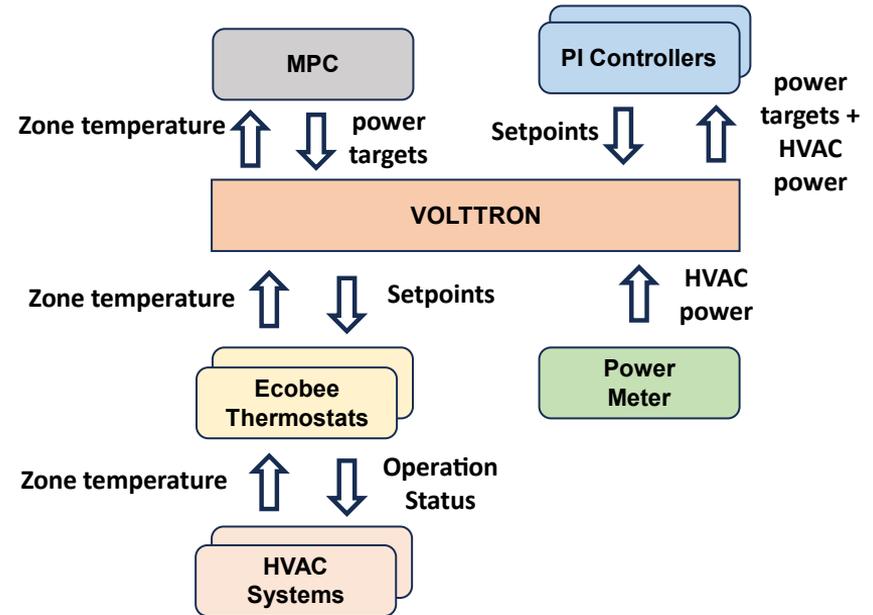
- LoRa-based Wireless Platform
 - Low-cost ($\leq \$10/\text{node}$)
 - Long operational lifetime (half-year battery life with a sampling interval of 2 minutes)
 - Multiple sensors: temperature relative humidity and CO_2
 - Thermostat





Progress: Plug-and-Play Model Predictive Control (MPC)

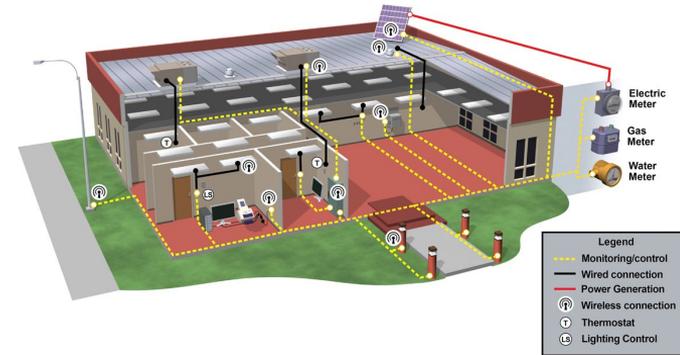
- Flexible control architecture
 - Online system model identification
 - Autonomous tuning of control architecture
- Streamline the process for deploying MPC
 - Programming Interfaces (APIs) for MPC configurations
 - Standard and detailed documentation for MPC specification
 - Minimum human involvement (~2-3 person-hour/one small & medium office building)





Future Work

- Finalize the SC-SMB system for field deployment
- Select field test sites to test and validate the SC-SMB system and conduct the field test – 9/30/2025
- Finalize the SC-SMB system for opensource release and commercial deployment – 12/31/2025
- Document reference design and commercialization plan – 12/31/2025
- Outreach to stakeholders through Technical Advisory Committee



Thank you

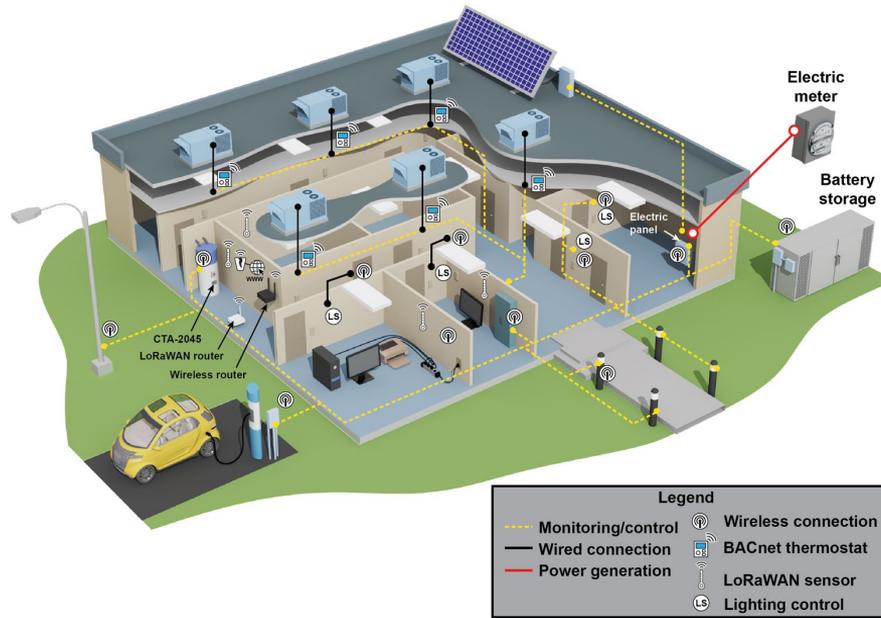
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Reference Slides





Project Execution





PNNL Team and Project Partners



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