2024 PROJECT PEER REVIEW
U.S. DEPARTMENT OF ENERGY
BUILDING TECHNOLOGIES OFFICE

Reduced Cost Heat Pump Space-And Water-Heating in Cold Climates

LBNL, ORNL,Emanant Systems, TRC, GTI Energy, Harvey Mudd College
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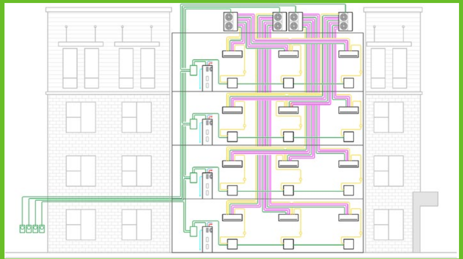
WBS 3.2.2.61

Project Summary

OBJECTIVE, OUTCOME, & IMPACT

Reduce the cost of decarbonizing multifamily buildings in cold climates by using air to water heat pumps and thermal energy storage. Utilize R290, novel polymer heat exchangers for TES, and novel system architecture to avoided electric panel upgrades and reduce cost for electrification by 20-40%.

BAU Approach



New

TEAM & PARTNERS

BERKELEY LAB

OAK RIDGE National Laboratory

HARVEY MUDD COLLEGE

TRC

GTI ENERGY

EMANANT

STATS

Performance Period: 10/1/2022 to 10/1/2025

DOE Budget: $3,000, Cost Share: $1078k

Milestone 1: Complete mechanical design of modular combi R290 AWHP system with low-cost PCM TES

Milestone 2: Complete laboratory testing of modular combi R290 HP system with low-cost PCM TES

Milestone 3: Complete summary presentation on results from field evaluation

Problem

This project aims to accelerate decarbonization of **multifamily buildings** in **cold climates** by **overcoming initial cost and performance challenges** associated with current practice heat pump technology, including:

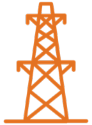
- piping, insulation, electrical, and control wiring infrastructure
- high likelihood of refrigerant leakage and associated impacts
- oversizing of heat pumps, poor part load efficiency, and issues with sizing and zoning.
- inflexibility of electric demand, and high peak electric demand
- cost and complexity associated with auxiliary heating systems
- cost of upgrades to apartment panels, service entrance, and meters
- energy and maintenance costs

Alignment and Impact

GHG Reductions

- No combustion for heat or DHW
- Reduces CO_2 emissions >50%
- Reduces refrigerant GHG >90%

Grid Decarbonization



- TES enables syncing consumption with renewables production
- Reduces renewables curtailment

Energy Justice

- Addresses challenges common in lower income multifamily buildings
- Pathway to energy democratization

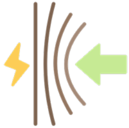
Affordability

- Reduce initial cost by ~20-40%
- Avoid panel upgrades
- Reduce installation cost
- Novel reduced cost TES

Efficiency

- Improve part load efficiency
- Heating seasonal COP increase >50%

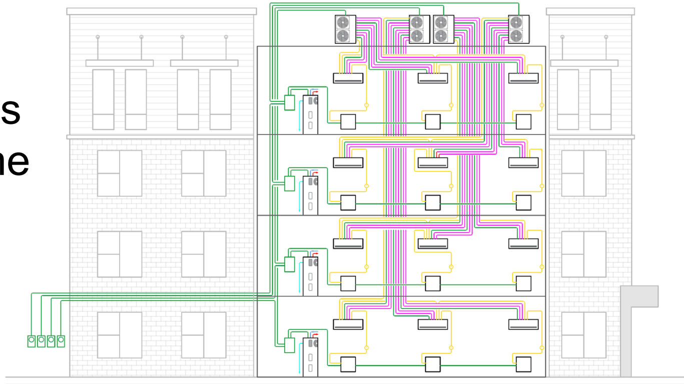
Resilience

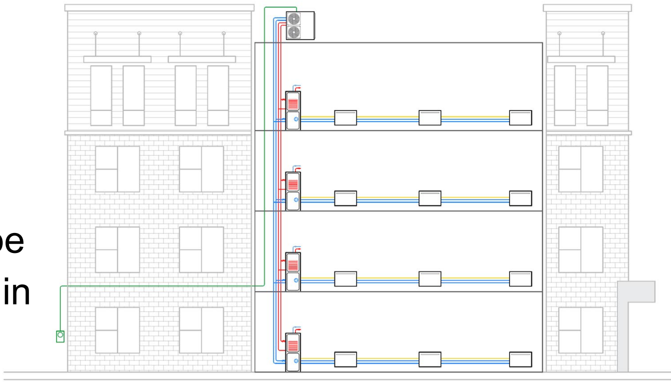


- TES can provide services in times of extreme grid stress
- Modular central heat pump system more resilient to equipment failures
- Demand flexibility without discomfort

Approach

Simplified Installation & Operation





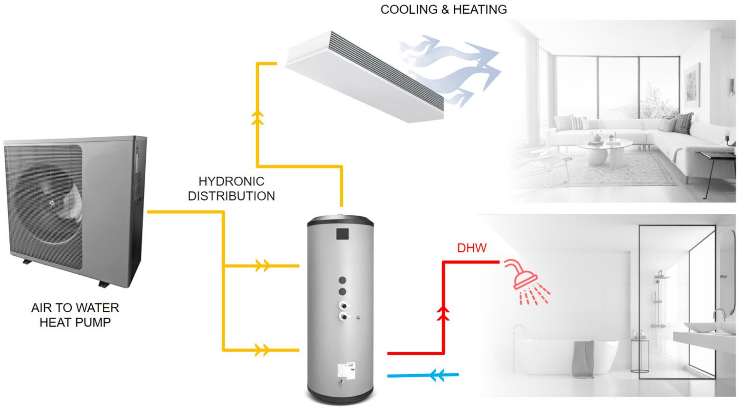
Focus on hard to decarbonize buildings:

- cold climate - demonstrating we can meet loads heat pumps
- multifamily - installation challenges and targets lower income households

1. Market research on cost reduction for HPs multifamily cold climate HPs
    - Build on previous California Energy Commission project by TRC
1. Model and design a packaged low GWP combi HP with refrigerant-to-PCM TES
2. Staged prototype development and validation
    a. Field evaluation of R32 HP with PCM TES in cold climate
    b. Design, fabricate and lab test staged TES and CO_2 HP prototype
    c. Field evaluation of R 290 combi air-to-water HP with PCM TES in cold climate multifamily building

Approach - benefits of proposed system

1. Low power consumption heat pump that does not require new electric circuits or new panels/utility service drops
2. An R290 (GWP=3) AWHP with good low temperature performance (UEF = 3.75, SCOP = 2.9)
3. TES using several PCMs that allow for staged thermal storage to
   - further increase efficiency at low temperatures,
   - enhance compatibility with AWHPs
   - provide sufficient capacity to meet household heating and hot water demand
   - allow for shifting 9+ hours of energy use off-peak
   - enable cost-reductions by reducing AWHP size by 16 kBtu/hr (1.33 tons) per unit (~$3-4,000).
4. Modular design – prepackaged sub assemblies for quick and easy field installs

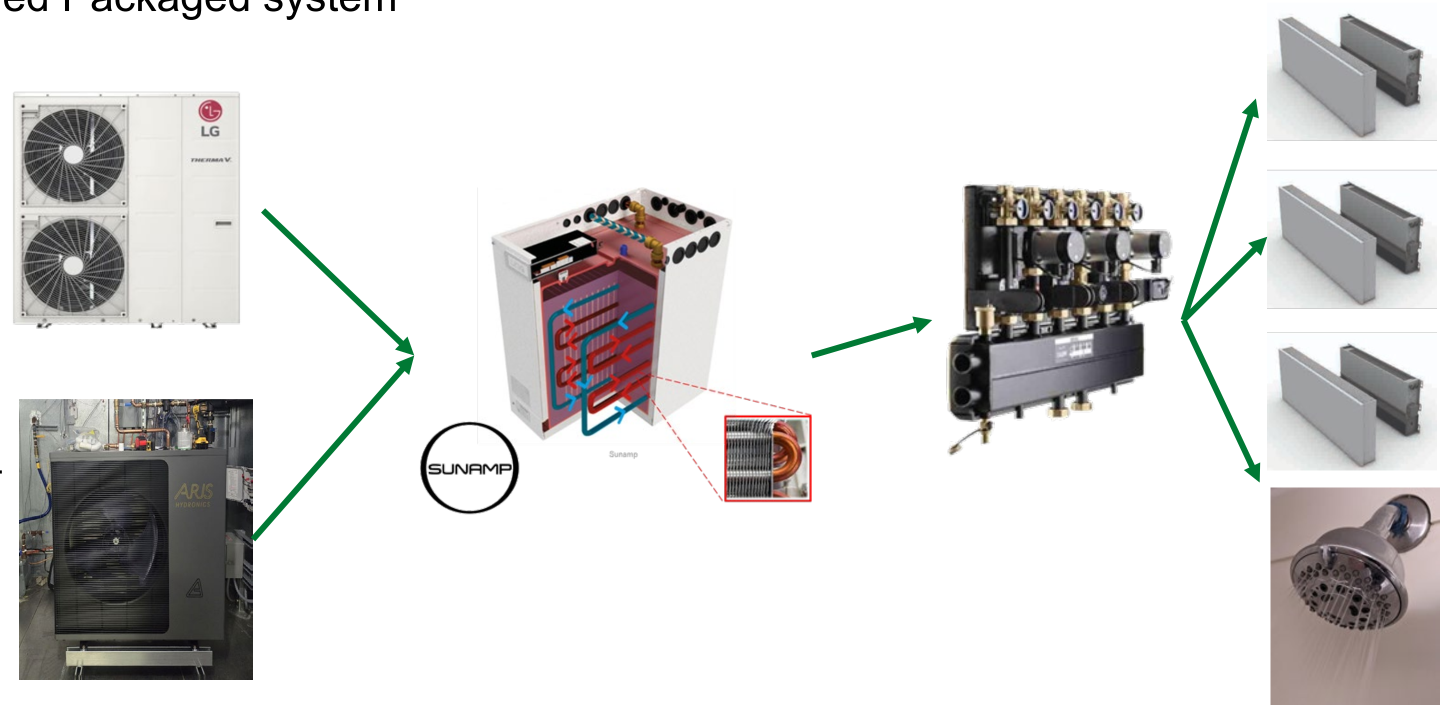


Approach – Unique Features

- Energy dense low-cost salt hydrate PCM - staged TES
  - 30 kWh-th / 20 ft^3 / apartment unit
- Inexpensive polymer heat exchanger
- Engineered Packaged system

LG ThermaV
R32 (GWP = 677)
Operates to -13 °F
Supply water to 148 °F

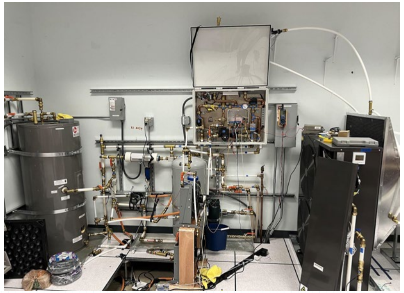
Aris Hydronics
R290 (GWP = 3)
Operates to OAT = -13 °F
Supply water to 158 °F
Graduate of LBNL's IMPEL+

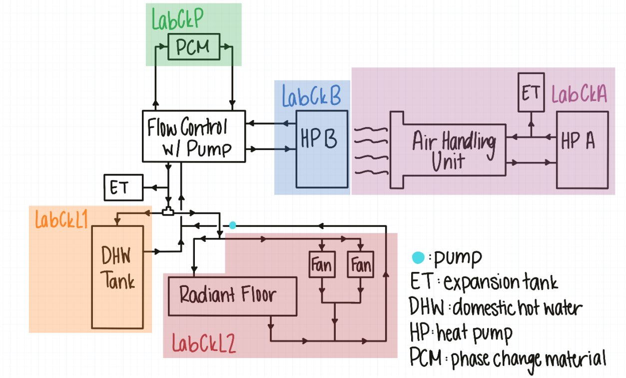


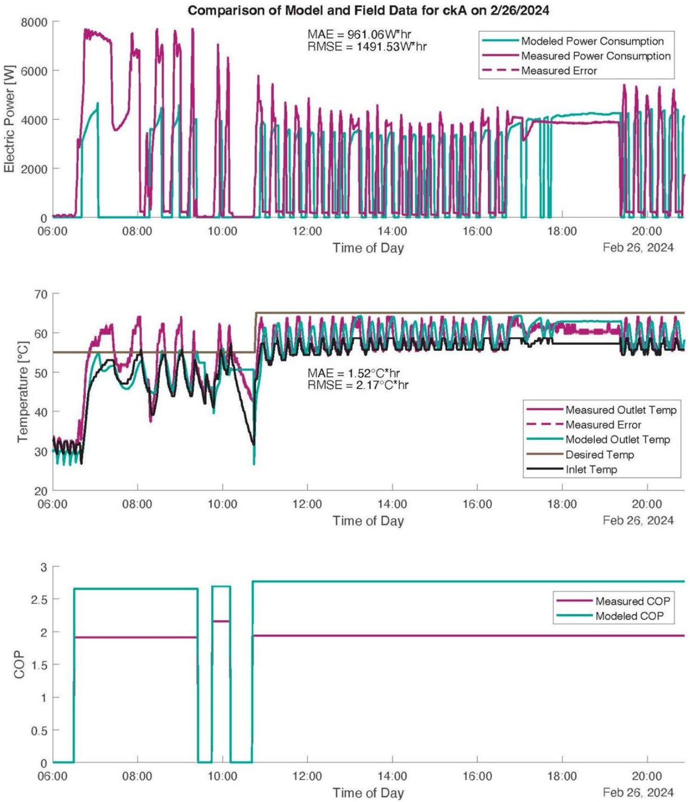
Approach - Phase 1 Field Test and Lab Modeling

Comparing field data to lab controls

Lab data fills gaps in field data







Approach - Key Challenges

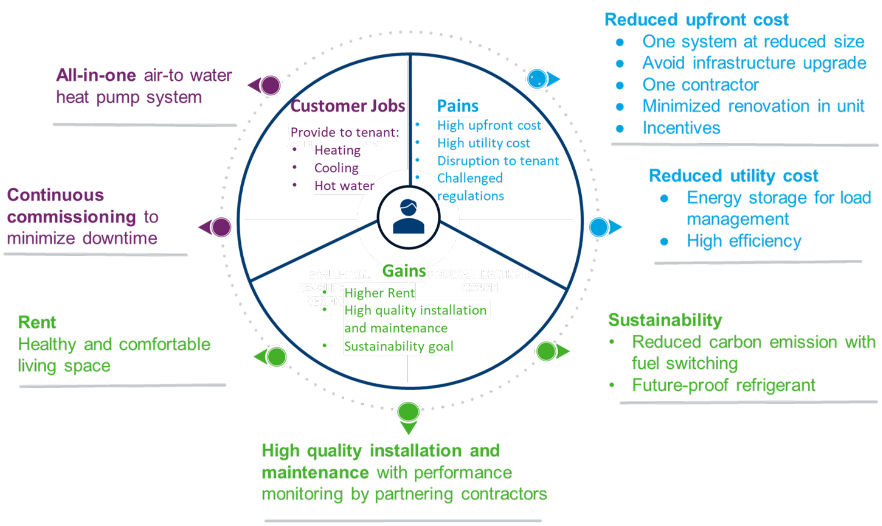
1. Multi-temperature phase change materials and polymer PCM-refrigerant heat exchanger require considerable prototype development .
2. Lack of engineered solutions combining the heat pump, heat exchangers, and thermal storage into a packaged easy to install unit.
3. Lack of existing control strategies

Technical risks and mitigation strategies are:

1. Failure to realize theoretical performance – *identify alternatives and options for improvement*
2. **Failure to develop TES compatible with CO_2 HP - *use alternate low GWP HP- R290***
3. Failure to find a field testing site – *identify multiple possible sites*
4. Failure of prototype in field testing – *repair and retest and include fail-safe systems*

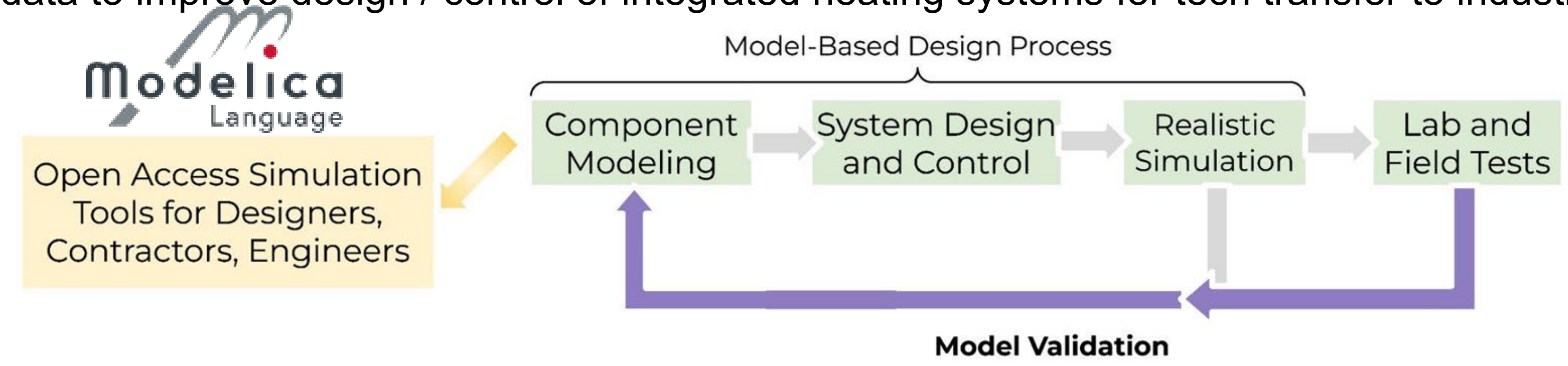
Progress and Future Work: Market Analysis

  - 10 technical interviews
  - 75 customer discovery interviews
- Key findings to date
  - First cost as key decision-making criteria
  - Installation challenges increase first costs
  - Owner preference for individual systems to shift utility costs to occupants
  - Uncertainty about cold climate performance
  - UNcertainty about future utility bills
  - HVAC retrofits to heat pump at deep retrofit
- Impact
  - CCHP is less invasive and may be able to avoid deep retrofits
  - Centralized approach can avoid cost shift to tenants, but may not be preferred without a sub-metering option
- Upcoming tasks
  - Life cycle cost comparisons and cost compression research



Progress and Future Work: Model Validation

We make and validate freely available component and system models with lab and field data to improve design / control of integrated heating systems for tech transfer to industry.



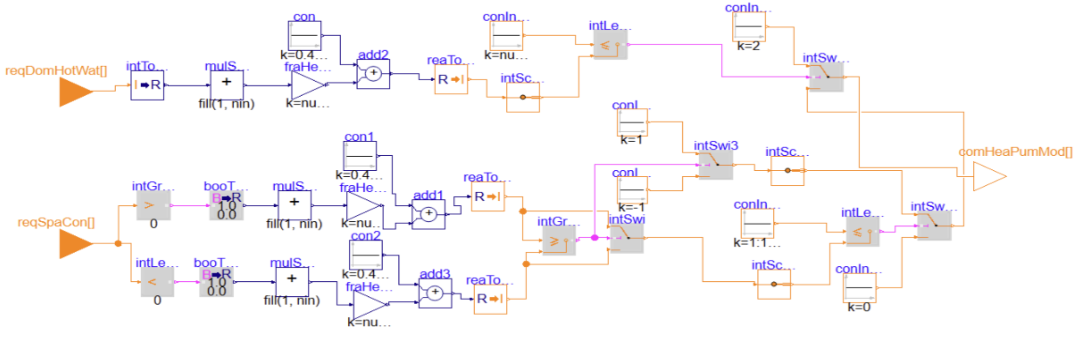
<u>**Milestone 3.3**: R32 Combi System Model Validation Publication(s)</u>

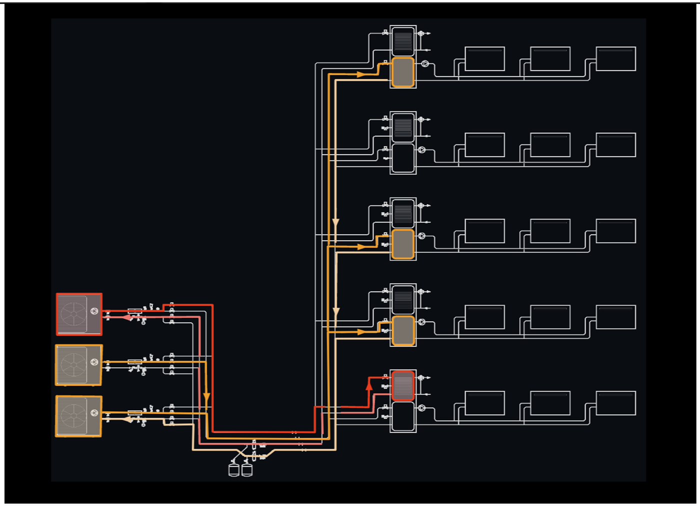
- **PCM TES Model**: lab-validated models available on Github*, draft paper in progress
- **R32 AWHP Model**: field-validation underway, draft paper completed, to be revised
- **Combi System Model**: contingent on validity of all integrated component models

* https://github.com/lbl-srg/modelica-buildings/tree/issue3806_pcmTesModels_slPCMlib

Progress and Future Work: Prototype Design

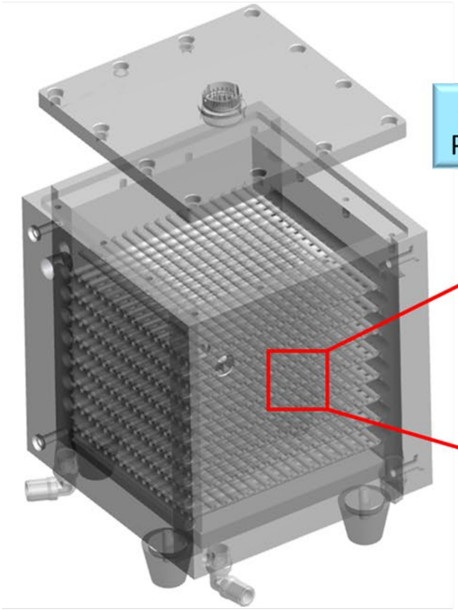
- Control logic for AWHP grouping and staging written via ASHRAE 231p standard
- Developed **scalable** control logic in Modelica modeling language:
  - Takes downstream “requests” from inline storage systems
  - HPs are grouped into cooling, space heating or DWH mode to serve downstream requests
- Next steps:
  - Integrate envelopes from 1 floor of DOE mid-rise prototype model
  - Demonstrate and assess system performance





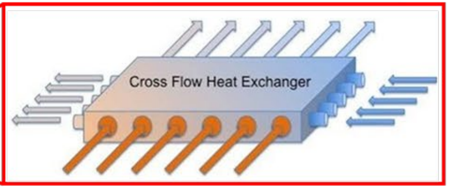
Progress and Future Work: HX Lab Testing at ORNL

PCM TES Heat Exchanger Prototype and Test Facility



3D View of Prototype

As-built Prototype

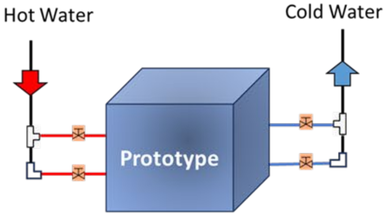


Key Design Features

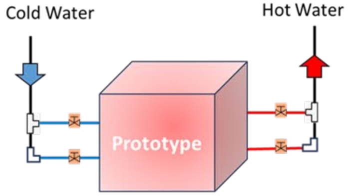
- **Poly Carbonate Tubes**- low cost and corrosion resistant
- **Cross-flow design**- Minimizes charging time
- **Salt-Based PCM**: Cheap and well-defined phase change temperature

Progress and Plan

- **Prototype:** Fabrication completed
- **Test Loop development:** Expected by 10/15/2024
- **Experiment Runs:** Expected by 15/12/2024



Charging PCM



Discharging PCM

Lab Testing: ARIS R290 Heat pump performance at GTI Labs

Test: Evaluate Heat pump performance across different heating and cooling conditions and operation parameters:

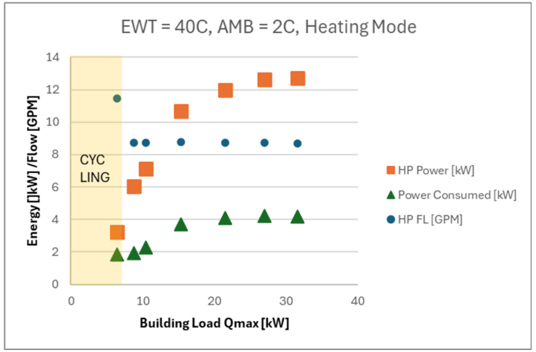
- **Ambient temperature:** 40 to -15 C tested
- **Building load:** varied from min to maximum part load in increments of 20%
- **Supply water temperature:** set to 12, 35, 45, 65 C

Measurement:

- Heat pump thermal output
- Electricity consumed and COP
- Temperature and flow rates at HP hydronic loop

Progress: ~20% of total testing completed

Sample results indicating change in HP heating capacity with building load



Progress and Future Work: FY24 Accomplishments

- **Submitted market analysis report**
  - Costs and Current Practice for Heat Pump Space and Water Heating for Multifamily in Cold Climates
- **Submitted draft paper** on Modelica model of AWHPs
  - R32 Air-To-Water Heat Pump Model Validation
- Began testing of **Aris R290 AWHP**
- **Constructed scaled-down prototype** of reduced cost PCM TES
- Developed design of **integrated AWHP + PCM TES system**
- Recruited two likely **field site partners**

Thank you

Lawrence Berkeley National Laboratory

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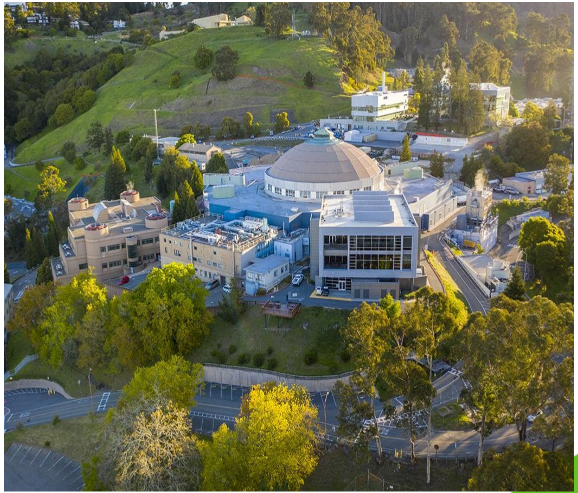
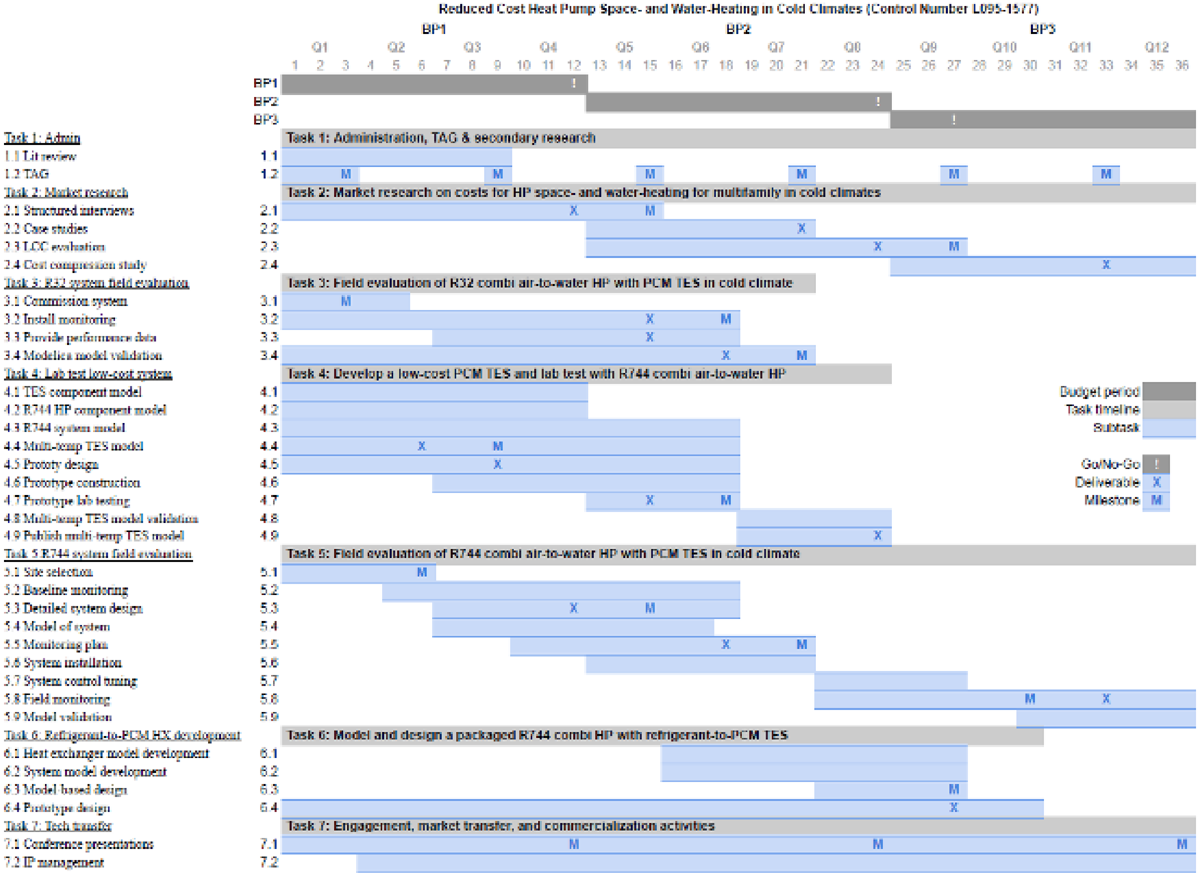


Reference Slides

Project Execution



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