Thermal Storage-Ready High Performance Multi-Split Heat Pump System

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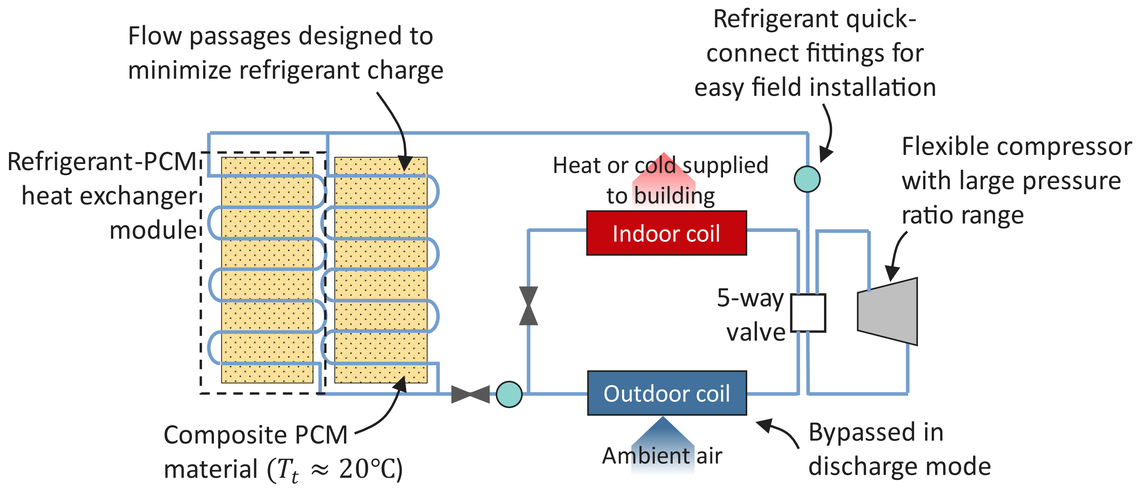
Project Description and Goals

Plug-and-play multi-split vapor compression system with modular thermal energy storage (TES) components that shift loads in the summer and winter.

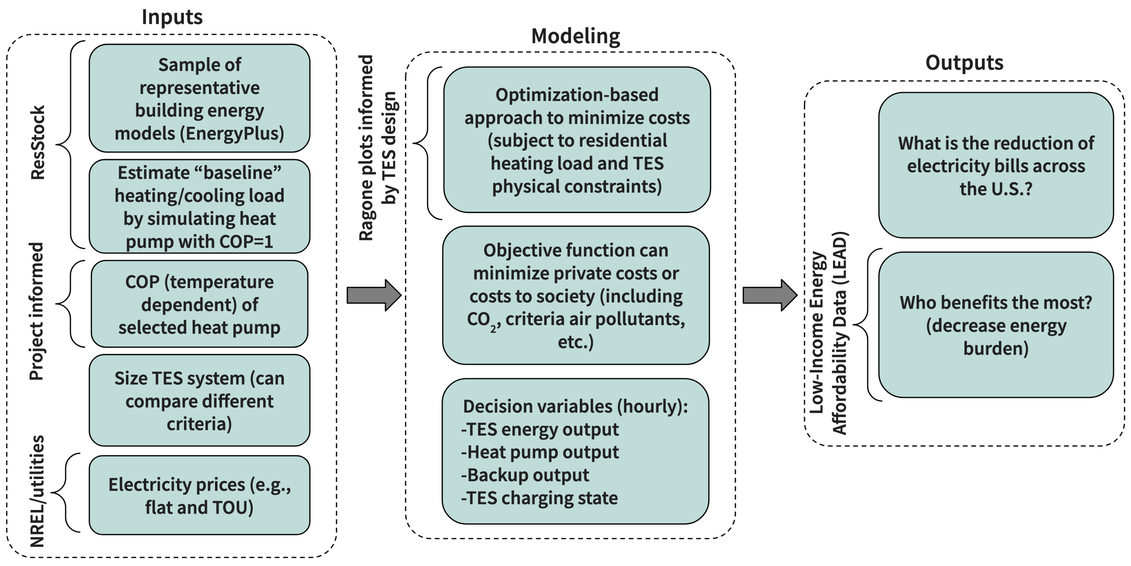


Project Goals:

1. Develop low-cost (<$15/kWh) salt-hydrates for the proposed system with <10% degradation over 1000 cycles
2. Design modular thermal storage cells that reduce demand by >40% for 4 hours in the summer and winter
3. Develop TES controller that can connect to a Daikin multi-split unit with minimal modifications to the supervisory controller
4. Measure performance and experimentally show:
   - Peak demand reduction >40% for 4 hours
   - >50% CO_2 reduction compared to 90% AFUE/SEER-13
   - Net-positive energy savings throughout the year

Net Benefits Screening Tool

Identified relevant inputs and developed optimization-based approach to maximize benefits of TES across the US.



Phase Change Materials

Initial PCM selection:

Selected commercial PCM for bench-scale prototype considering:

- Thermophysical properties (melt temperature, energy density, etc.)
- Performance in graphite matrix (ease of integration, expected degradation, etc.) based on past work.

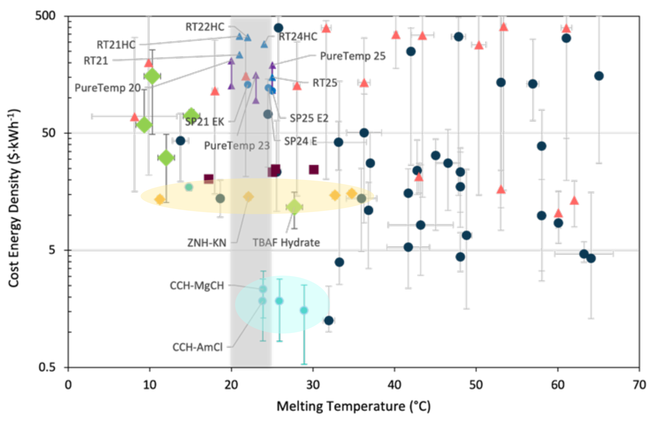
Identified 12 candidates, selected ***PureTemp 23***.

Low-Cost salt-hydrate PCMs:

Selected 4 candidate systems:

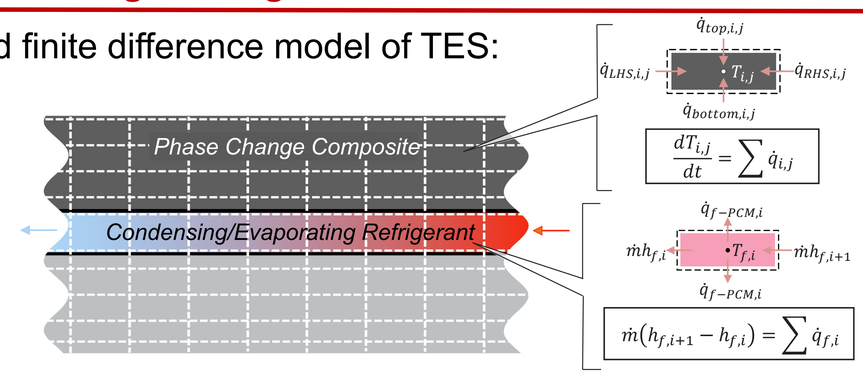
- $Zn(NO_3)_2 \cdot 6(H_2O)$-KNO_3
- $TBAF \cdot 29(H_2O)$
- $CaCl_2 \cdot 6(H_2O)$-NH_4Cl
- $CaCl_2 \cdot 6(H_2O)$- $MgCl_2 \cdot 6(H_2O)$

Cycling neat, +graphite, and +graphite, polymer, and NP.

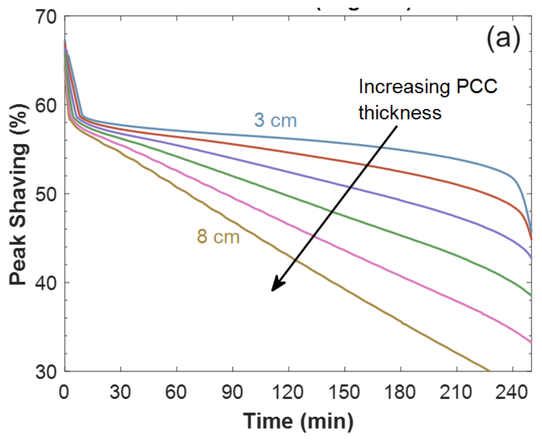


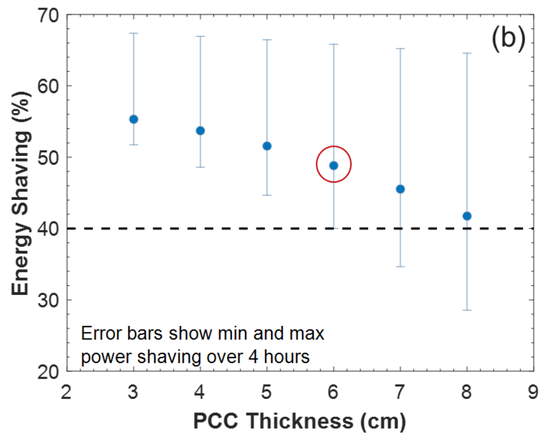
TES Heat Exchanger Design

Developed finite difference model of TES:



Using approximate COP relationship, modified key design parameters and selected TES that can provide at least 40% peak shaving at 35°C and 0°C ambient temperatures.

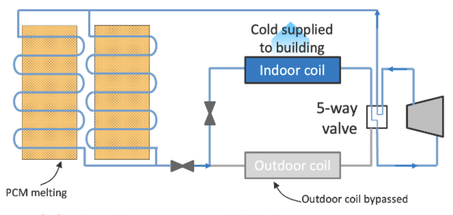




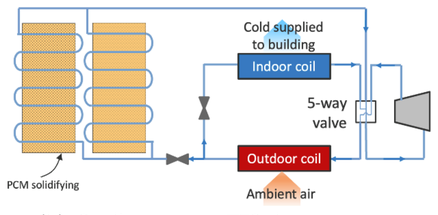
Used model to train artificial neural network (ANN) maps when freezing/ thawing the TES in different control modes. Mean errors < 0.01%.

Modeled System Performance

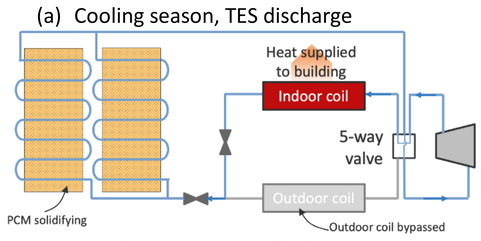
- Developed thermodynamic model with compressor performance curves (Daikin) and TES operating pressures/ flow rates (ANN)
- Controlled discharge rate with refrigerant pressure and charge rate with refrigerant flow rate. ANN maps made for each mode
- Baseline is the same system without TES



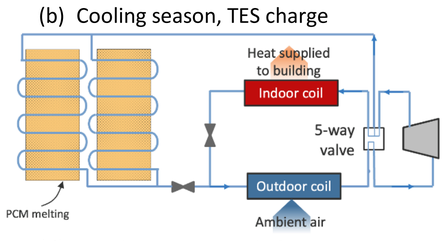
(a) Cooling season, TES discharge



(b) Cooling season, TES charge



(c) Heating season, TES discharge

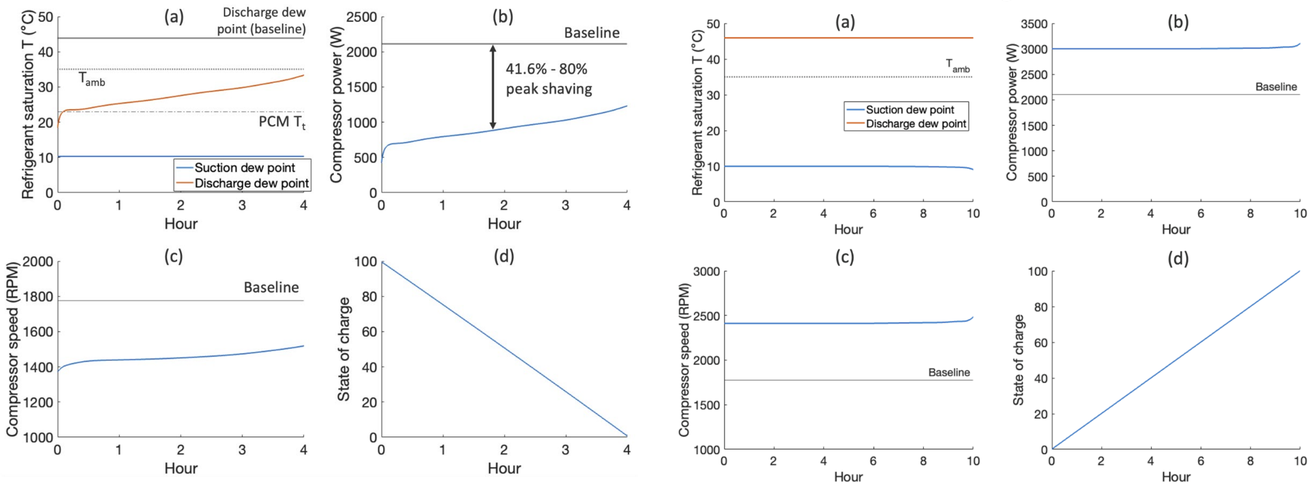


(d) Heating season, TES charge

Season	Room load (kW)	Ambient T during discharge (°C)	Indoor dry-bulb T (°C)	Indoor wet-bulb T (°C)
Cooling	10.5	35	26.7	19.4
Heating	10.5	0	25	N/A

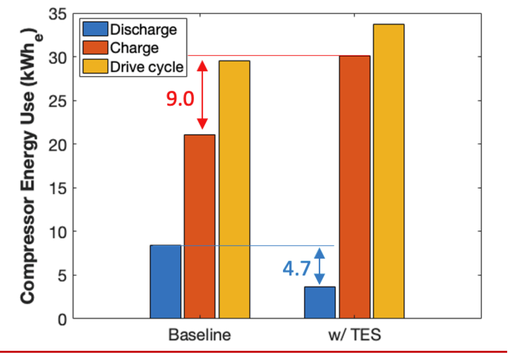
Cooling season results (similar results for heating season):

Discharge Mode: *Charge Mode:*



Key Takeaways:

- Reduces power by ***41% - 80%*** over 4-hour window in the summer and by ***56% - 72%*** in the winter
- If charging & discharging occur at same ambient temperature, 14% net increase in total energy use



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