# ThermoVerse™

Elevating Comfort | Transforming Thermal Environments

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Fellow, 2023

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Knoxville, *2026*

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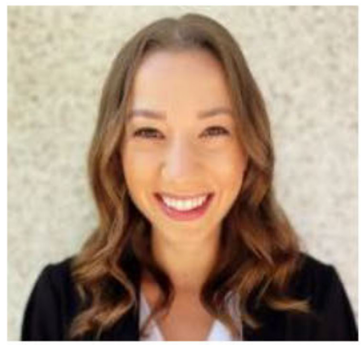
Ann Arbor, 2026

## Business Development



**Valerie Crumb,**
**Business Analyst,**
**MBA,** University of
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**BSE, Digital Content**
**I (CAD & Animations)**,
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Dearborn, *2027*

**Justice Long, BAA,**
**Digital Content II**
**(Content Creation)**
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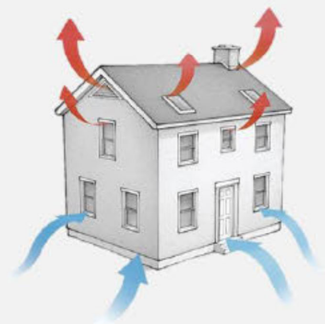
University, *2025*

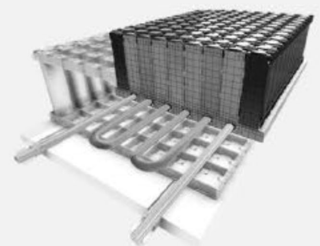
# ThermoVerse | Company

**Advanced thermal controls startup** developing smart insulation material systems (SIMs) for application in buildings, mobility and the energy sectors.

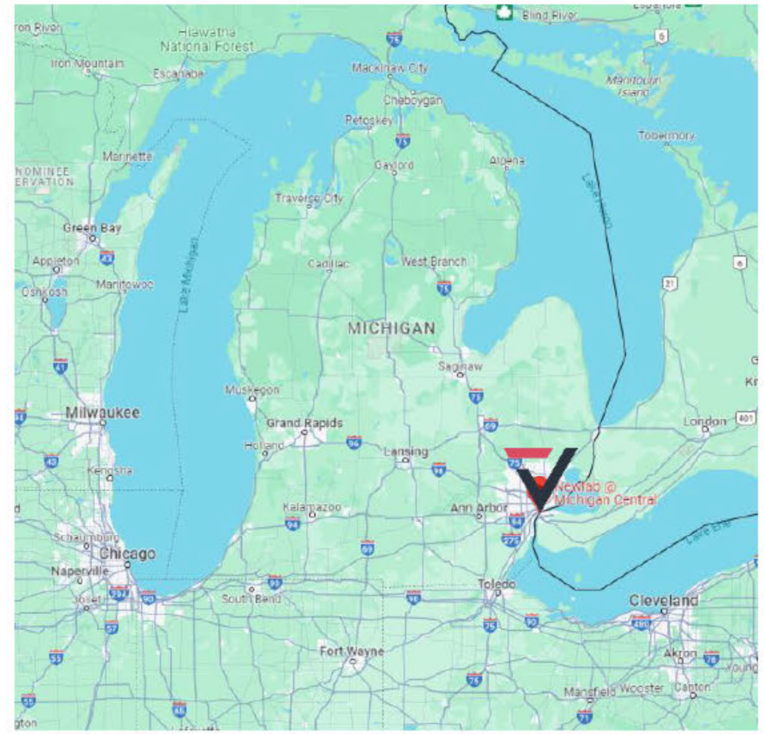


Buildings

Mobility



Energy




U.S. DEPARTMENT OF ENERGY

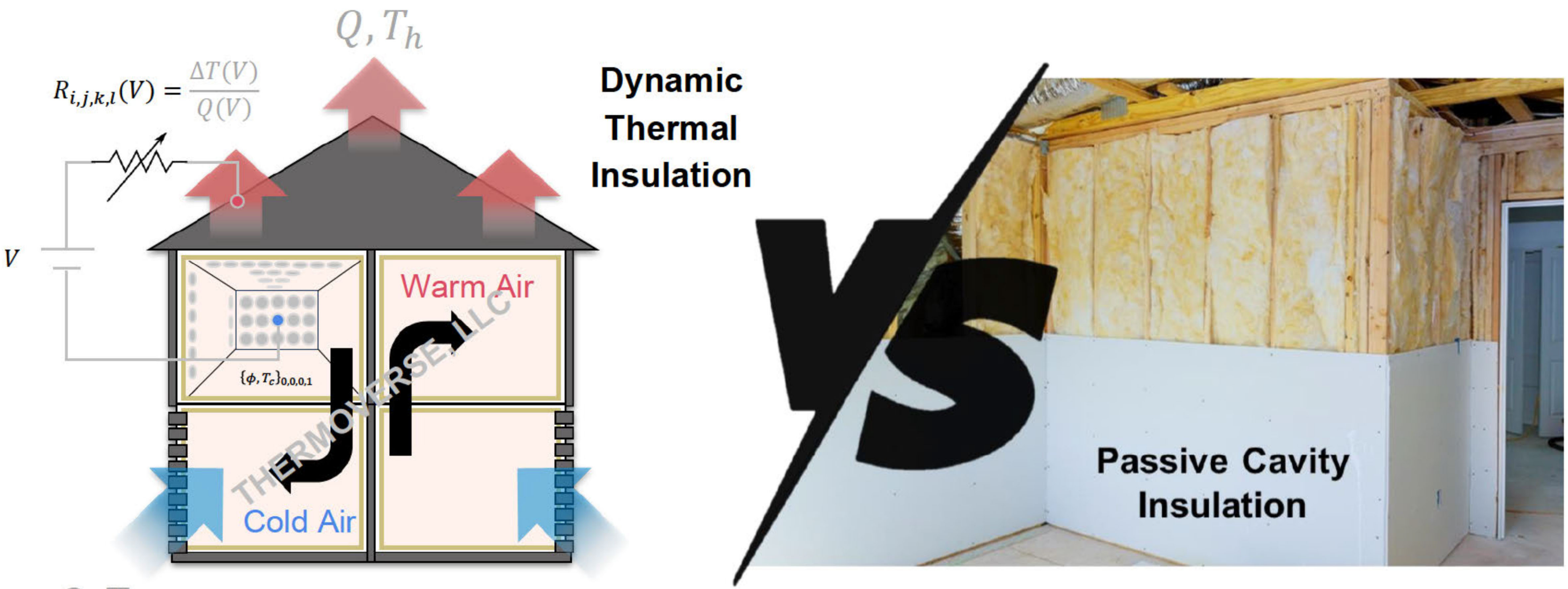
INNOVATION CROSSROADS
OAK RIDGE NATIONAL LABORATORY

ABC ADVANCED BUILDING CONSTRUCTION Collaborative

Newlab

# ThermoVerse | Concept

## An TES-based Smart Insulation Material System (SIMs).




$Q$- heat flux; $T_h$- hot temperature; $T_c$- cold temperature; $R$- R-Value; $V$- voltage; $\Delta T$- temperature difference; $i, j, k, l$- wall/room indices.

# ThermoVerse | Tech Validation Status

TRL 3-4 (Simple Embodiment Prototype) →**TRL 4-5 (2 ft. x 2 ft. MVP Drop Ceiling Panel)**

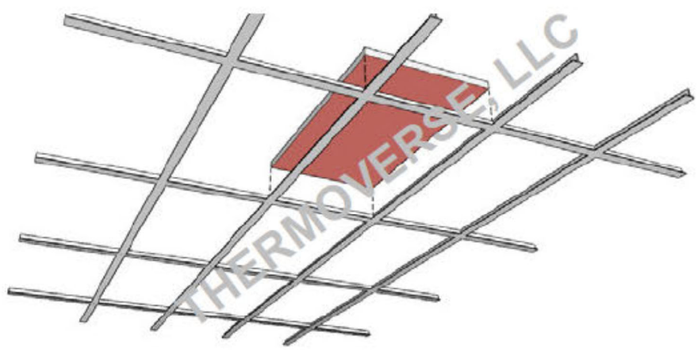
[redacted]

| Valid. | Capabilities | TRL |
|---|---|---|
| ☑ | **smart (intelligent) load control** | 3-4 |
| ☑ | **zone temperature control** | 3-4 |
| ☑ | **dynamic thermal insulation & storage** | 1-2 |
| ☑ | **waste heat recovery** | 3-4 |

# ThermoVerse | Product Roadmap

**Begin with drop ceiling panels and end with retrofiting multifamily buildings.**

## Q3 2024




### Milestone I

Minimal Viable Product (MVP) drop-celing panel for lab testing.

## Q4 2025


### Milestone II

Onsite visible testbed for year-long pilot & data acquisition.

## Q2 2026


### Getting Pilot-Ready

Pilot demo for reducing thermal EUI in U.S. multifamily, targetting existing buildings.

# ThermoVerse | TES Challenges & Opportunities

## Standardized Testing

- **Challenge** – Lack of methods for assessing thermal properties of active, inhomogeneous materials *(cf. ASTM C177 & C518 vs. C1155 & 1363)* and IECC standard-ization for PCMs usage.

[redacted]

## PCM Utilization

- **Challenge** – PCM utilization in most applications relying on ambient heat or solar thermal radiation remains low ~10%.

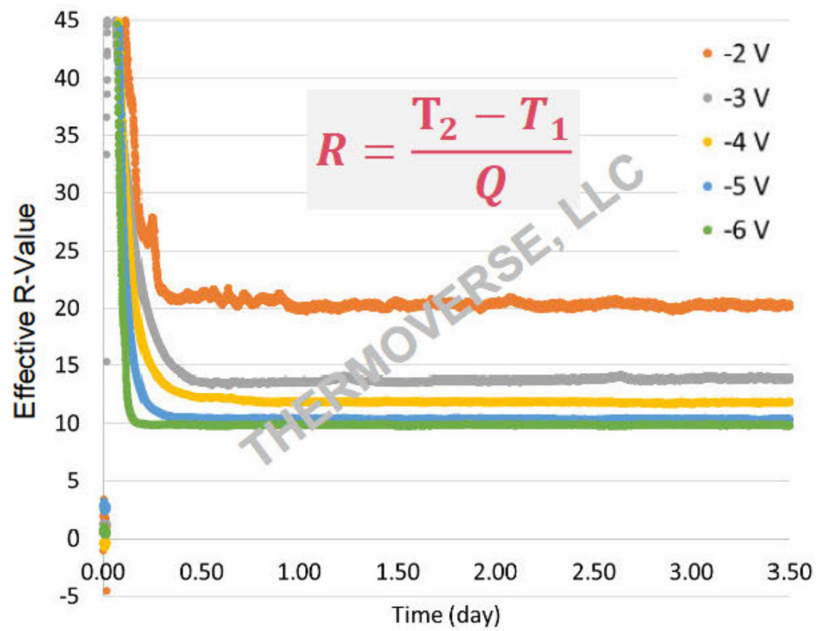


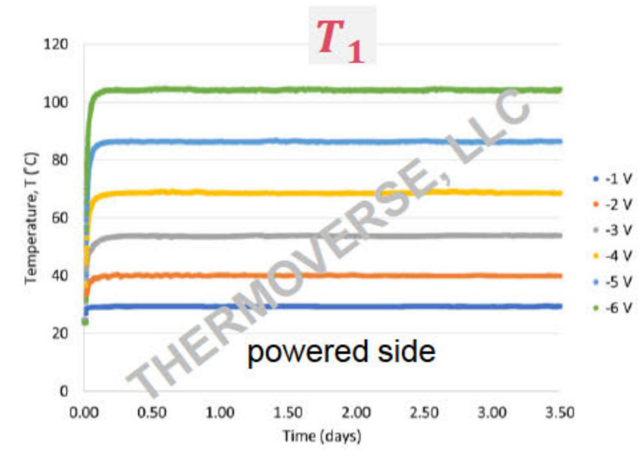
## Parametric Control

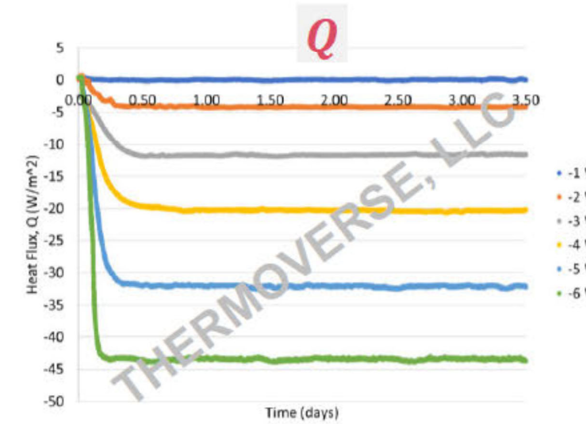
- **Challenge** – Difficulty to establish temperature control near the PCM phase transition temperature (T*).

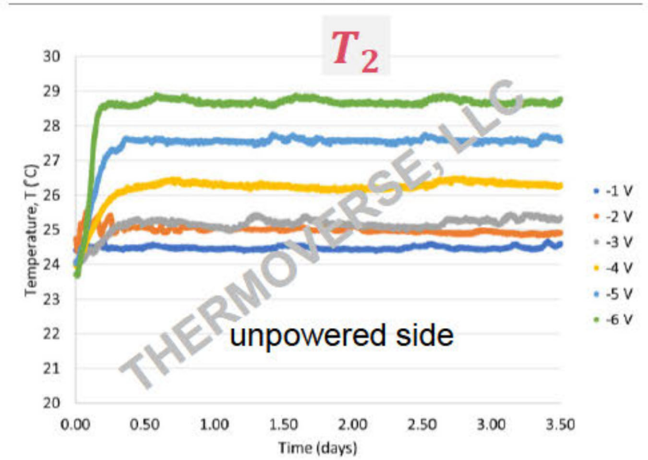
# ThermoVerse | In-situ R-Value Measurement

**ASTM C1155** for evaluating the R-Value of non-homogenous and active materials.




**Challenge:** While all steady state criteria are met for R-Value evaluation by ASTM C1155, "R-Value" is only defined for passive materials.

## ASTM C1155

| ThermoVerse, LLC | **Predictive Model for Dynamic Insulation** | Newlab, Michigan Central |
|---|---|---|

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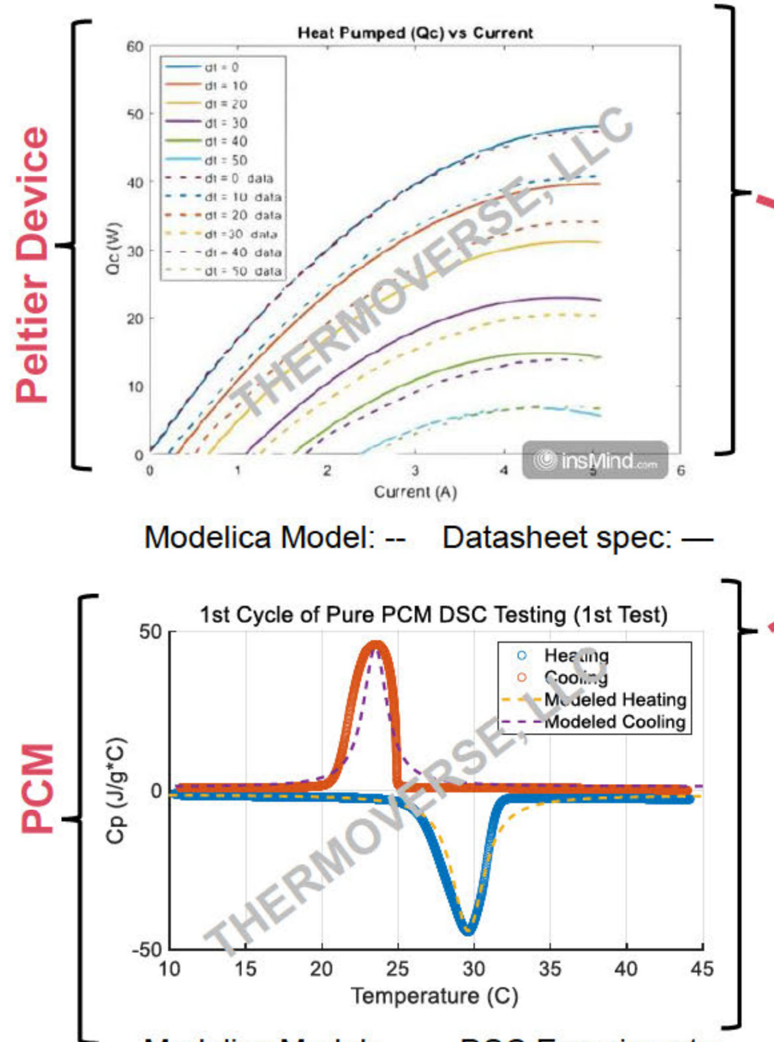
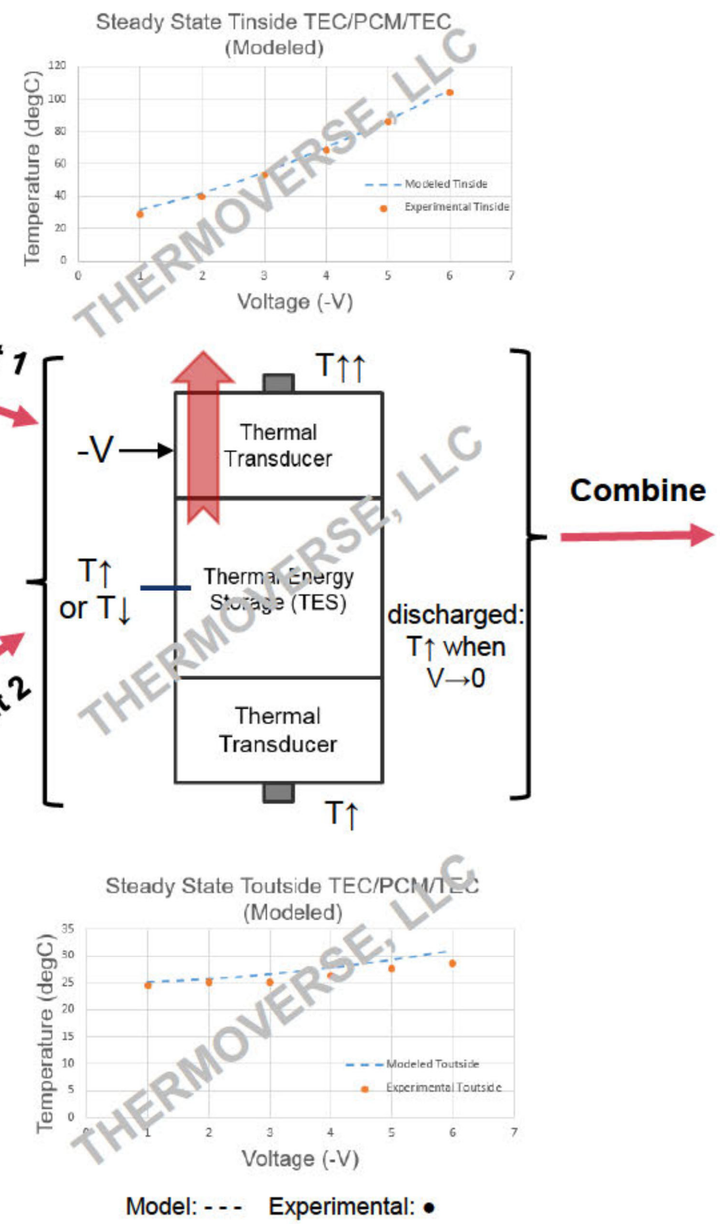
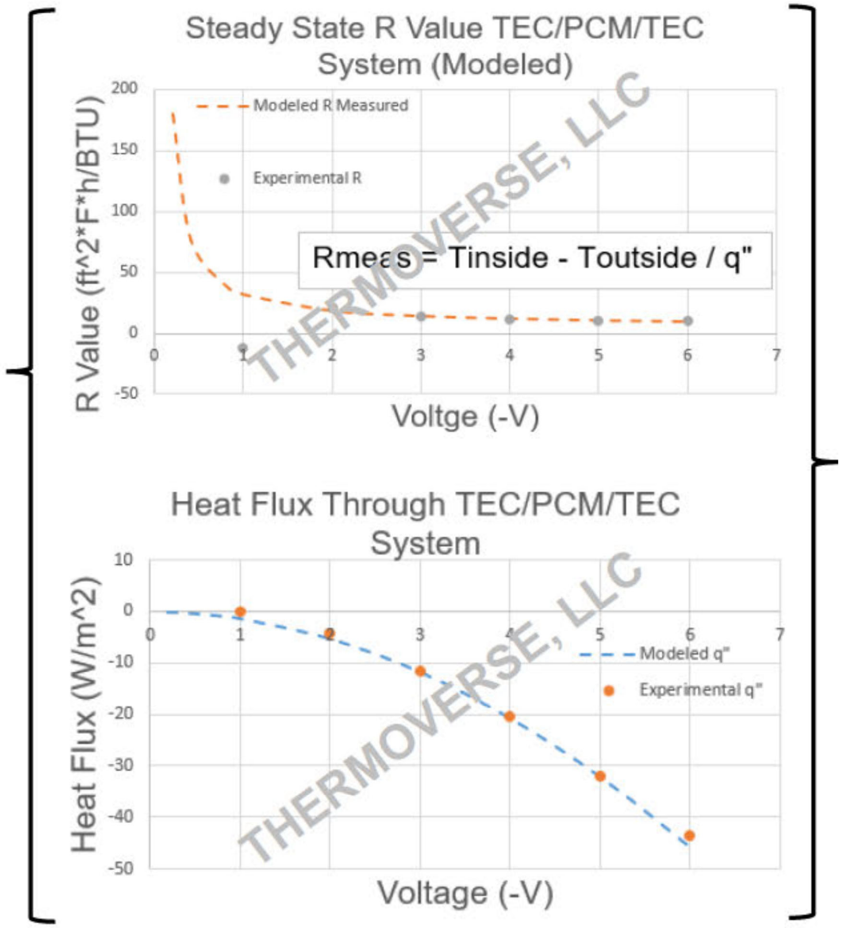



$$R_w \approx \frac{\Delta T(0)}{\dot{Q}} exp(-\boldsymbol{\beta} t),$$




Takeaway: Dynamic modulation of $R$ is largely driven by $\boldsymbol{\beta}^{-1} = \boldsymbol{RC}$.

# ThermoVerse | TES Challenges & Opportunities

## Standardized Testing

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- **Opportunity** - Leverage *In-situ* and HFMA *(cf. C1784)* for 1-D DIMs → new IECC standard for "Latent Mass Walls" *(cf. 402.1.2)* based on the $\beta^{-1} = RC$ time constant.

[redacted]

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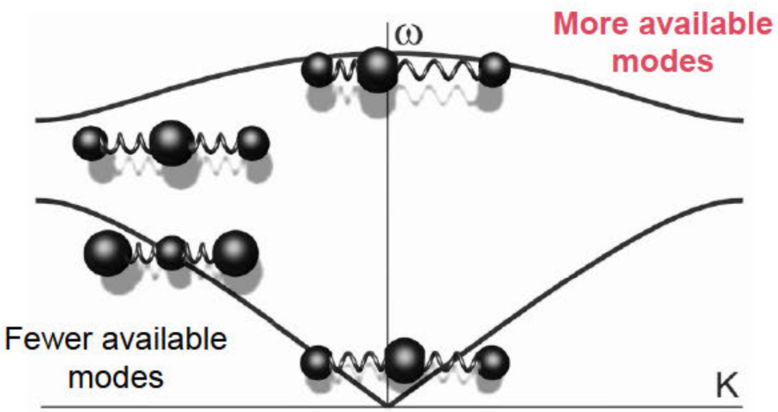
# ThermoVerse | Selective Tuning of $c_w$

Using "resonant vibrations" to excite Einstein phonons → increase specific heat ($c_w$).

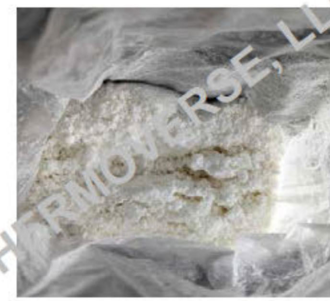
Capacitive resistance

**Specific heat**

$$R_W = \frac{\Delta T}{\dot{Q} - m_W c_w \frac{d\Delta T}{dt}}$$



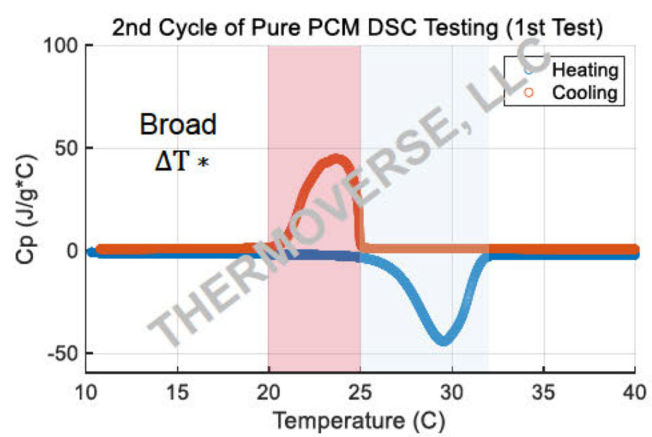

$\Delta h = 168\ J/g$

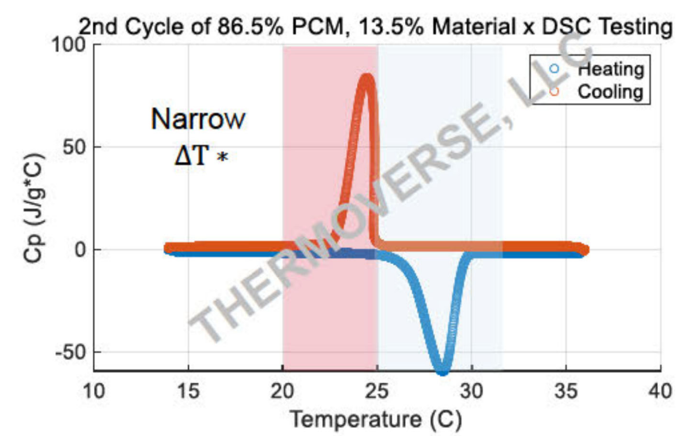



**1.8 X** increase in $c_p$

(cf. neat PCM)

$\Delta h = 110\ J/g$

# ThermoVerse | Supplemental Heating/Cooling

Even with material optimization, supplemental heating/cooling is needed for full utilization.

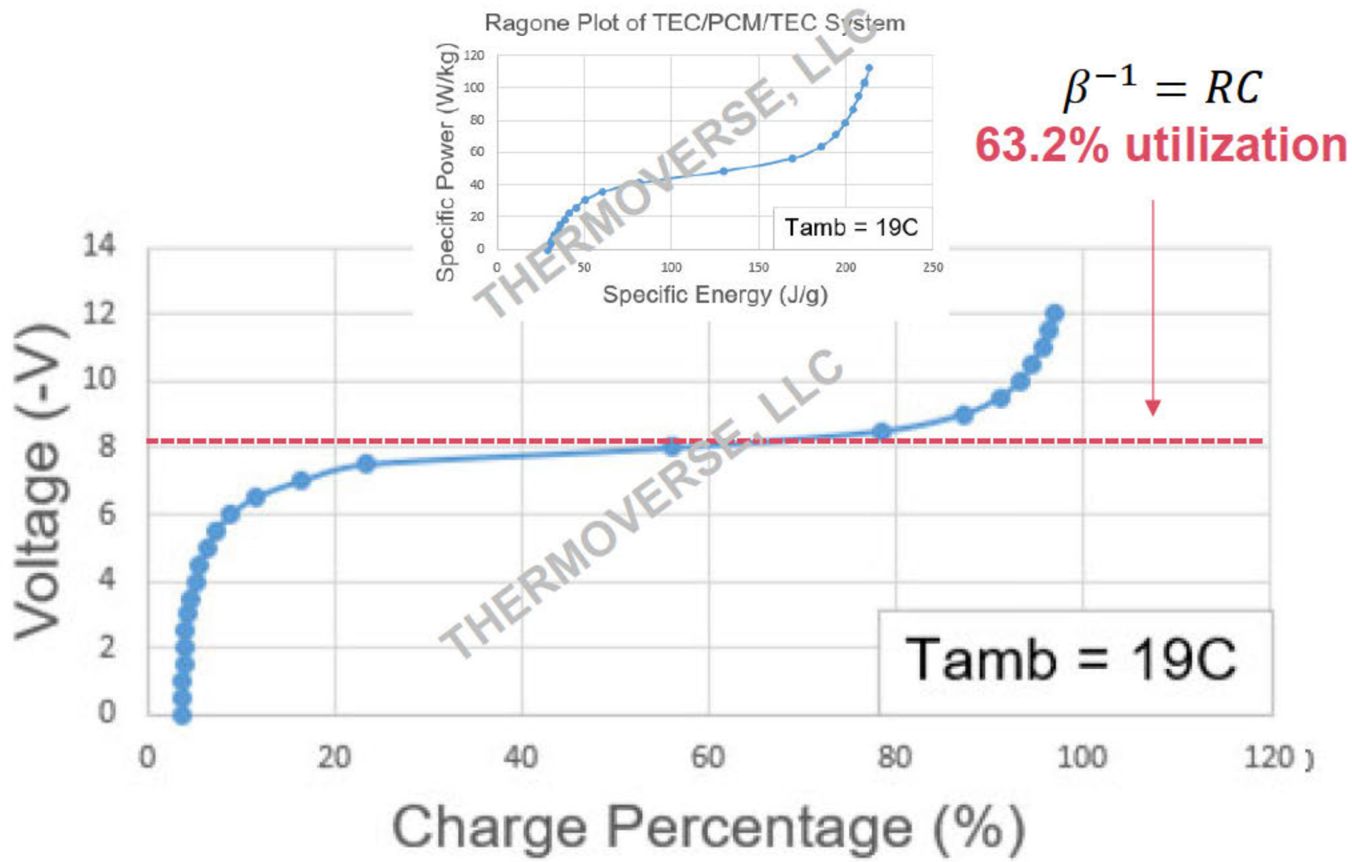
Capacitive resistance

Temperature difference

$$R_W = \frac{\Delta T}{\dot{Q} - m_W c_W \frac{d\Delta T}{dt}}$$

**Electrical tuning of Fourier heat conduction**

Transient conduction



# ThermoVerse | TES Challenges & Opportunities

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[redacted]

## PCM Utilization

- **Challenge** – PCM utilization in most applications relying on ambient heat or solar thermal radiation remains low ~10%.
- **Opportunity** – Increase nucleation by either enhancing specific heat OR supplementing PCM charging and discharging using auxiliary device.



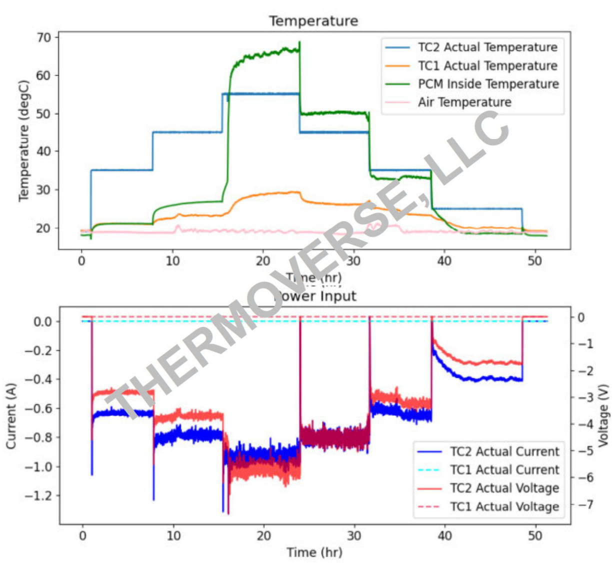
## Parametric Control

- **Challenge** – Difficulty to establish temperature control near the PCM phase transition temperature (T*).

# ThermoVerse | Parametric Control Challenges

Challenges for controlling TES-based systems, such as LATCHES, stems from the following system classification:

## ☑ Active System

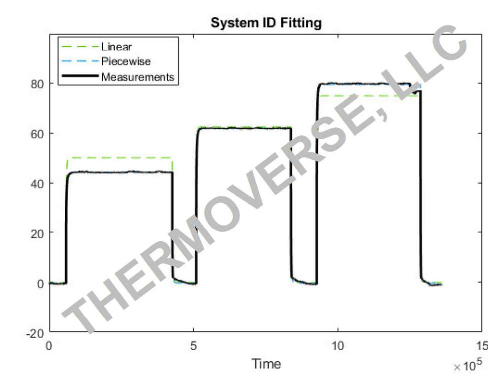



## ☑ Non-linear System

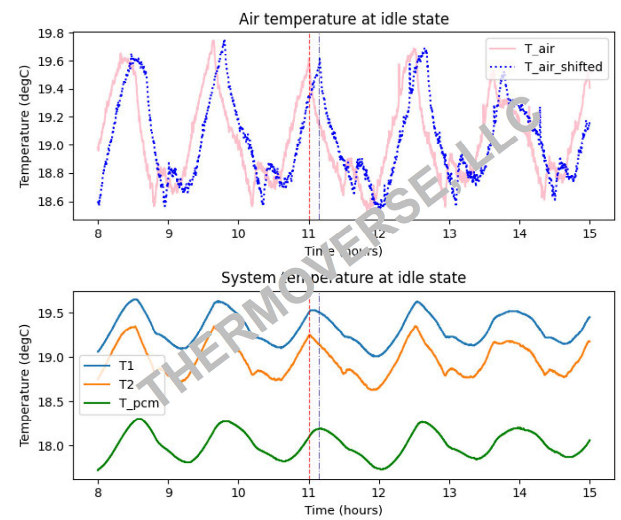

None
piecewise (3)

2 zeros,
3 poles,
1 delay

None
piecewise (10)



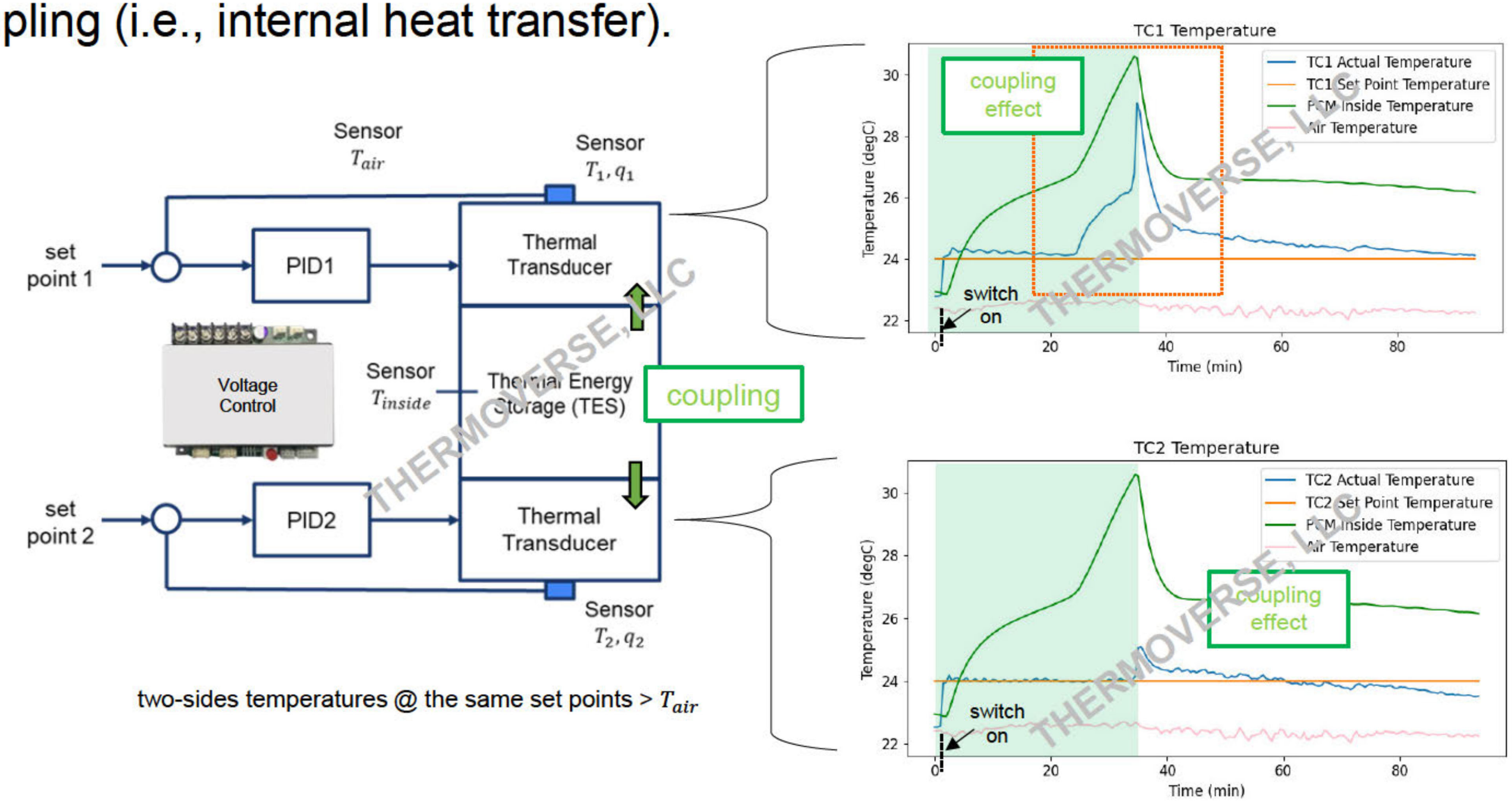

## ☑ Casual System




thermal lag: 9~10 min

# ThermoVerse | Establishing Control

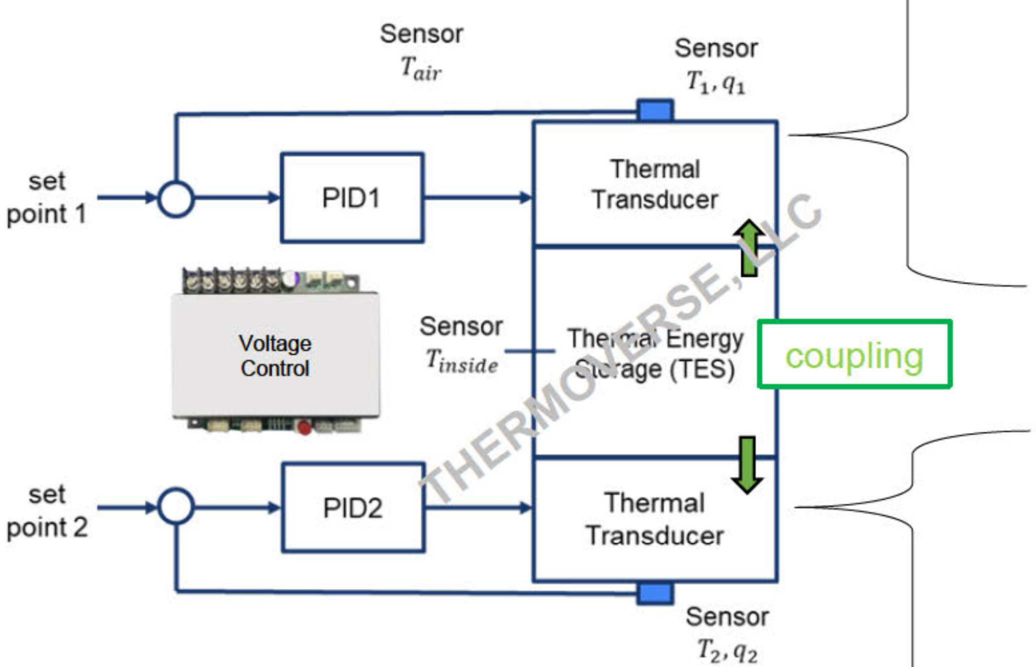
Early attempts at establishing temperature control in LATCHES proved difficult for due to coupling (i.e., internal heat transfer).



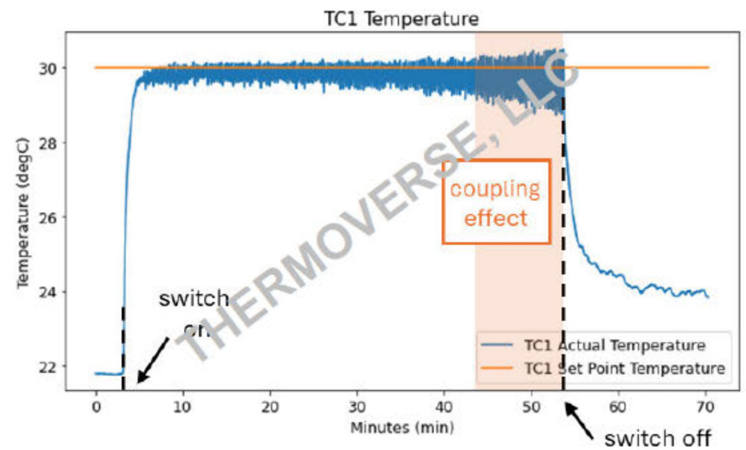

☑ **poor control over the rate of heat transfer**

# ThermoVerse | Establishing Control

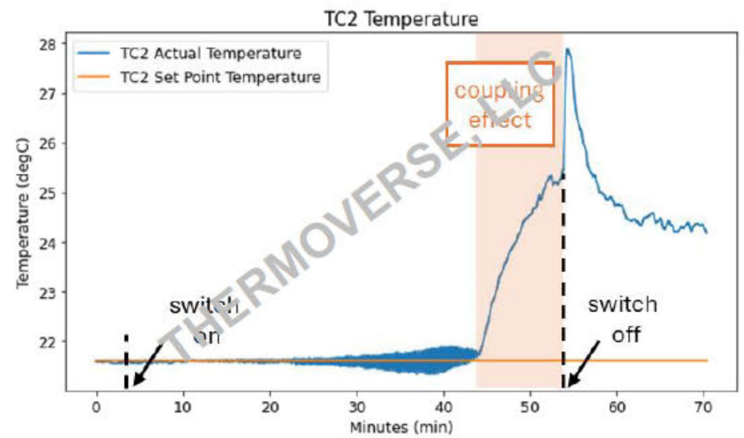
Even with improved control over the heat transfer rate, poor control over the direction of heat flow causes the system to lose control.




one-side temperature @ the set point > $T_{air}$,
one-side temperature @ $T_{air}$



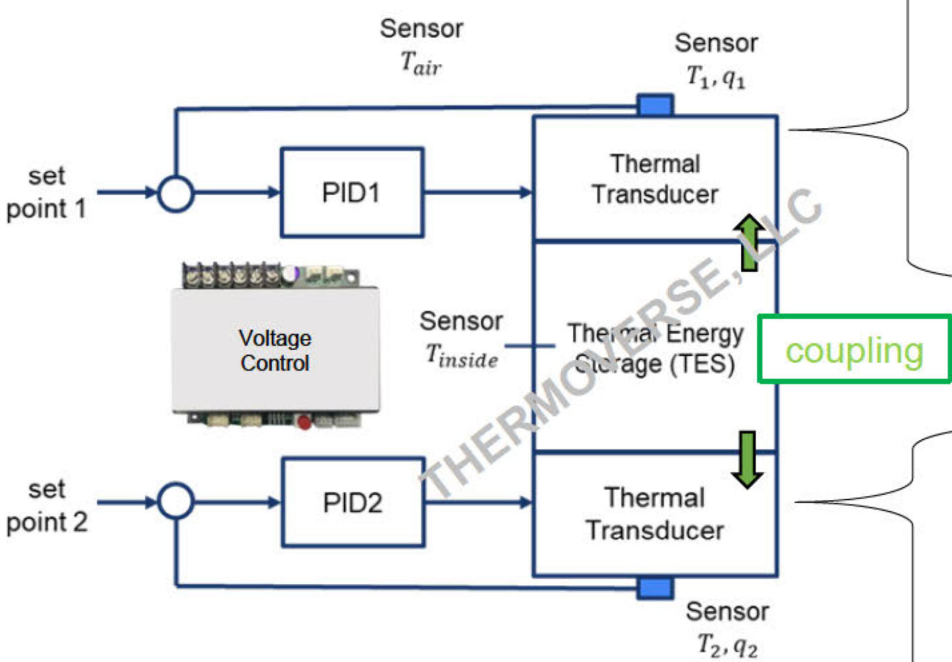

☑ better control over the rate of heat transfer



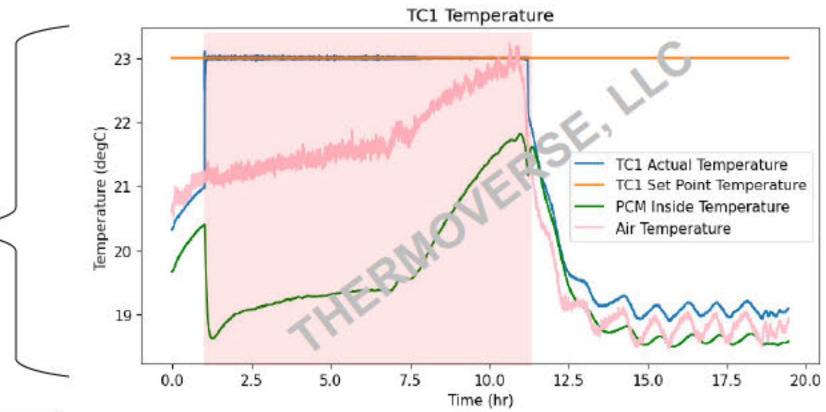

☑ poor control over the direction of heat flow

# ThermoVerse | Establishing Control

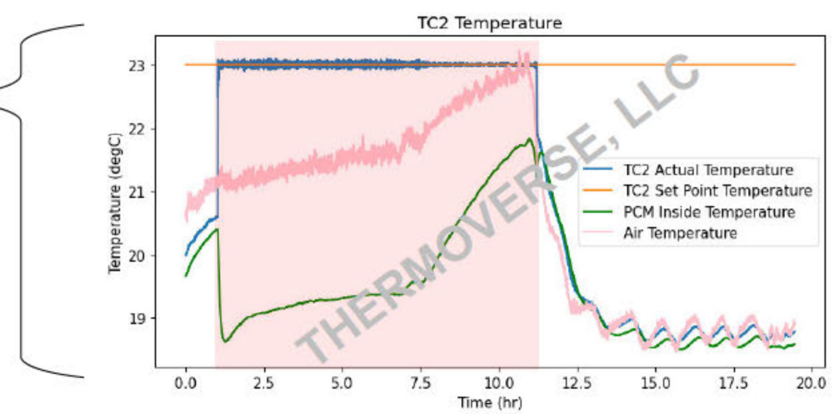
Parametric control only possible after establishing control over both heat transfer rate and direction of heat flow.




two-sides temperatures @ the same set points > $T_{air}$




☑ **precise control over the rate of heat transfer**




☑ **precise control over the direction of heat flow**

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- **Opportunity** – Increase nucleation by either enhancing specific heat OR supplementing PCM charging and discharging using auxiliary device.

## Parametric Control

- **Challenge** – Difficulty to establish temperature control near the PCM phase transition temperature (T*).
- **Opportunity** – Electrical tuning for precise control over the rate and direction of heat flow into and out of the PCM.

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# Thank You!

Shantonio Birch, Ph.D.

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