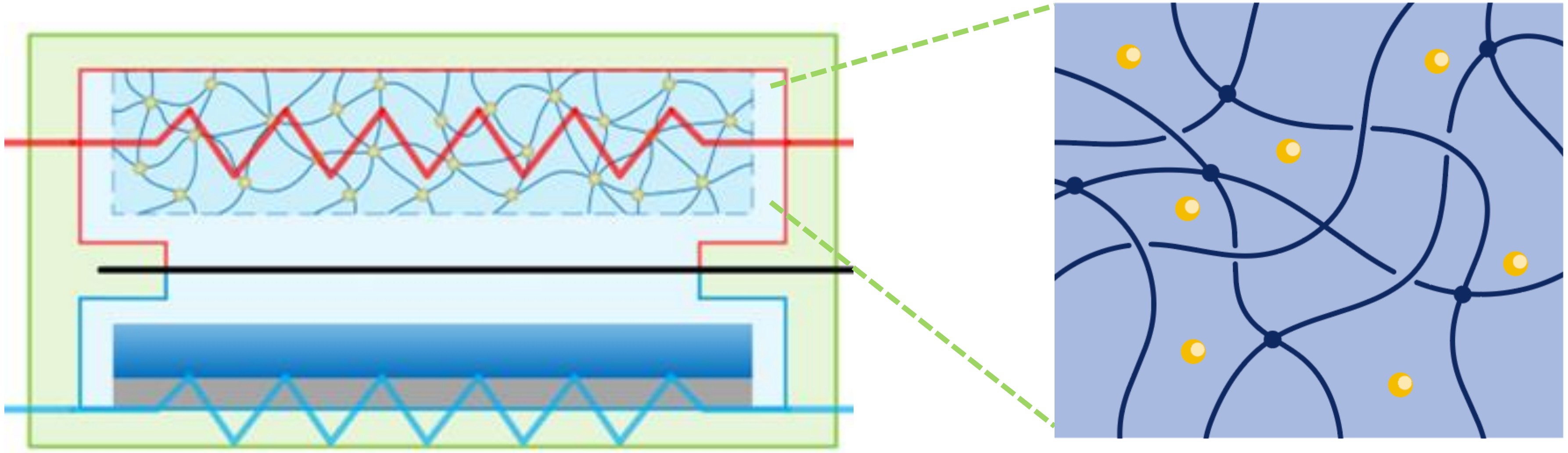
High Energy Density Hydrogel Thermo-Adsorptive Storage



Performing Organizations: Massachusetts Institute of Technology (MIT), Heat Transfer Technologies (HTT), Rheem Manufacturing

PI: Bachir El Fil, Research Scientist; Asegun Henry, Professor
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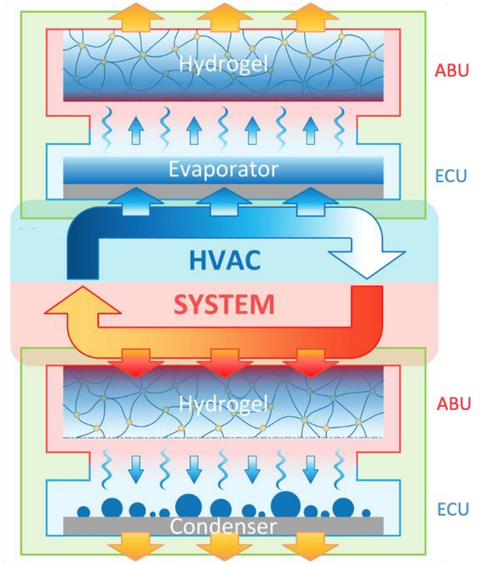
Project #: DE-EE0009679

Project Summary

Objective and Outcome

Novel thermal energy storage (TES) device based on the adsorption of a hydrogel/salt composite, promising the following performances:

- High energy density over 200 kWh/m^3
- Desorption at ≤ 70˚C
- Building energy savings of ≥ 50 $kWh/m^3/day$
- System cost of ≤ $\$13.8/kWh_{th}$



Team and Partners

Team	Role in project
MIT (Prime)	Device design, modeling, characterization, & integration
HTT	Component fabrication, characterization, & commercialization
Rheem	Device integration, characterization, & commercialization

Stats

Performance Period: 10/01/2021-09/30/2024

DOE budget: $2,623,595, Cost Share: $661,500

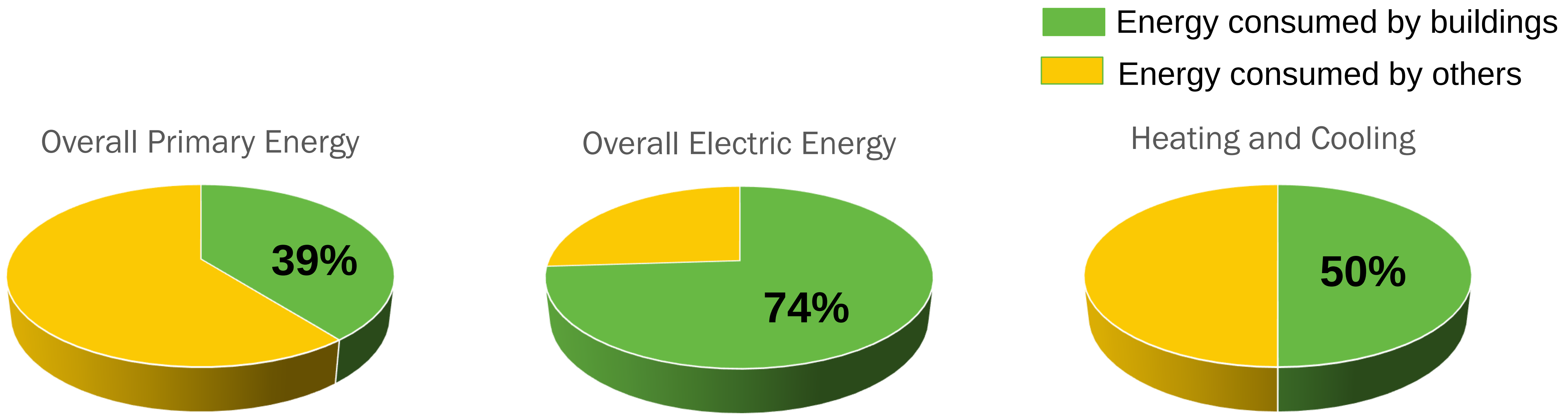
Milestone 1: Thermodynamic model and numerical models of system

Milestone 2: Detailed numerical models for ABU and ECU

Milestone 3: Device design, cooling savings, and material performance

Background and Motivation

- In the US households (142 M) and buildings consume

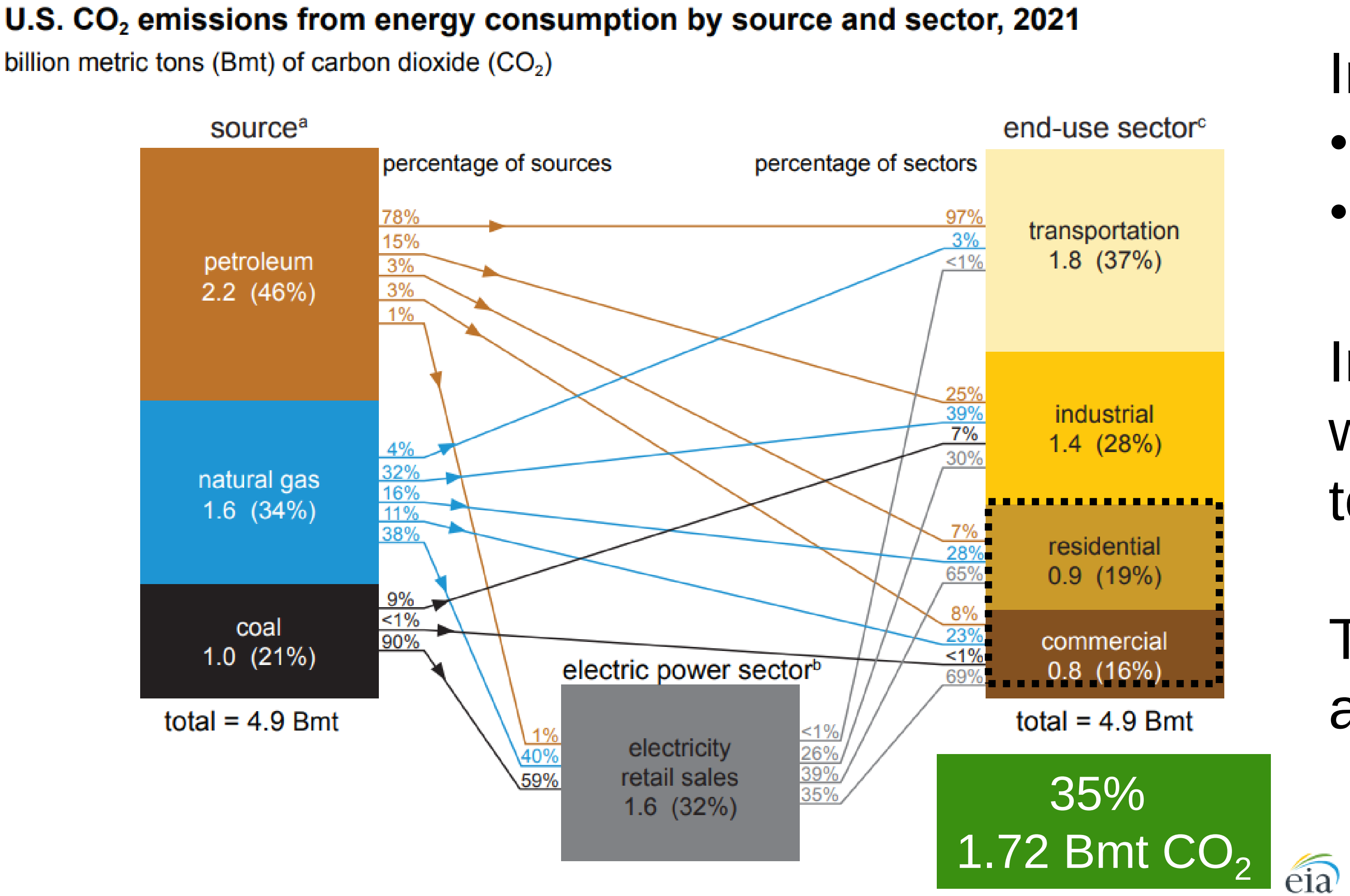


To accomplish the low-carbon and cost-effective energy goal in the building sector, TES offers several benefits by:

- reducing energy consumption
- increasing load flexibility

Background and Motivation

- In the US commercial and residential sectors (> 90% Buildings) emit around



In summary US buildings annually

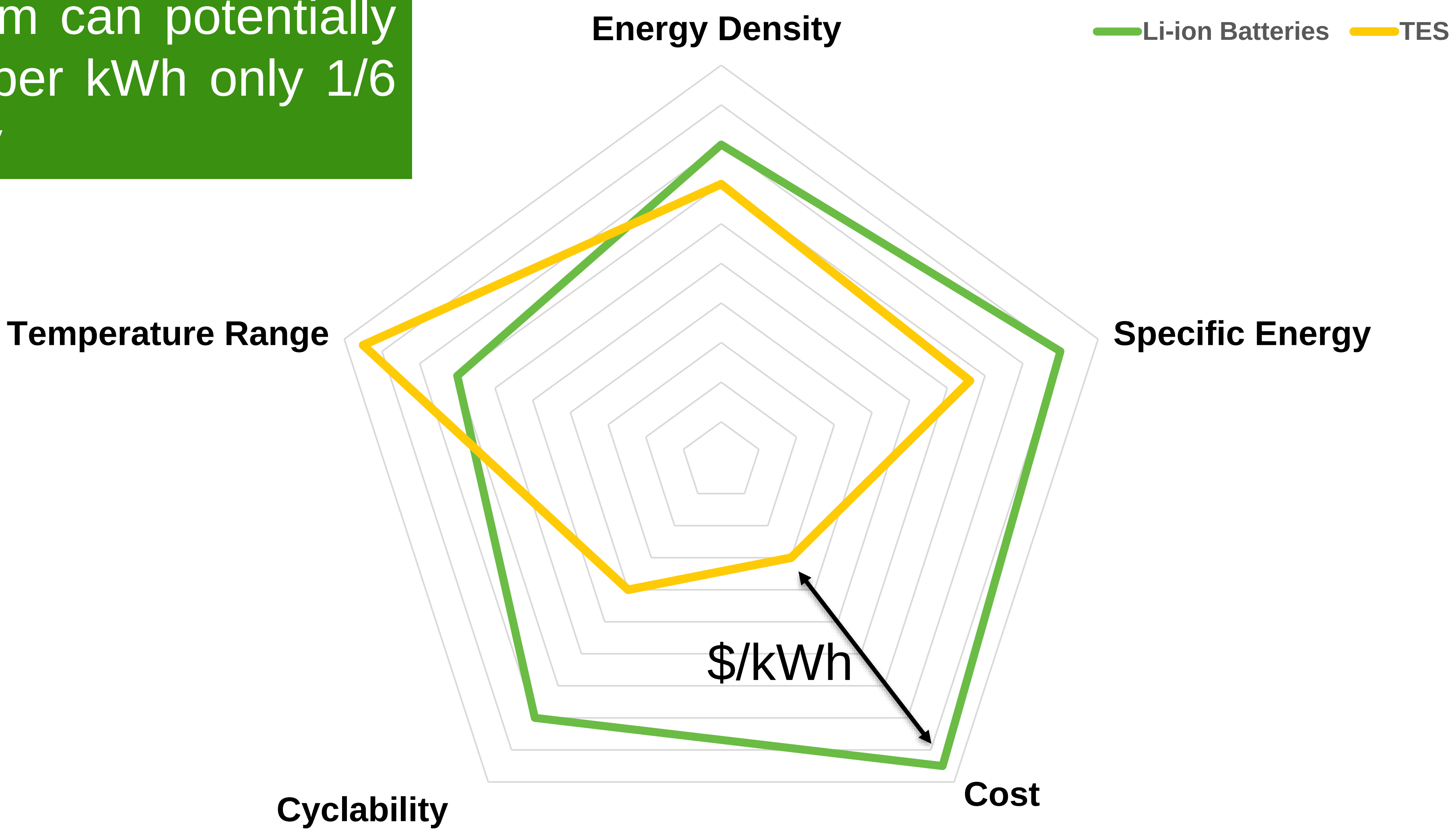
- consume > 37.9 quads
- emit > 1.7 Bmt CO_2

In fact, buildings consume > 50% of worlds electric consumption → goes toward meeting thermal loads

TES can provide a cost-effective alternative to Li-ion batteries

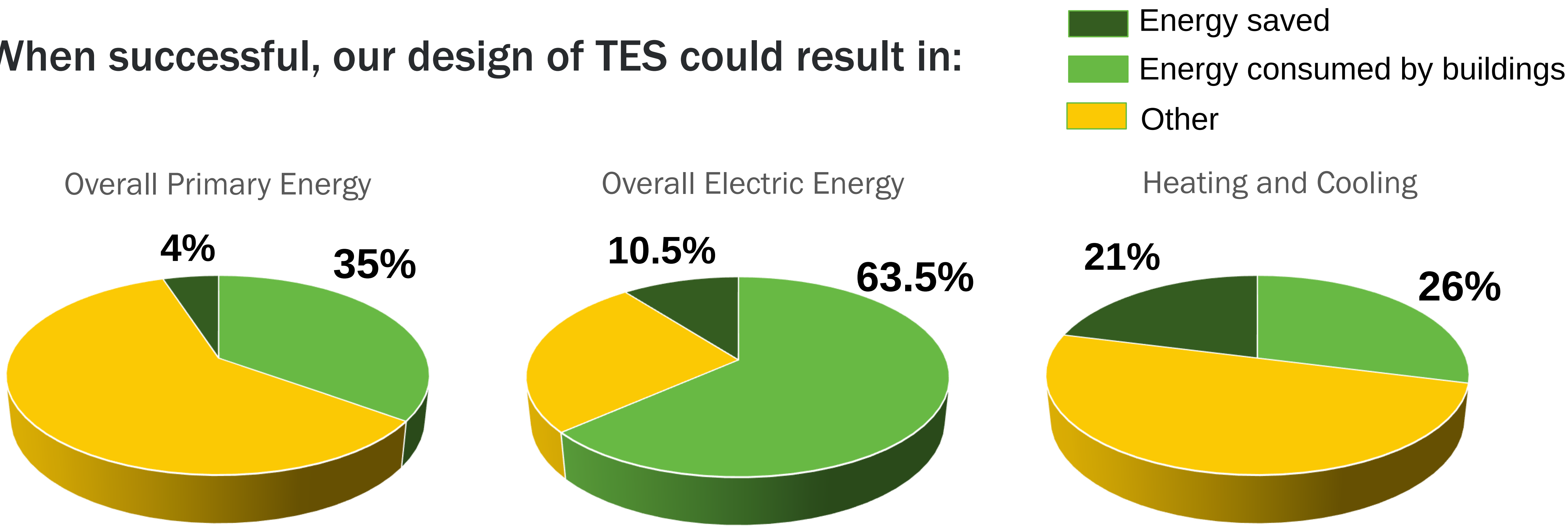
Comparing Li ion-battery vs Potential TES systems

Our TES system can potentially have the cost per kWh only 1/6 of Li-ion battery



Alignment and Impact

When successful, our design of TES could result in:

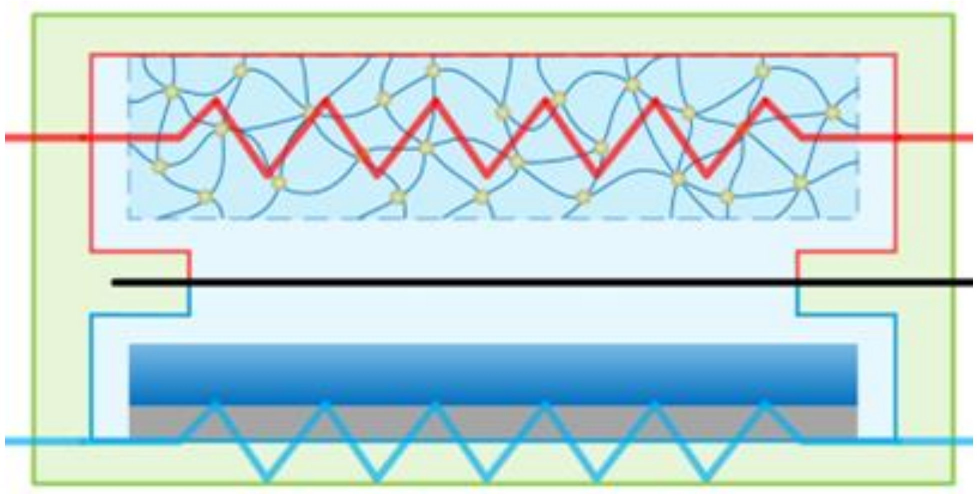


Additionally, integrating hydrogel-based TES could reduce overall CO_2 emissions by 0.2 Bmt CO_2 (11.4% of CO_2 emissions by residential and commercial sectors)

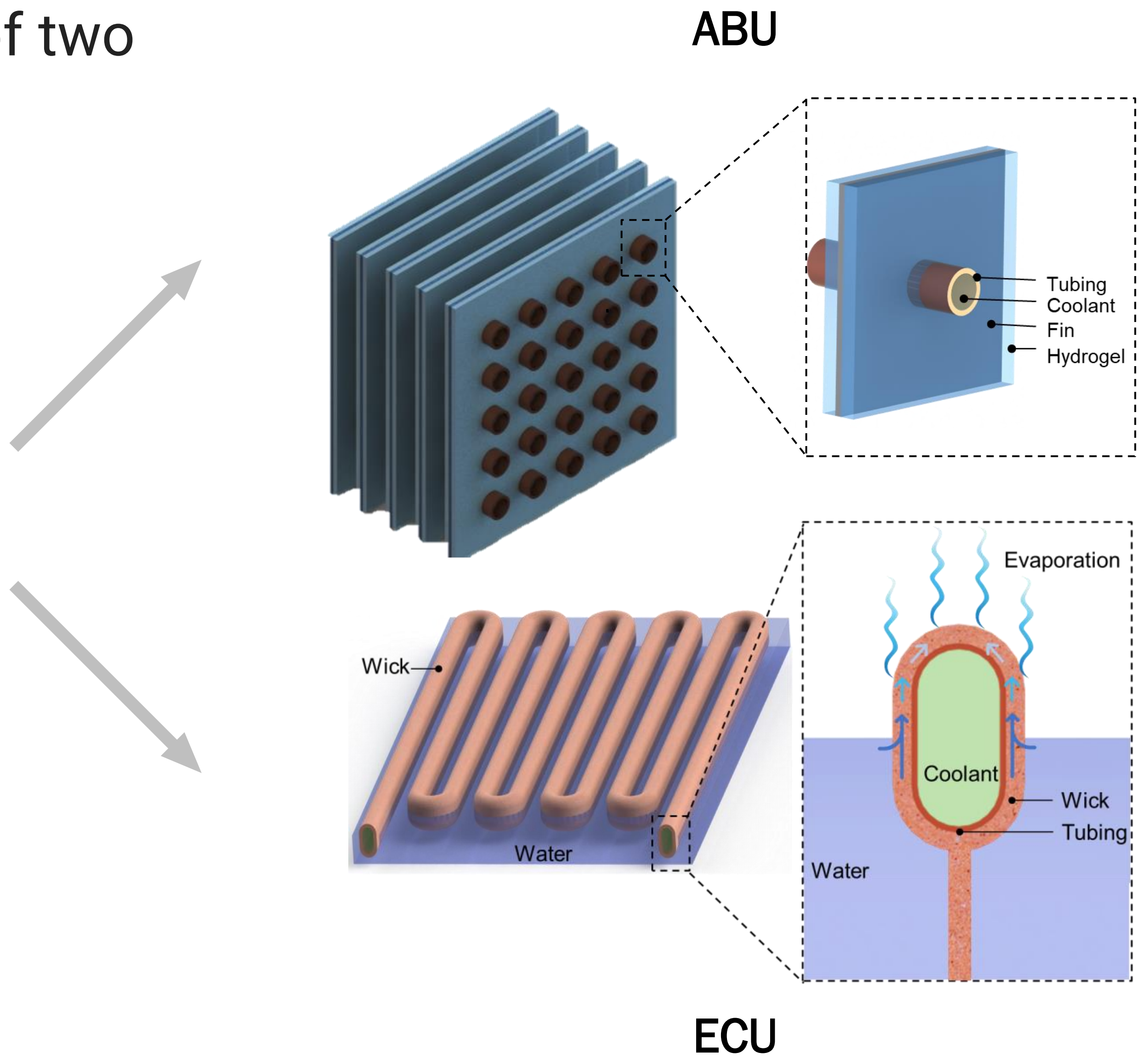
Approach: Hydrogel-Based TES System

The proposed device is composed of two components:

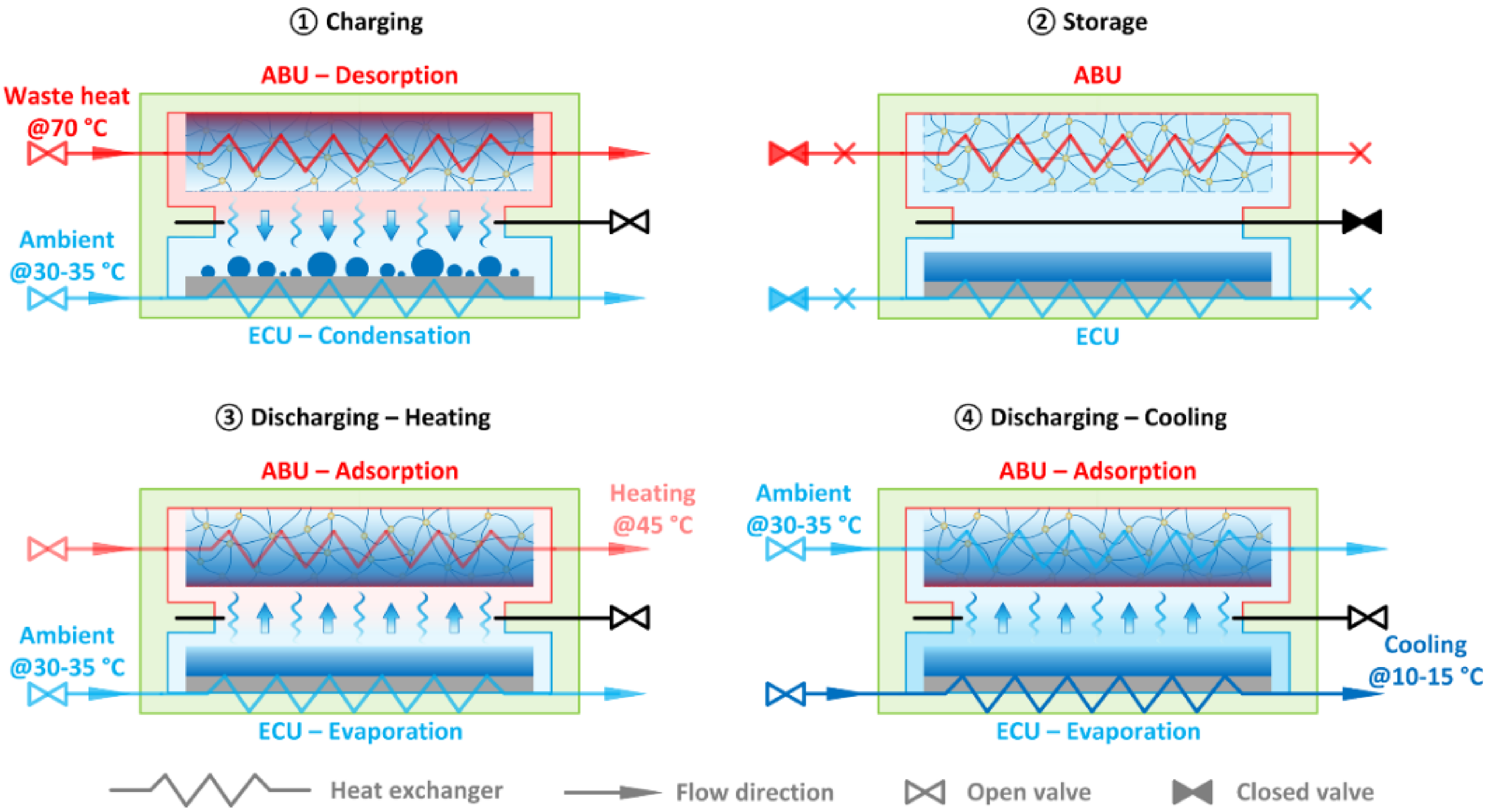
Adsorbent Bed Unit (ABU)



Evaporator/Condenser Unit (ECU)



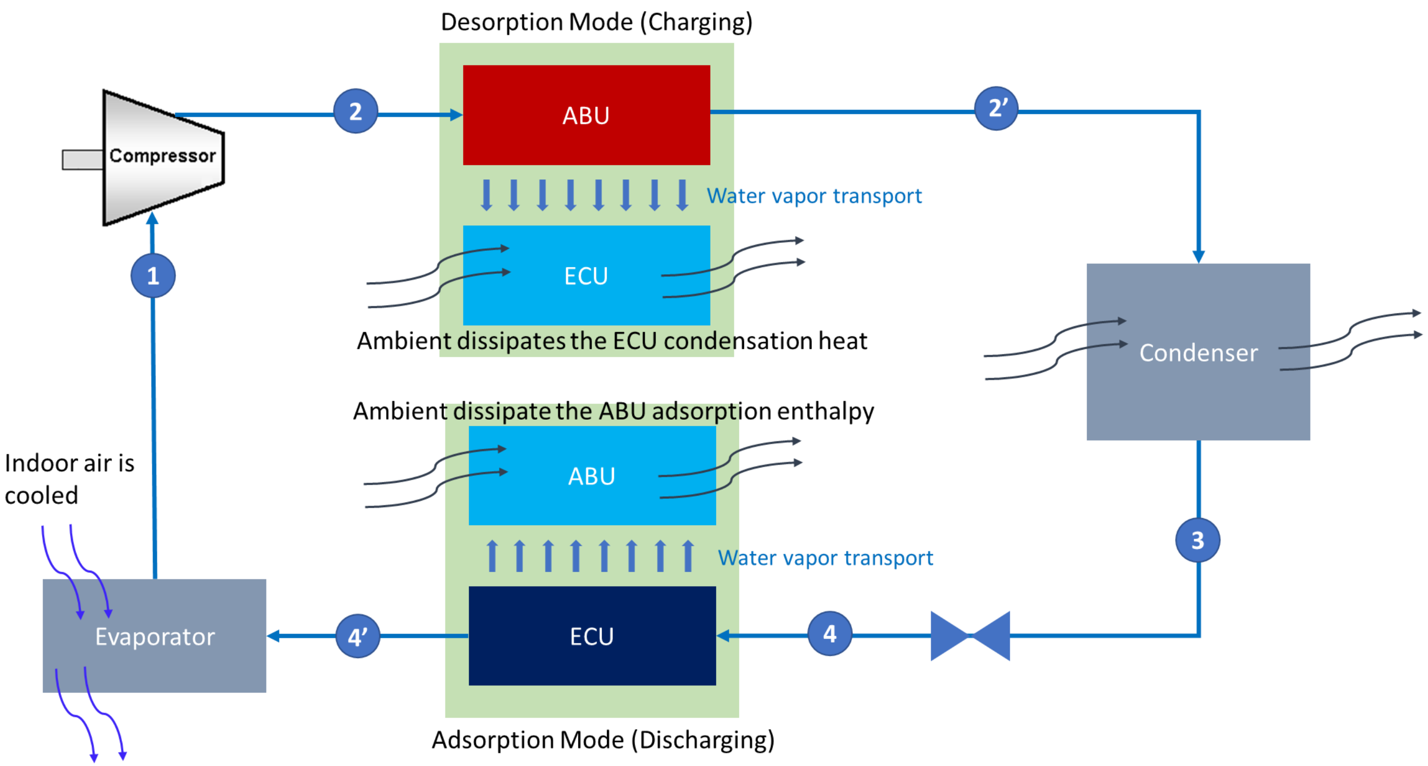
Approach: Operating Principle of TES

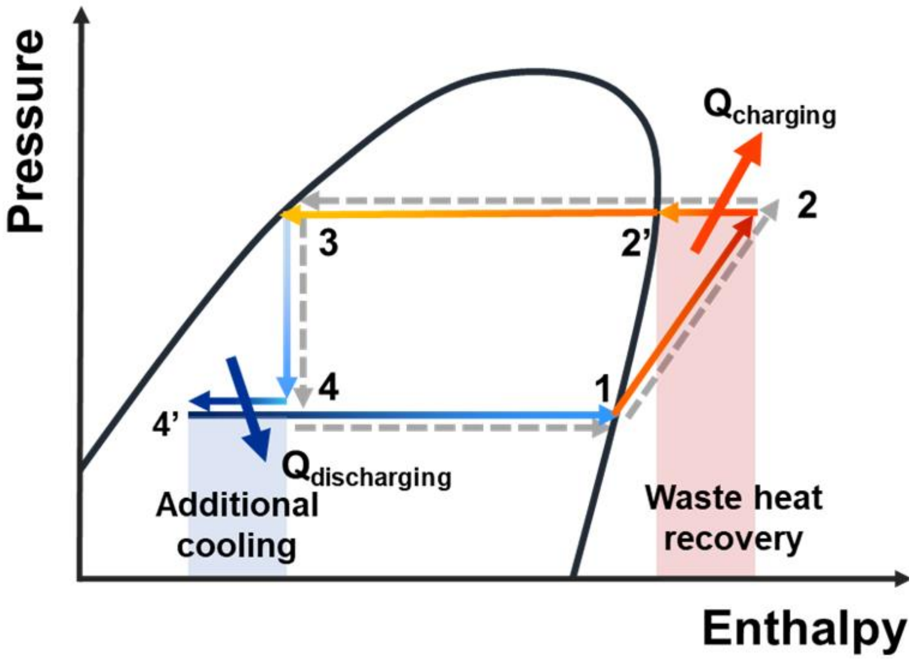


ABU = Adsorbent bed unit

ECU = Evaporator/condenser unit

Approach: TES Integrated with HVAC



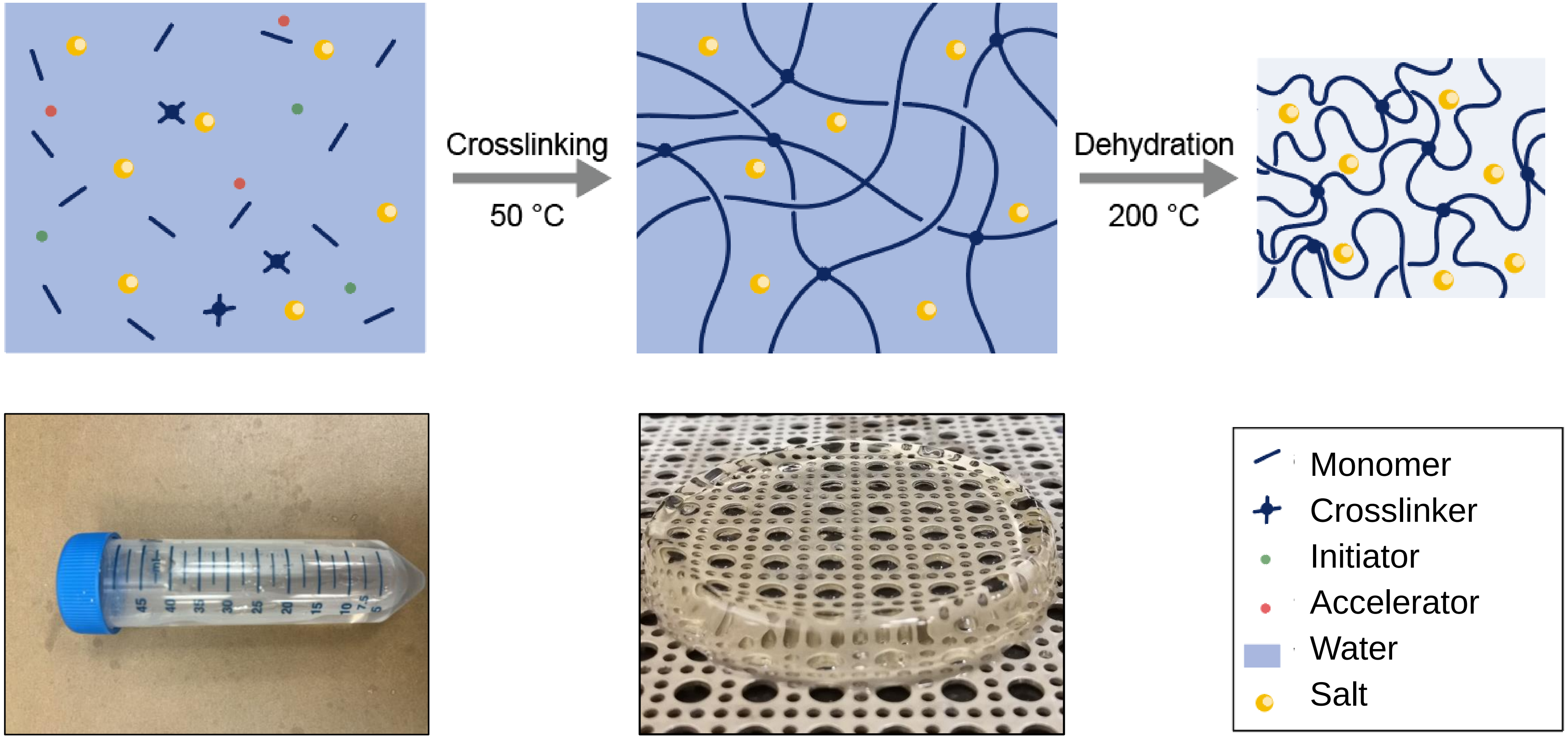


- Waste heat is stored in TES (2 → 2')
- Additional cooling (4 → 4')

TES-HVAC integration can boost COP by **41%**

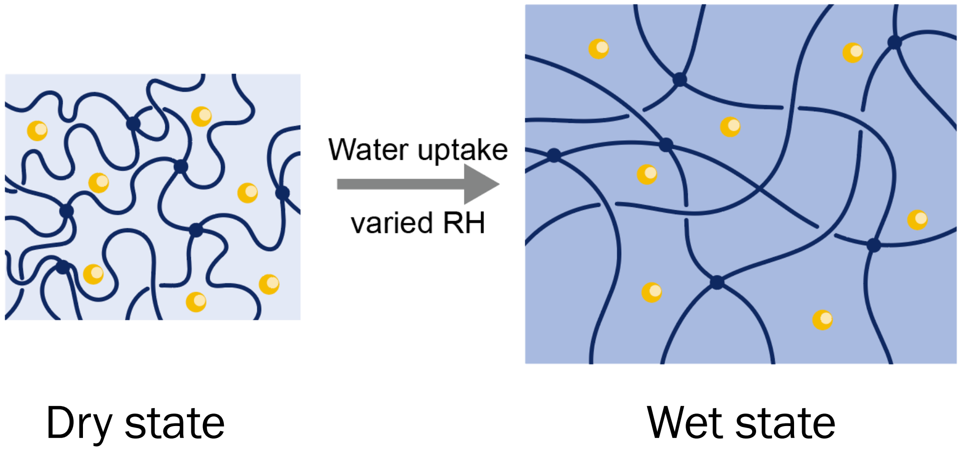
Approach: Hydrogel/Salt Composite Synthesis

Material synthesis: Incorporate hygroscopic salts into the hydrogel matrices

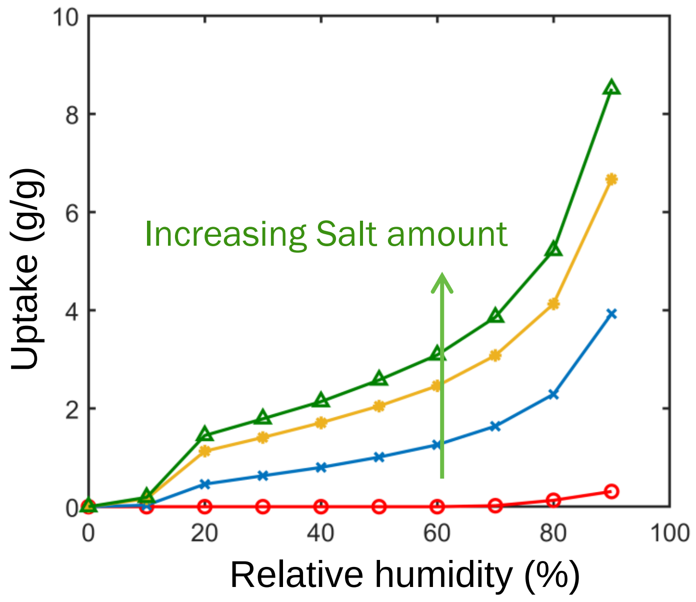


Sorption Characterization of Hydrogel/Salt Composites

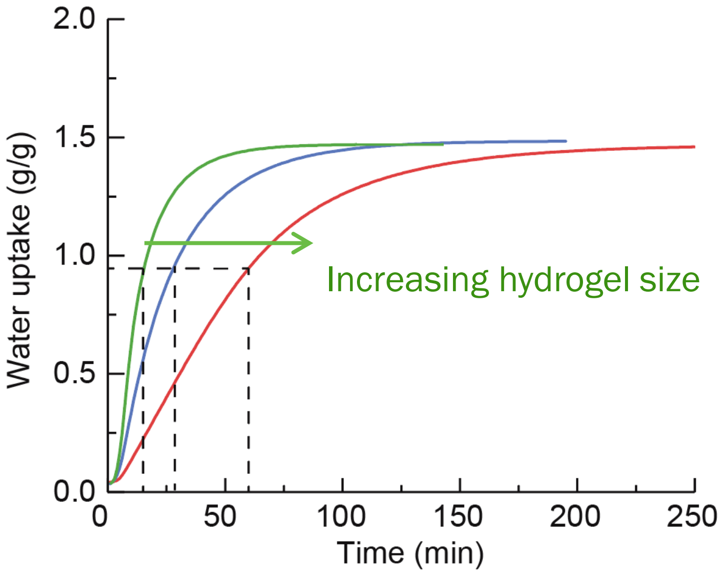
Water sorption process



High water sorption amount



High water sorption kinetics



Current Progress:

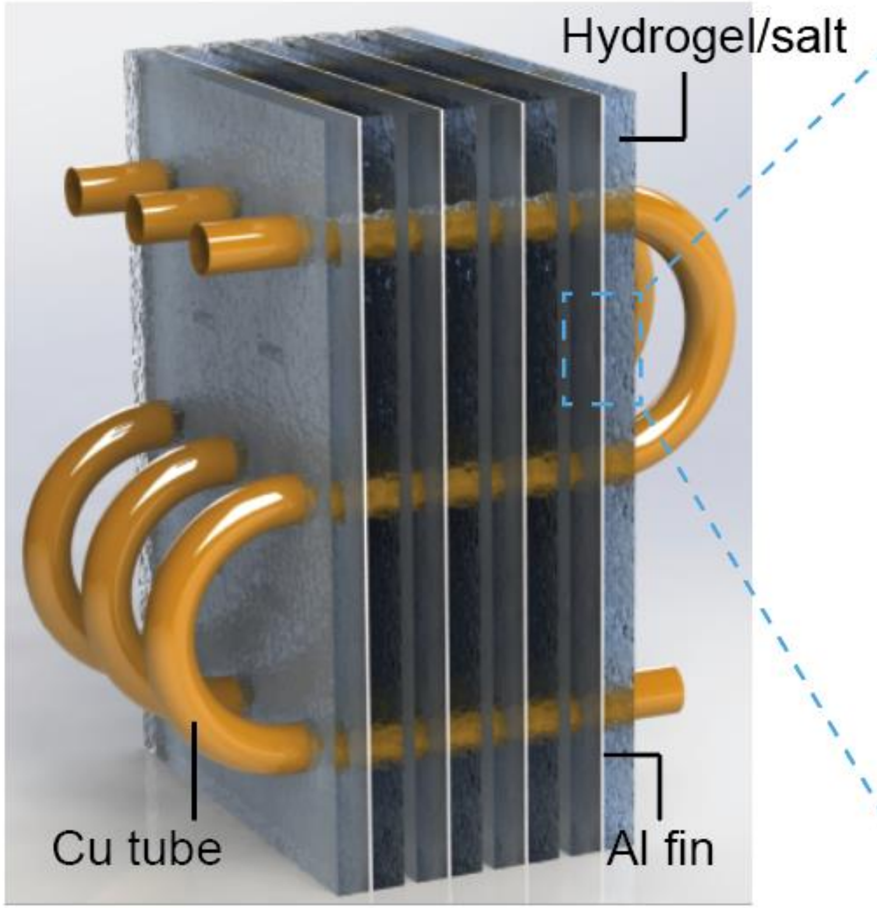
- Uptake of the hydrogel/salt adsorbent exceeds 1.0 g/g at 40% RP

Future Work:

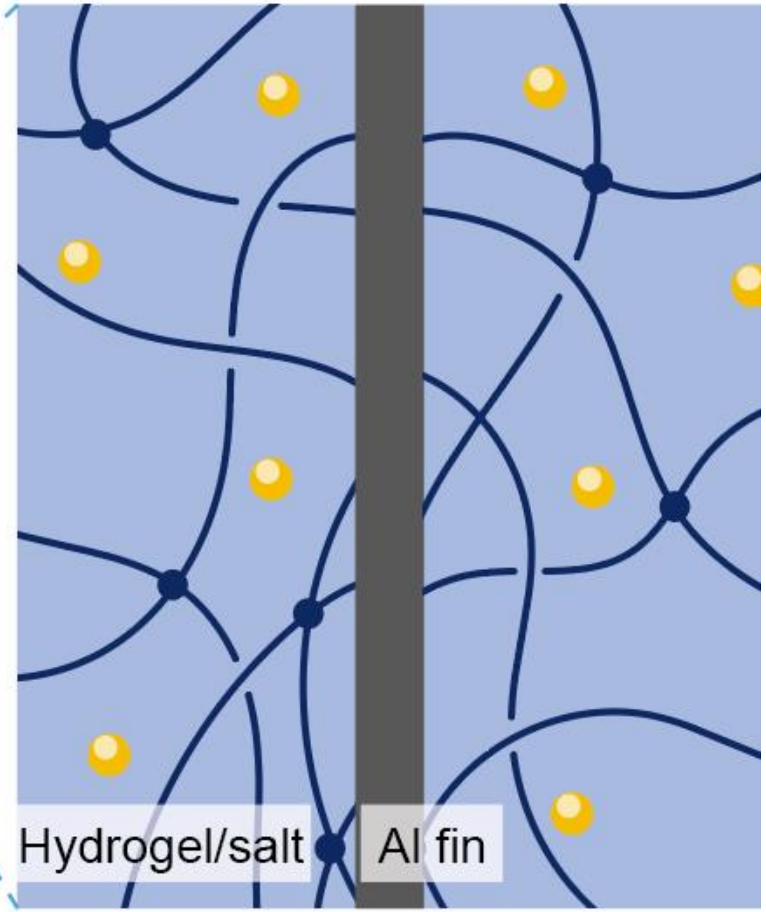
- Cyclic sorption/desorption performance of hydrogel-salt composites
- Corrosion and hydrogel adhesion

Approach: Adsorbent Bed Unit (ABU) Design

Overall ABU design



Material Schematic



Current Progress:

- Design of finned-tube HX coated with hydrogel to for energy density > 200 kWh/m^3

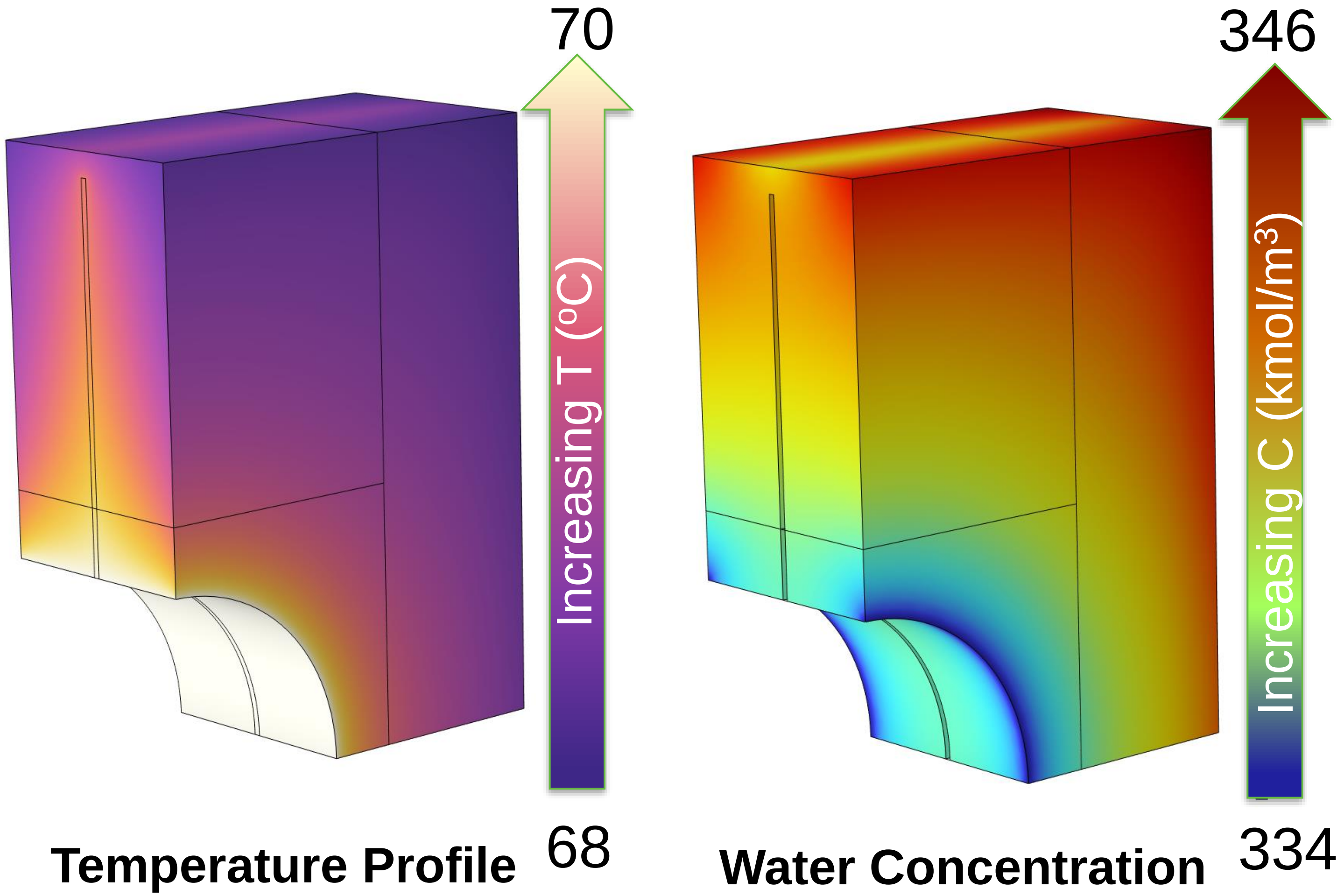
Future Work:

- Experimental characterization
- Fin adhesion
- Quantify measured energy density

Thermo-fluidic models for ABU

Highlights:

- Water uptake swing is > 0.8 g/g
- Heat and mass transport model of hydrogel coated fin
- Predicting temperature and water concentration profiles

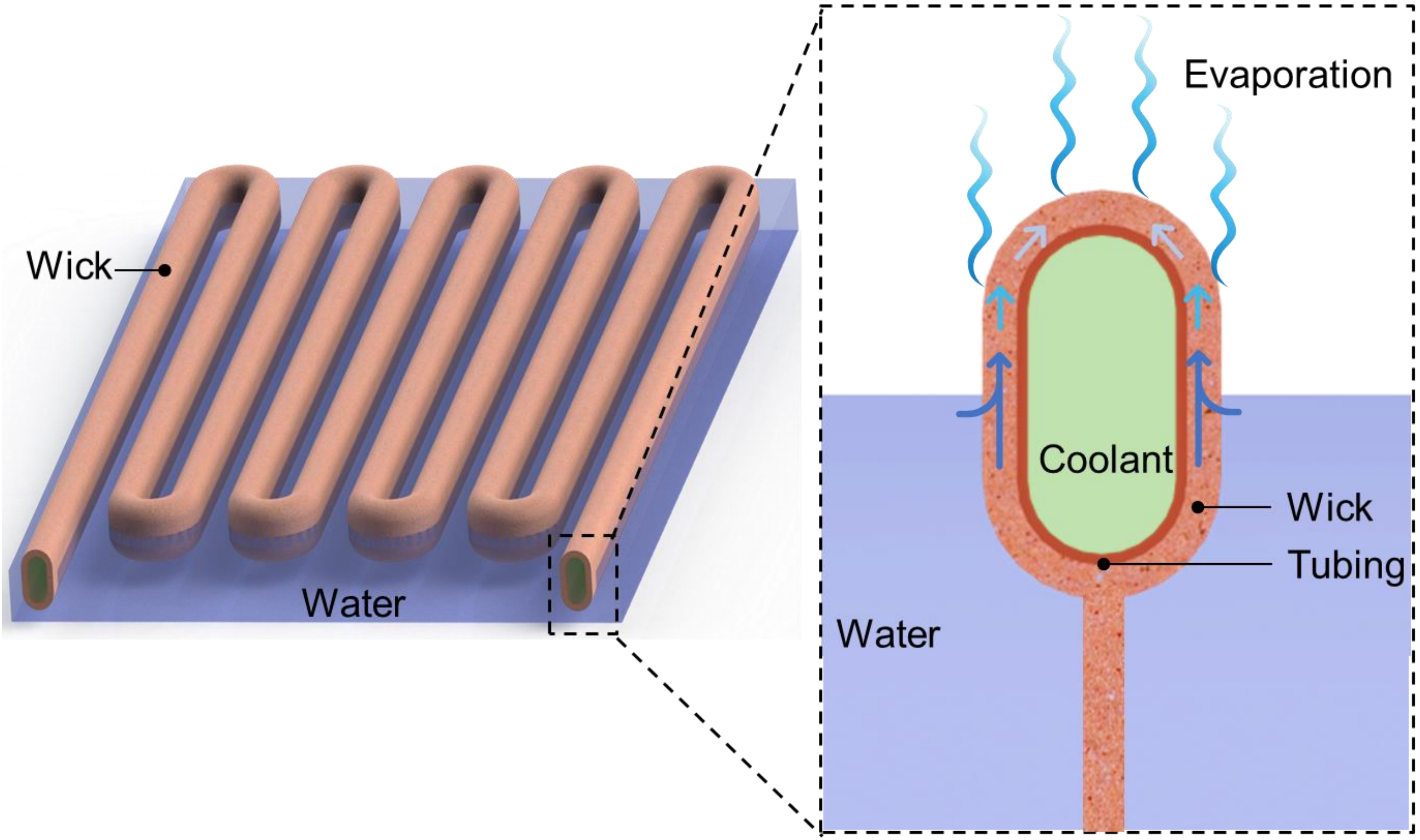


Approach: Evaporator/Condenser Unit (ECU) Design

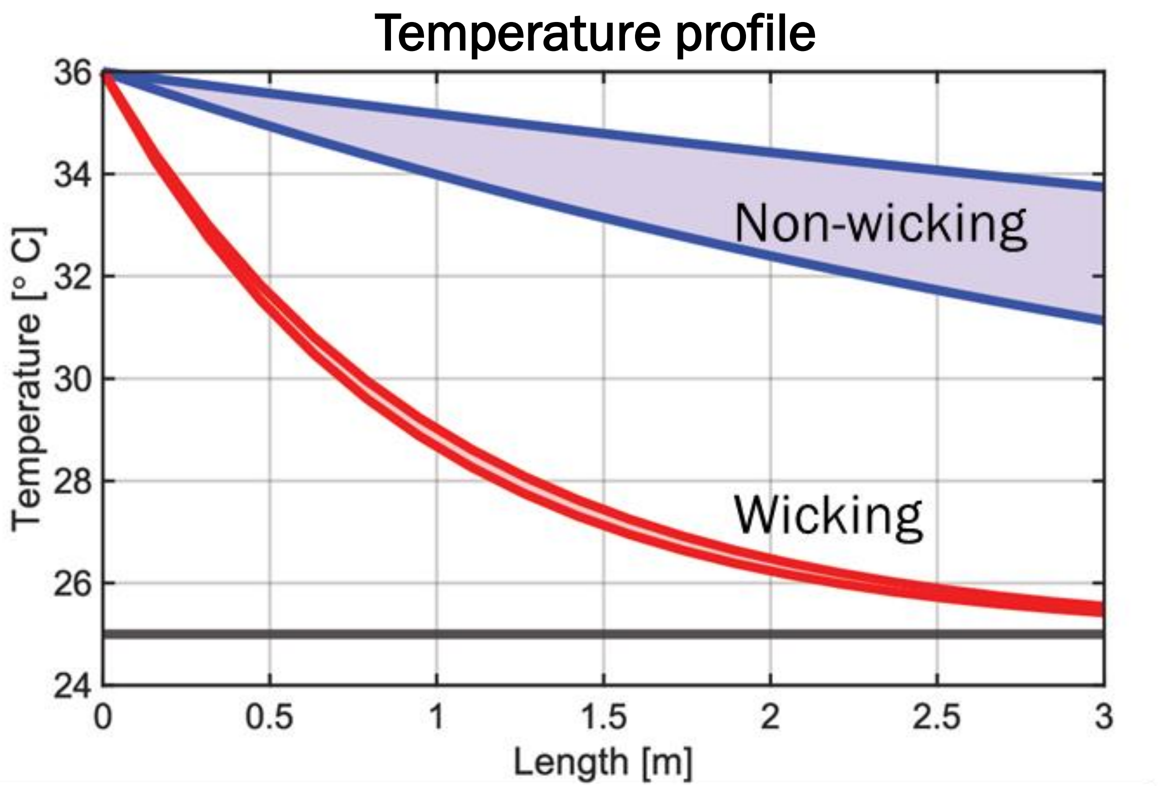
Current Progress:
- Enhanced evaporation and condensation via wicking structures

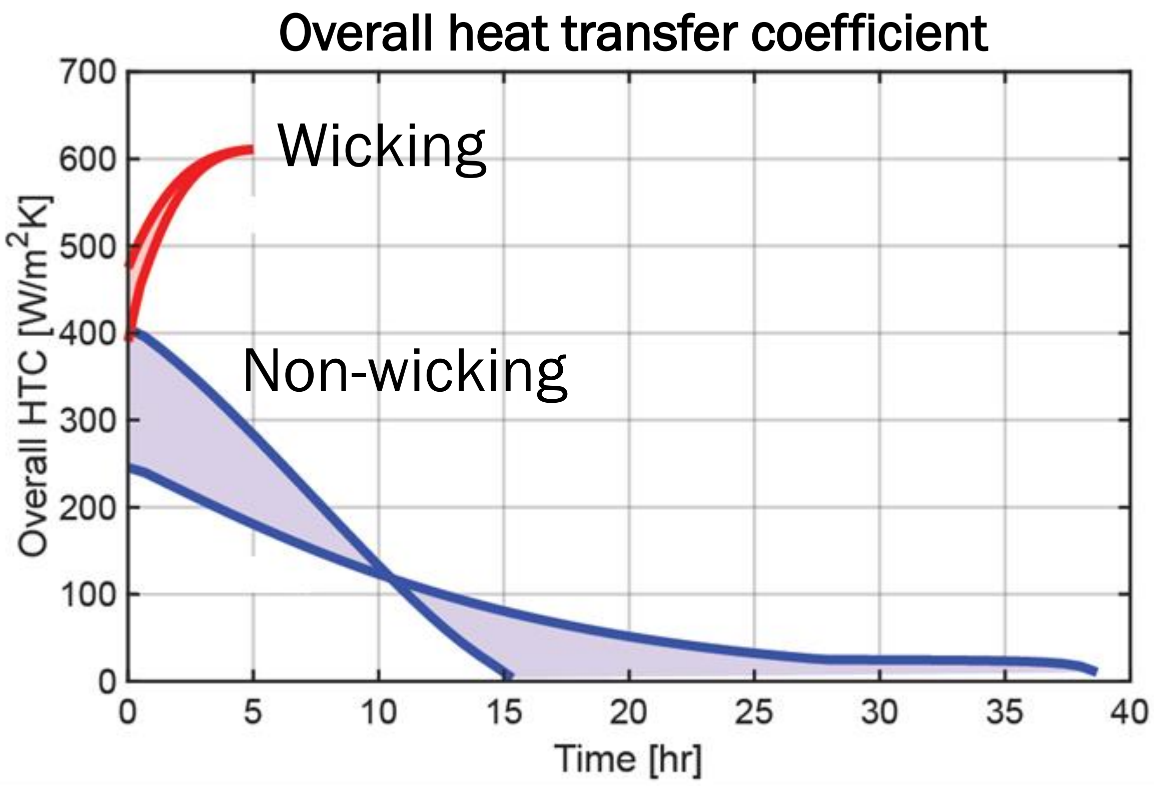
Future Work:
- Optimize wicking structures to achieve best performance and cost-effective ECU
- Experimental characterization of ECU in vapor environment

Overall ECU design



Numerical Model of ECU





Numerical heat and mass transfer of ECU used for:

- Designing and sizing of the overall component
- Predicting the performances (T, UA, evaporative flux, etc...)

Value Proposition & Competitive Differentiation

- High energy storage density of 0.20 – 0.29 kWh/L
  - 6× higher than sensible heat storage and 3× higher than PCMs
- Lower regeneration temperature of 70°C, compatible with HVAC and solar energy
- Reduced power consumption,
  - Enables a smaller capacity and lower cost AC or HP unit, with more compact size
  - ECU combining functions of evaporator and condenser reduces system size and removes the need for a water pump
- Payback time of < 2 years if running everyday

Future Work for TES

Optimize
- Maximize performance
- Minimize cost

Characterization
- Validating the ABU and ECU design
- Risk assessment

Integration
- Testing ABU + ECU in vapor conditions
- Cyclic testing

Field testing
- Integrating device to HVAC system
- Assess performance

Thank You

MIT, HTT, Rheem

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DE-EE0009679

REFERENCE SLIDES

Project Execution

S.No.	Task/ Milestone Description	Teams	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
1	**Preliminary Device Design, Model and Optimization, Material Fabrication and Characterization**													
1.1	Device Design, Model and Optimization	MIT, HTT, Rheem												
1.2	Adsorbent Synthesis and Characterization	MIT												
1.3	Preparation for Commercialization (Cost Model)	MIT, HTT, Rheem												
2	**Component Fabrication and Characterization**													
2.1	Component Fabrication and Characterization	MIT, HTT												
2.2	Preparation for Commercialization	MIT, HTT, Rheem												
3	**Device Integration, Characterization, Validation, Preparation for Commercialization**													
3.1	Device Integration, Characterization and Validation	MIT, HTT, Rheem												
3.2	Preparation for Commercialization	MIT, HTT, Rheem												

☆ Represent milestones | Represent Go/No-Go decision points

Team

Team Member	Role in project
Massachusetts Institute of Technology (MIT - Prime)	Device design, modeling, characterization, and integration
Heat Transfer Technologies (HTT)	Component fabrication, characterization, and commercialization
Rheem Manufacturing	Device integration, characterization, and commercialization

Team Members:

MIT: Bachir El Fil (co-PI), Asegun Henry (co-PI), Xinyue Liu, Hyeongyun Cha, Liliosa-Eyang Cole, Young Ko, Geoffrey Vaartstra, Carlos Diaz Marin

HTT: Yoram Shabtay, John Black

Rheem: Harshad Inamdar, Sachin Nehete, Dennis Drzewieck