ThermoVerse™

Elevating Comfort | Transforming Thermal Environments

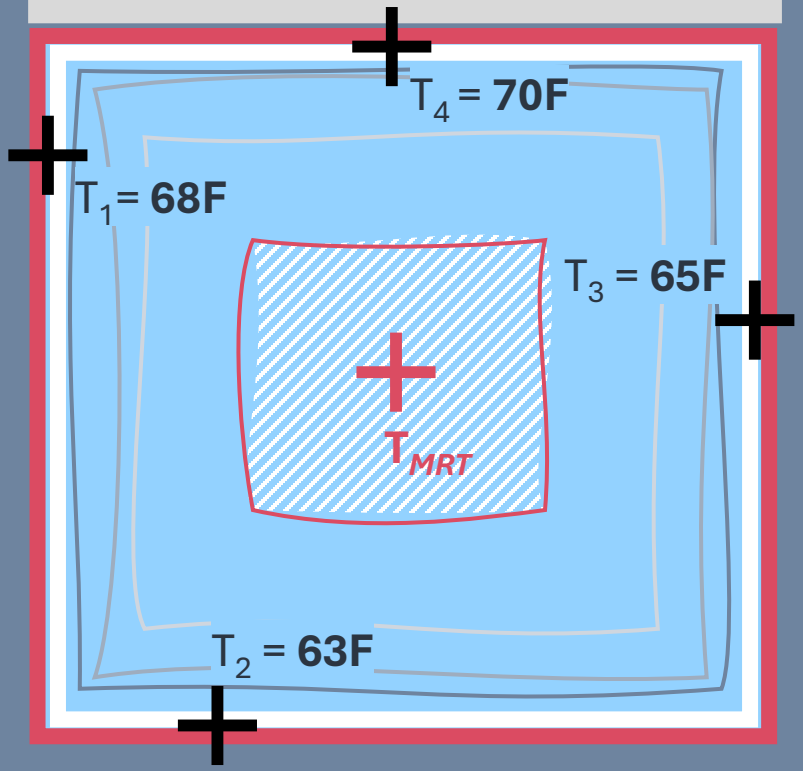
Heat at Scale:

Thermal Management in Large Enclosure Systems

Khush Kapadia

Building & HVAC Integration Engineer

Thermal Boundary



$T_{MRT} = 66F \neq T_{set}$

Navier-Stokes equations

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + \nu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right)$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial y} + \nu\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}\right) + g\beta(T - T_0)$$

$$\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \kappa\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}\right)$$

$\delta \sim 3mm$

Textbook Thermal Boundary Layer thickness

$\delta \gg 3mm$

Thermal Boundary Layer thickness in large enclosures

Factors Impacting the Thermal Boundary

The boundary between the unconditioned and conditioned spaces of large enclosures determines how efficiently we manage heat within the enclosure.

In Buildings

30%

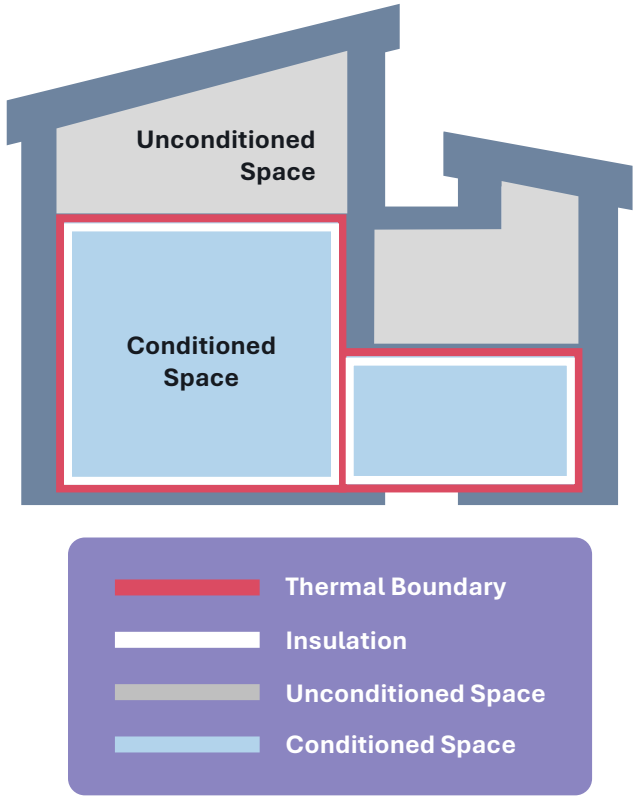
Heat loss from poor air sealing

25%

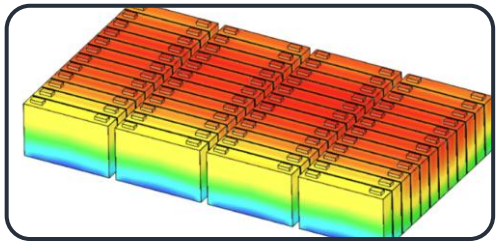
Heat loss from poor thermal insulation

30%

Heat loss from Thermal Bridges



Thermal Boundary Effects on Large Enclosures



Buildings

Poor insulation leads to **20-30% heat loss,**

Thermal bridges cause **30% loss**

Refer Trailers

Diesel Refrigeration Costs **$100's - $1000's/wk ,**

600 million tons of food gets **thrown out (~13%)**

BESS

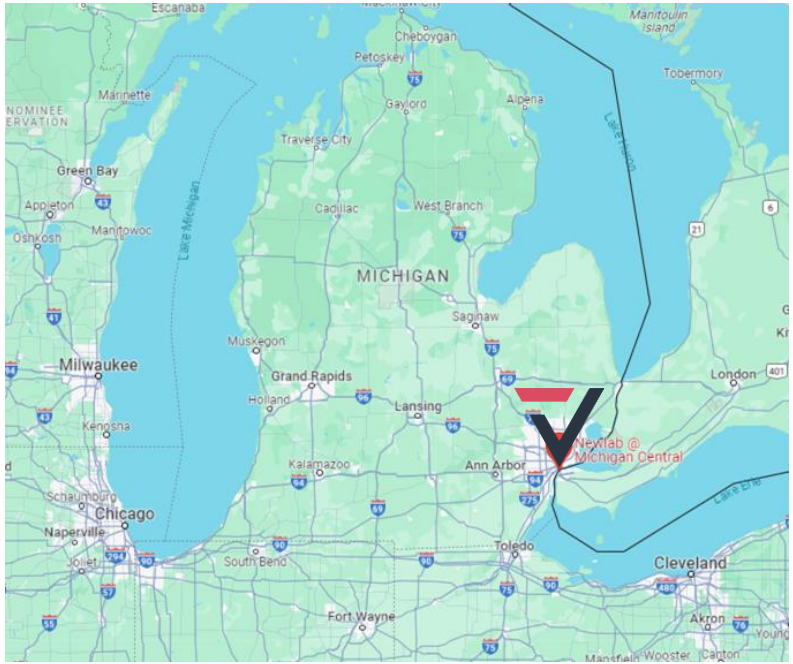
5-10% Battery Capacity Loss per year

Uncontrolled Hot spots cause **Thermal runaways**

ThermoVerse

Advanced Thermal Controls startup pioneering a novel class of smart insulation material systems (SIMs) that:

- Eliminates Hot Spots,
- Eliminates Cold Spots, and
- Eliminates Uneven Temperature Distributions.



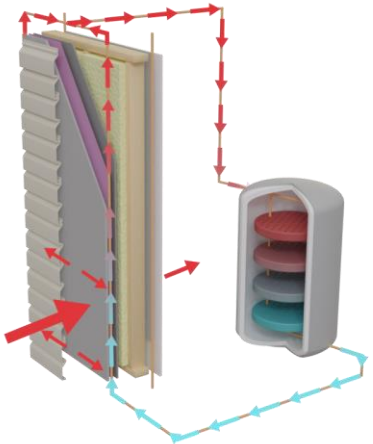
INNOVATION CROSSROADS
OAK RIDGE NATIONAL LABORATORY

ABC
ADVANCED BUILDING CONSTRUCTION
Collaborative

U.S. DEPARTMENT OF ENERGY

Newlab

Smart Insulation Material system



Thermal Energy Storage

+

Advanced Thermal Controls

↓

SIMs

Shift and shed
HVAC/Thermal Loads

TABE

Thermally Anisotropic
Building Envelope

LATCHES

Large Area Transactive Cooling,
Heating, & Energy Storage

TABE

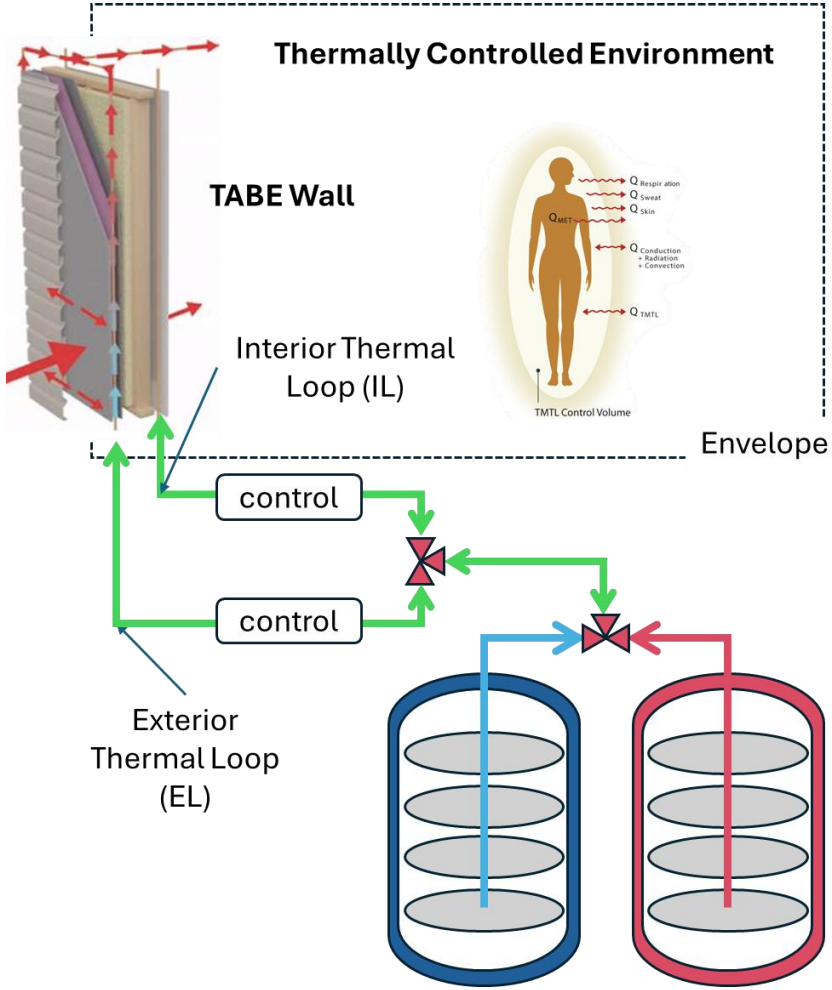
Combines Thermal Energy Storage & **Analog (Valve-based) Temperature Controls** To Minimize Heat Loss Through the Envelope.

30-70%

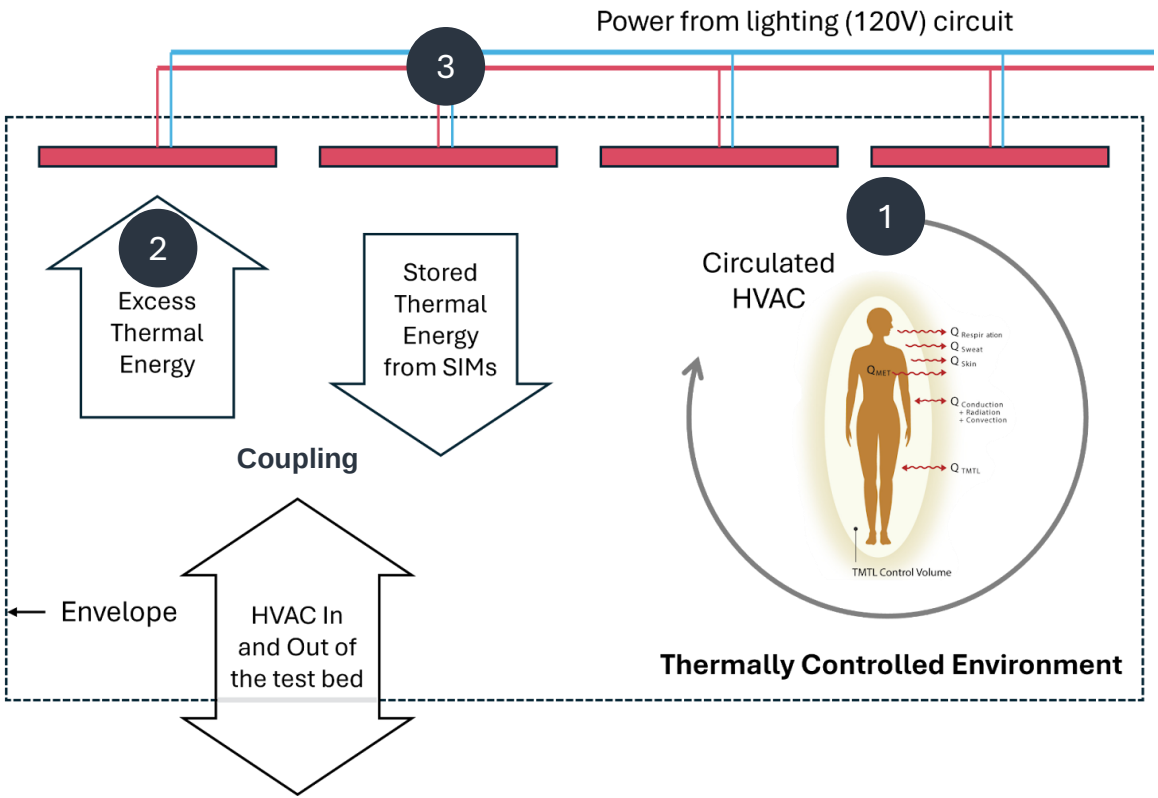
Peak load shaving

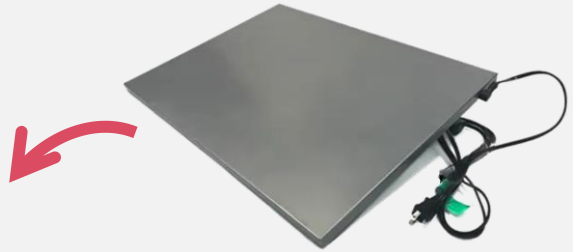
424 kWh

Peak electricity savings



LATCHES

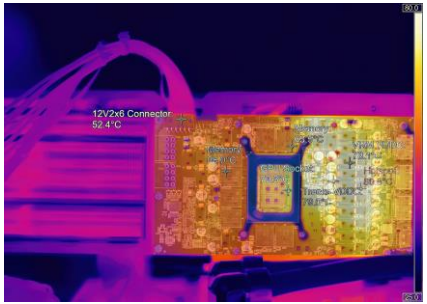




1. **Coupling of SIMs** to the existing HVAC to regulate comfort and temperature of conditioned space.
2. **Absorption of excess thermal energy** from solar heat gains, HVAC operation, and body heat.
3. Low-power actuation of SIMs to release stored thermal energy to **maintain indoor setpoints**.

Paradigm Shift: Distributed Heat Mngmt

Thermal management of large enclosures is lagging; traditionally relied on decades-old techniques



RTX-5000 cards

Explosive advancement in **localized thermal management** of microelectronics

ELIMINATING

HOT SPOTS

COLD SPOTS

AND UNEVEN TEMPERATURE DISTRIBUTIONS

Thermal Management in Large Enclosures

Heat Management via Distributed Thermal Controls.

Utility Scale BESS

Extend EV range and performance by optimizing battery thermal management.

Cold Chain Logistics

Ensure food quality and safety by maintaining precise temperatures in transit and storage

Buildings

Boost energy efficiency and comfort by balancing localized & centralized space conditioning.

ThermoVerse

Email: info@thermoverse.com