INVESTIGATION OF THERMAL ENERGY STORAGE-HEAT PUMP INTEGRATION FOR RESIDENTIAL APPLICATIONS

DESIGN REQUIREMENTS

- Based on the energy flows of the ACE Lab, when excess energy is available the system shall begin to charge the TES
- TES shall be discharged during the day to flatten the required cooling loads during the day.
- System shall remain in functioning order for at least 10 years.
- TES System shall keep comfortable temperature in the ACE Lab for 4 hours at ASHRAE standards
- An external power supply shall be added to the system to force air over the TES for 4 hours without power gird dependency.
- The system shall be able to withstand a point load of 150 lbf without causing harm to the unit or person.

FINAL DESIGN CHOICES

- PureTemp20 and/or hexadecane chosen as working PCM
- 29 Rows of 5 Tubes (145 Tubes Total)
- Constructed primarily of aluminum extrusions, HDPE, PCM, and acrylic panels.
- Air will be forced through the tube bank to melt and freeze the PCM, when applicable.
- Modular design chosen to work with various mini-split systems.
- Active control surface, controlled by an Arduino for charging and discharging the PCM

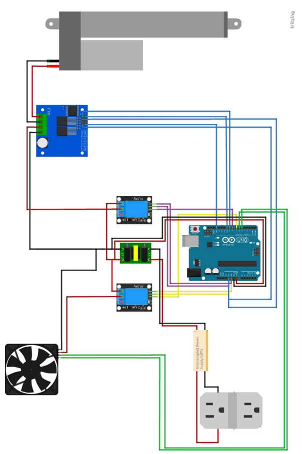

Figure 2: Electrical Control System Diagram

Figure 3: Final Design in Charge State

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BACKGROUND

Amidst escalating global warming concerns, the imperative to cut greenhouse gas emissions takes center stage in engineering research. Buildings, responsible for 10% of global greenhouse gas emissions and consuming 75% of grid electricity, pose a substantial challenge. As renewable energy integration surges on the grid, the need for energy storage intensifies. While large-scale battery storage seems intuitive, its cost and scale render it a problematic sole solution. Given buildings' significant electricity demand, local energy storage is commonplace, with a substantial share of that demand stemming from thermal loads like space conditioning and refrigeration. There is a mismatch between future energy supply profiles and building load requirements, with the primary energy needs being thermal in nature, making thermal energy storage (TES) a well-suited, potentially cost-effective, and longer-lasting alternative to electrical batteries.

PROJECT OVERVIEW

- Design and test a thermal battery system to shift energy usage from peak hours to off-peak hours.
- Thermal battery will be made using phase change materials (PCM) as they absorb and release energy when it changes phase.
- Adaptable Clean Energy (ACE) Lab, used as a test bed as it currently has a mini-split heat pump, small scale, and off-grid.

Figure 1: Adaptable Clean Energy Laboratory

TESTING & DATA ANALYSIS

- Both the thermal battery and the Adaptable Clean Energy (ACE) Lab were instrumented at determine key data points to determine if the system functioned as designed
- Testing will determine the energy flows and if it can maintain comfortable temperatures of the conditioned space for four hours.
  - Once determined, mathematical modeling will be used to scale the system to determine if it is feasible for a large-scale implementation of a variety of households.
- Determine if the validation model meets the design requirements and determine if pressure drops remains within tolerance to be able to maintain a suitable flow for conditioning the space.

Figure 4: Partially Assembled Prototype

Figure 5: Thermocouple Placement on Minisplit

FUTURE WORK

- Further iterate the model and validate against experimental data to further increase the efficiency and effectiveness of the heat pump-thermal energy storage system.
- Test other tube configurations
- Seek more funding for further testing and iterations
- Go through the patent process to secure our intellectual rights to this design
- Market the model, prioritizing smaller households and apartments.

Figure 6: Production Design Concept for Marketability