Stor4Build
U.S. DEPARTMENT OF ENERGY

Stor4Build Overview

A Multi-Lab Building Energy Storage Consortium

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2024 Stor4Build Lab Consortium Meeting

Stor4Build is a multi-lab consortium designed to accelerate the development and deployment of affordable energy storage technologies for buildings.

Funded By:

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Co-Directors:

BERKELEY LAB

NREL Transforming ENERGY

OAK RIDGE National Laboratory

Supported By:

ACEEE American Council for an Energy-Efficient Economy

Pacific Northwest NATIONAL LABORATORY

National buildings Blueprint: Alignment

Reduce U.S. building emissions 65% by 2035 and 90% by 2050 vs. 2005 while enabling net-zero emissions economywide and centering equity and benefits to communities

CROSS-CUTTING GOALS

Equity – Advance energy justice and benefits to disadvantaged communities

Affordability – Reduce energy burden and technology costs so all can benefit

Resilience – Increase the ability of communities to withstand and recover from stresses

STRATEGIC OBJECTIVES

Increase building energy efficiency
Reduce on-site energy use intensity in buildings 35% by 2035 and 50% by 2050 vs. 2005

Accelerate on-site emissions reductions
Reduce on-site GHG emissions in buildings 25% by 2035 and 75% by 2050 vs. 2005

Transform the grid edge
Reduce electrical infrastructure costs by tripling demand flexibility potential by 2050 vs. 2020

Minimize embodied life cycle emissions
Reduce embodied emissions from building materials and construction 90% by 2050 vs. 2005

Decarbonizing the U.S. Economy by 2050: A National Blueprint for the Buildings Sector

National buildings Blueprint: Alignment

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

Prioritize equity – Proper storage solutions will reduce blackouts that disproportionately impact LMI communities, in the worst case leading to avoidable fatalities during heat waves and extreme weather events. Storage can also make upgrades to buildings easier for resource-scarce communities, avoiding long permitting processes for utility service upgrades, down-sizing the equipment type to meet constraints unique to certain building types (lower weight, footprint, amperage, etc.).

Prioritize affordability – The roadmap identifies where thermal storage is a less expensive, more sensible approach than battery integration. It also considers how strategic storage integration can avoid costly upgrades and downsize HVAC systems and major appliances. Storage can work favorably with time-of-use rates to reduce demand surcharges and lower energy burden in LMI communities.

Prioritize resilience – Behind-the-meter storage is central to building resilience. Storage technologies will be increasingly critical to the safety and health of occupants during blackouts and extreme weather events (heat waves, cold snaps), and to preventing blackouts in the first place.

National buildings Blueprint: Alignment

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

Increase building energy efficiency

TES can improve HP efficiencies or harness free heating and cooling by taking advantage of daily variations in ambient temperature. DC-coupled EES, PV, and certain end uses can improve system efficiencies by eliminating inverter losses.

Accelerate onsite emissions reductions

Building energy storage makes electrification far more viable by reducing the need for electrical upgrades and right-sizing equipment. TES can increase the effective capacity of heat pumps, while EES can provide surge power to devices at the point of use rather than pulling from the grid. On-site storage can also displace backup diesel generators in many buildings.

Transform the grid edge at buildings

Energy storage can reduce peak demand providing a “non-wires” solution to substantially reduce required investments in distribution system upgrades that would otherwise be needed to support widespread electrification.

Minimize building life cycle emissions

By utilizing low embodied carbon materials, TES technologies have the potential to lower life cycle carbon impacts relative to conventional battery EES.

Research Areas

Stor4Build has identified five key areas of focus to accelerate the growth, optimization, and deployment of cost-effective thermal energy storage technologies that benefit all communities.

Materials Optimization and Development

Controls

Modeling and Analysis

Equipment and Envelope Integration

Standard Test Procedures

Materials Overview

Investigating optimized TES materials to lead the deployment of TES systems in buildings.

Phase Change Materials (PCMs)

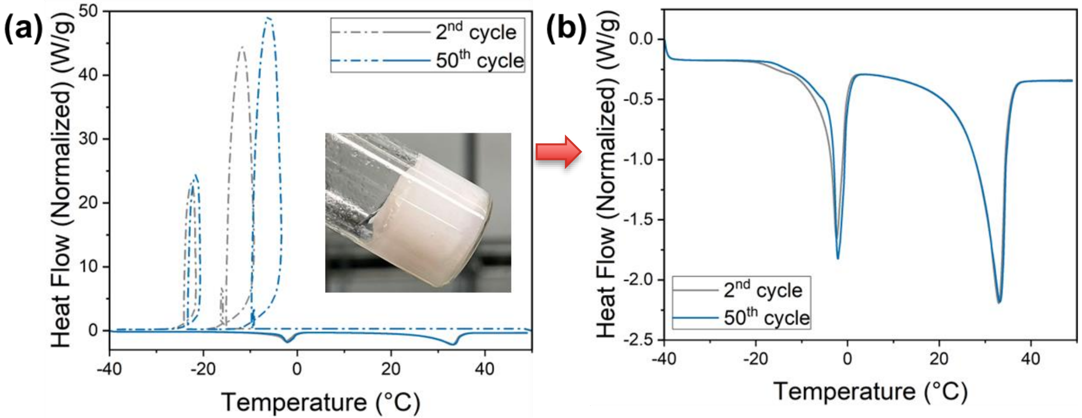
- Compatibility Investigation
  - Examine the compatibility of PCMs with existing heat exchanger and heat pump components
  - Address corrosion behavior and develop corrosion inhibition strategies
- Performance Improvement
  - Optimize PCM materials to meet system-level requirements
  - Reduce costs and enhance thermal energy storage capacity

Thermochemical Materials (TCMs)

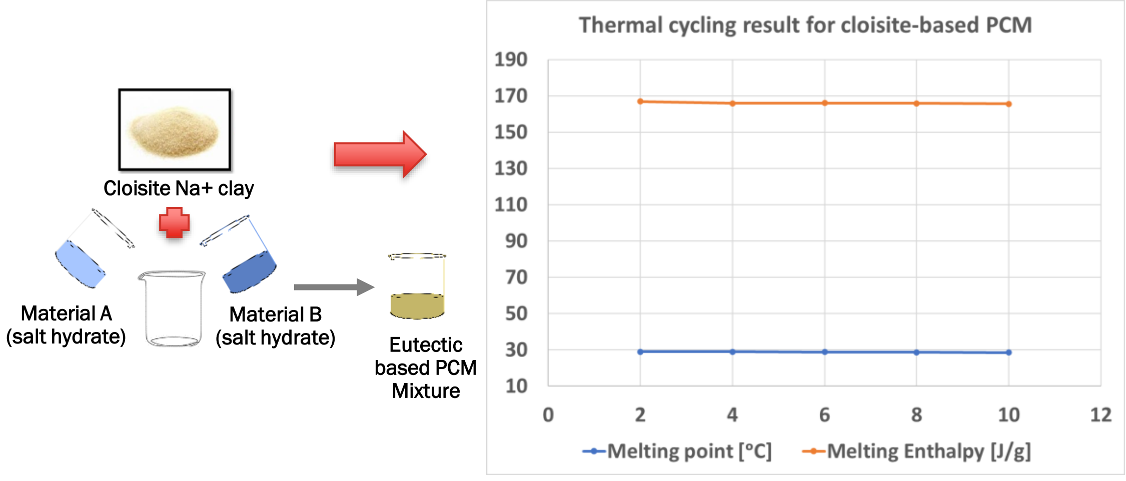
- Focus on optimizing materials for deployment in key areas.

Phase Change Materials

- Results and highlights:
  - Development of stable composite PCM with polymer hydrogel encapsulation (top right)
  - Eutectic PCM mixture with phase change temperature ~28°C and 165 J/g (bottom right)
  - Materials selection for compatibility test with HVAC components.
- Next steps:
  - Test eutectic PCM mixtures for longer thermal cycling and integration into TES systems.
  - Report corrosion results.



Thermal cycling plots and real image for the polymer encapsulated PCM sample showing cyclic stability up to 50 cycles.

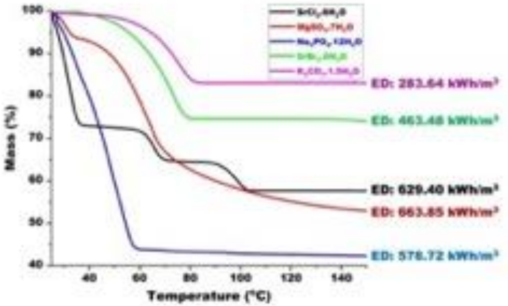


Eutectic PCM with near ambient phase change temperature.

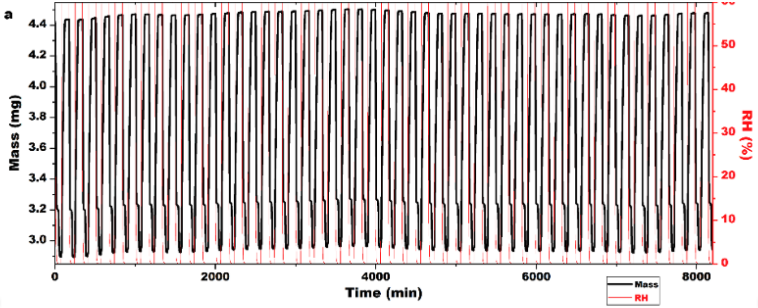
Thermochemical Storage

- Thermochemical materials (TCMs) have high storage capacities (~500 kWh/m^3) and negligible self-discharge are uniquely suited as compact, stand-alone units for daily-seasonal storage for residential, district-level or large commercial buildings.
- TCMs suffer from instabilities at the material (salt particles) and reactor level (packed beds of salt), resulting in poor multi-cycle efficiency and inconsistent power output.
- Using bottom-up approach to address the instabilities of the salt hydrates as well as optimize the reactor design
- Demonstrated stable performance >2000 cycles at materials/composite level and >80 cycles at reactor level.
- Next step: Testing Cascade TCM reactor and building filed demonstration unit.

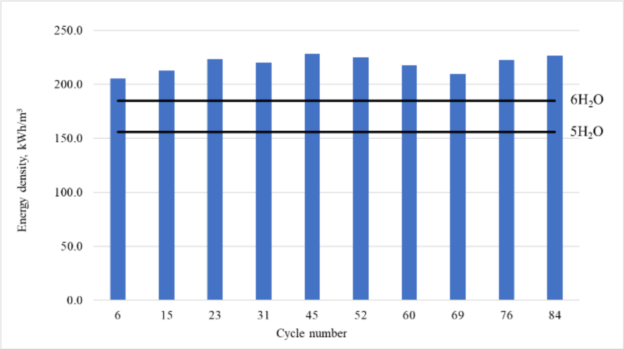
Down selection of TCMs for building



Cyclability (Salt)
(Sample size –mg)



Cyclability of composite
(275 x120x73 mm)



Modeling & Analysis Overview

TES Sizing, Benefits and Decision (TESSBeD) Tool

- Develop a third-party, physics-based, evaluation tool to estimate benefits and performance of thermal storage integrated with HVAC systems in buildings.

TESSBeD Tool

Develop a science-based tool to estimate TES benefits and assisting end-users in TES implementation decision making.

- Freely available source code
- Use standard, available tools

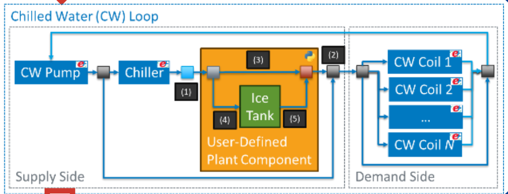
Progress:

- Engaged with industry stakeholders about tool use cases and features
- Architecture, requirements, and specifications complete or in progress
- Proof-of-concept development of ice tank TES with rule-based control complete

Web Interface

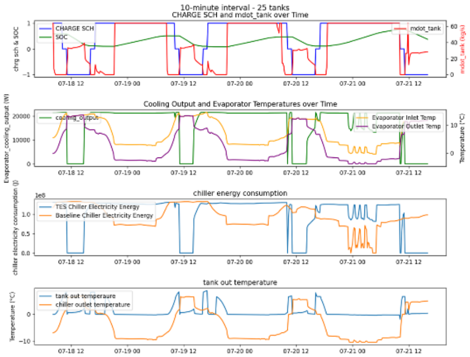
- Building type
- Utility rates and energy costs
- Technology specific details
- Other costs

Compute Analysis



Outputs

- Energy Use
- TES performance
- Economic impacts



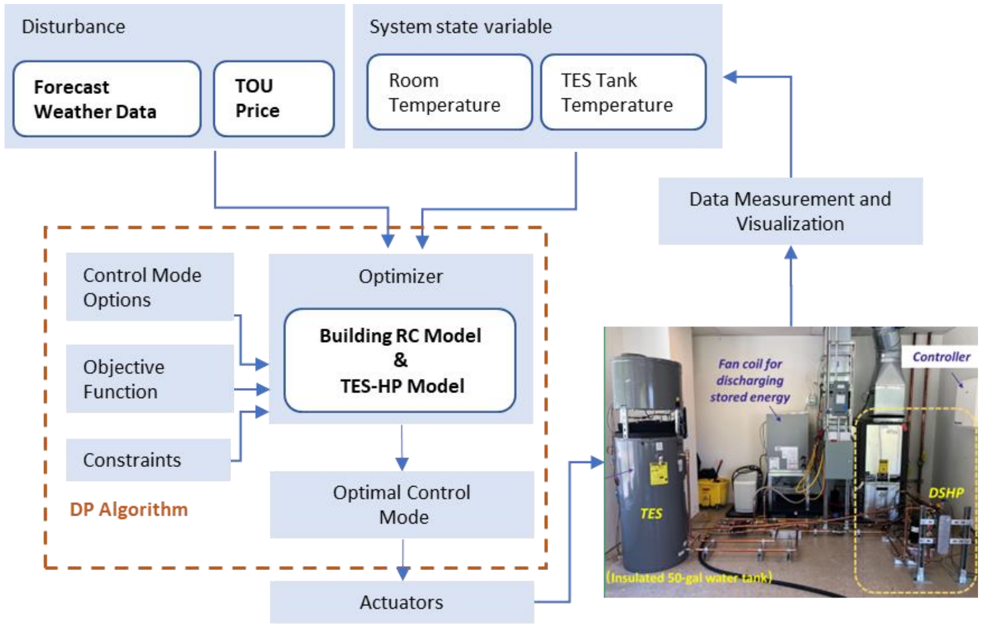
Controls Overview

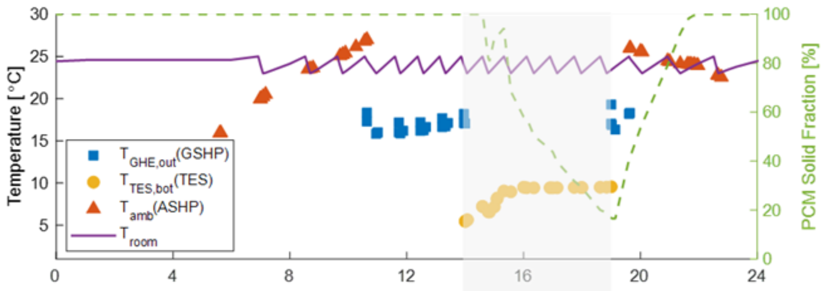
- Optimize the operation of the TES system
- Minimize energy costs and carbon emissions
- Manage building thermal comfort
- Balance grid supply and demand

Advancing TES Controls

- Development of robust, intelligent, low-cost, and plug-play controls for various TES systems. The advanced control would be grid-interactive so that the distributed TES systems can be aggregated to have big impacts on the electric grid.
- Automatically determine operation mode & TES charging level to maintain room temperature and shift electric demand to reduce energy costs or carbon emissions.
- Results to date
  - ✓ Both MPC and RBC have been implemented successfully.
  - ✓ MPC can reduce energy costs by 15%.
- Next Steps: improve control strategy and develop plug-play controllers.

Diagram of a Predictive Control





TES Discharge

Integration Overview

Equipment-Integration

- Develop a new heat pump that is TES-ready and can be directly plug-and-play with a TES in the field.
- Achieve both cooling and heating by implementing one TES tank in HP system.
- Fabricate HP-TES prototypes and evaluate HP-TES performance via both lab test and field test

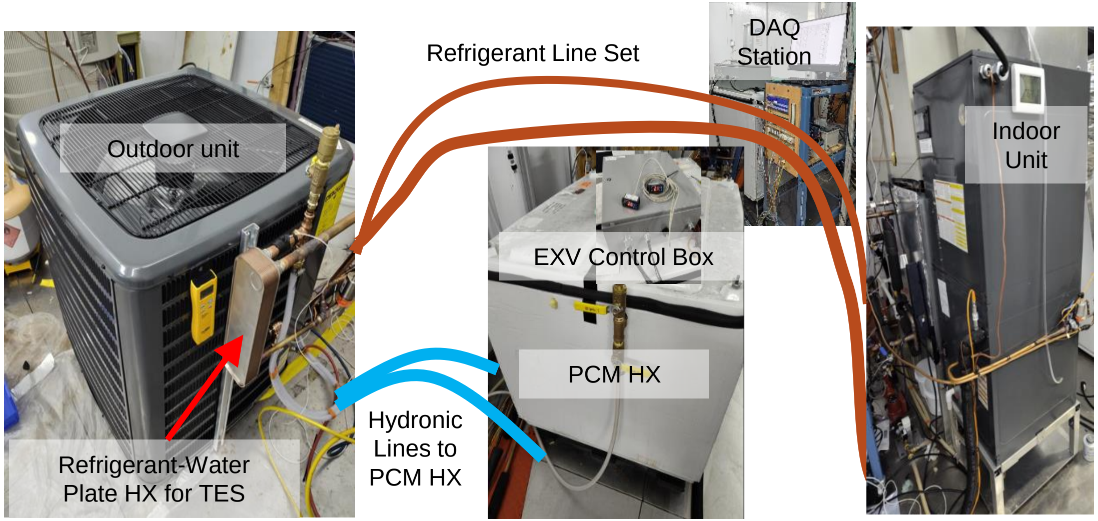
Envelope-Integration

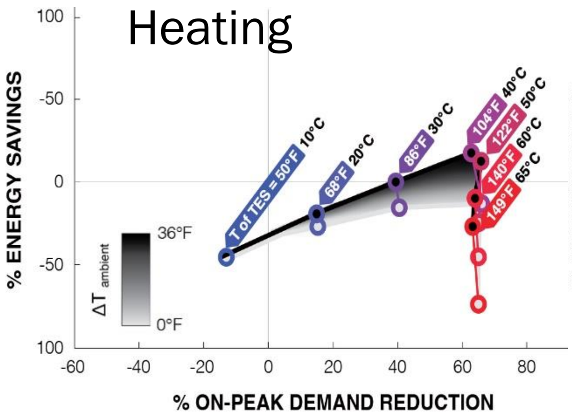
- Develop envelope integrated TES solutions for enhanced efficiencies, demand reduction, and thermal resilience
- Optimize designs for easier installation and reduced costs
- Fabricate prototypes and evaluate performance in lab and field

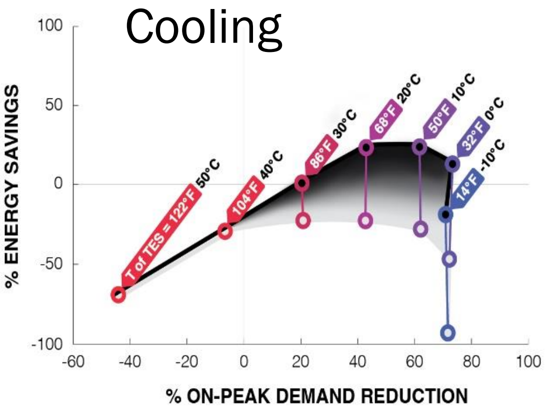
TES-HP for Combined Heating and Cooling

- TES is integrated into a heat pump to achieve peak load shifting, improve resilience, reduce heat pump size and energy cost
- Able to achieve both heating and cooling with a single TES material and phase-change temperature
- Developing a TES-HP prototype
  - ✓ Plug-and-play TES-HP
  - ✓ Using low-cost PCM as TES media
  - ✓ Six modes have been tested in lab
- Next Steps: implement supervisory control and conduct field tests

TES-HP Prototype for Lab Testing

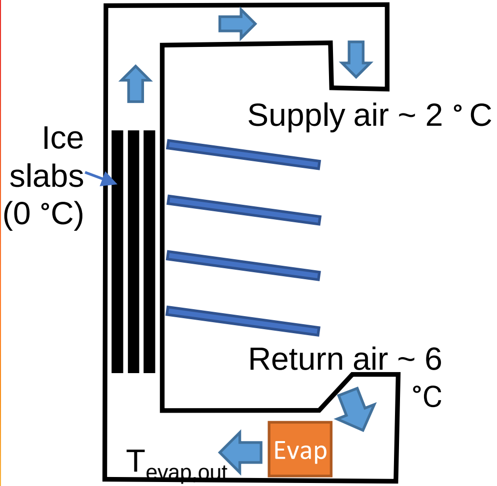






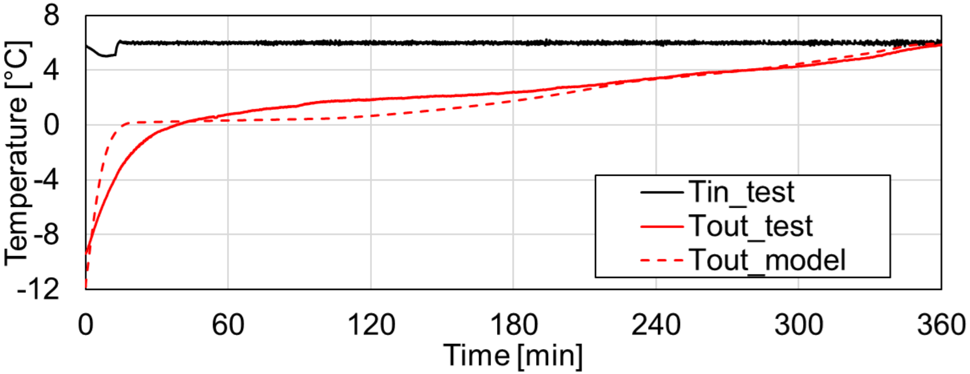
Load Shifting and Resiliency for Refrigerated Display Cases

- Integrate ice-based thermal storage on the air side (evaporator outlet) of a refrigerated case.
- Bench-scale experiments show ice heat exchanger can provide adequate supply air for 3 hours with the compressor off
- Next steps:
  - Scale up and integrate with a 1.8-m wide refrigerated case
  - Investigate other applications for air-to-PCM heat exchangers



Refrigerated Display Case
(side cross section)

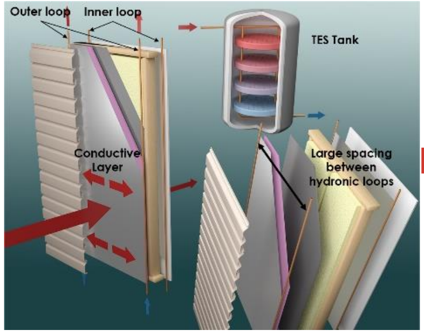
100 Wh Bench-Scale Prototype

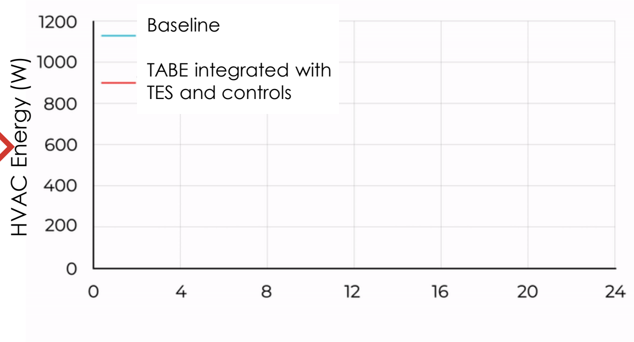


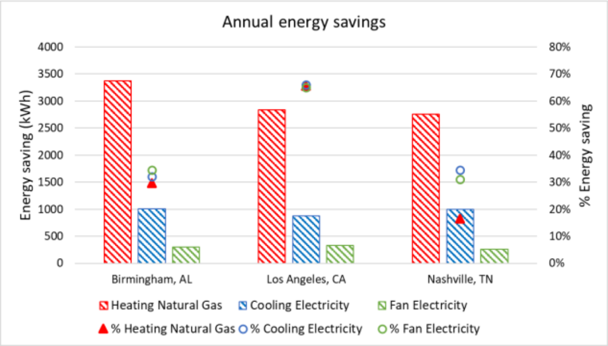
Discharge Test Shows TES Enables 3-4 Hours of Load Shifting

TES Integration with Active Building Envelopes

- TES + Thermally Anisotropic Building Envelope (TABE) to reduce HVAC loads, peak electricity demand, and equipment size, and improve resiliency
- TABE: one or more thin conductive layers connected to TES through hydronic loops to collect abundant untapped thermal energy sources in building envelopes
- Developing TES for TABE
  - ✓ Discharge 90% in 4 hours for max use during typical peak demand period.
  - ✓ Utilize 90% of the storage volume with PCM to maximize energy storage density.
  - ✓ ΔT < 10°F to optimize energy harvesting, HX size, and pump power.
- Next Steps: whole building field demonstration of TES + TABE

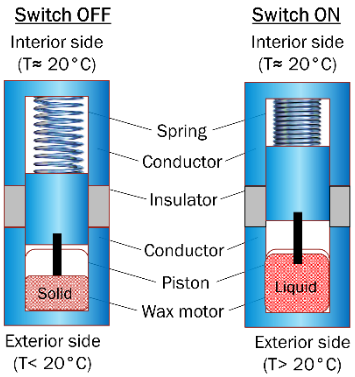




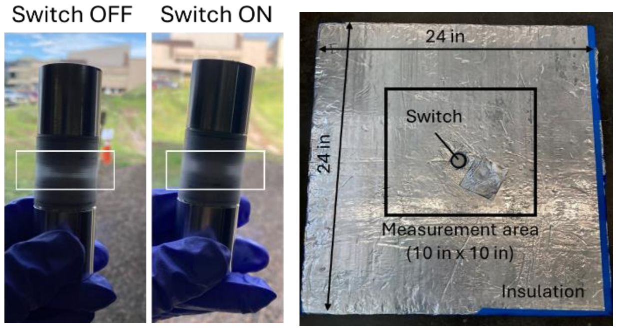


Plug-and-Play Thermal Switches with Thermal Storage

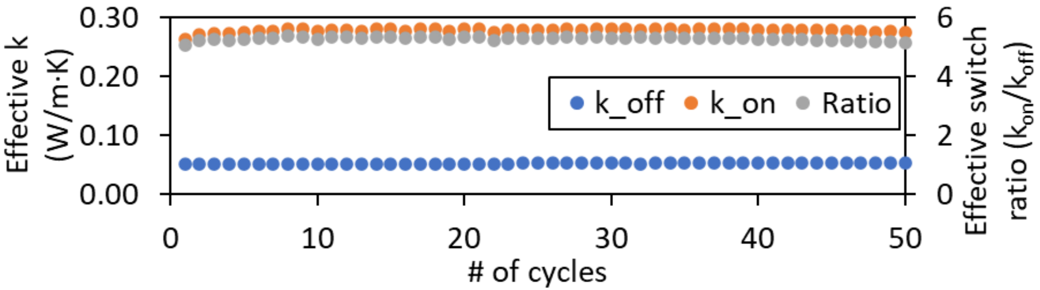
- Demonstrated plug-and-play thermal switches in the form of retrofittable plugs.
- Cyclability tests shows nearly consistent thermal performance.
- Why it matters:
  - Studies report dynamic envelopes can provide significant HVAC energy savings.
  - Supports underrepresented and disadvantaged communities by reducing energy-related cost burdens and enhancing occupants' comfort
- Next steps:
  - Scale up and integrate multiple units with a wall-component
  - Investigate the performance under real summer conditions in Golden



Thermal Switch
(Design and Operation)



Experimental Prototypes and Measurement
(1 switch per 10 in x 10 in insulation)



Cyclability tests over 50 cycles shows nearly consistent performance and switching ratio above 5.

Standards Overview

- Address the need for unified, standardized methods of testing material properties
- Understand current codes and standards and determine needs to optimize the storage technologies and enable safe adoption in buildings.

Two steering councils (R&D and Market Adoption) support equity-centric scaled adoption of building energy storage technologies and a market transformation to increase market viability.

Stor4Build welcomes participants from industry, utilities, nonprofit organizations, communities, building owners, academia, government, and other research institutions.


Photo by Werner Slocum, NREL 73692

Get Involved

Contact Stor4Build@ee.doe.gov for more information on ways to collaborate.

Learn more on Energy.gov or to receive the latest Stor4Build news.

Thank you!

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