Hybrid HVAC with Thermal Energy Storage Research and Demonstration

Performing Organization(s): LBNL, UC Davis, UC Berkeley, Emanant
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Project Summary

Timeline:

Start date: October 2018

End date: March 2022

Remaining Milestones:

1. Completion of system design tools, 7/2021
2. Lab characterization of Seeley HRV + IEC, 9/2021
3. Completion of "shovel ready" commercial building prototype, Fall 2021.
4. Competition of residential field installation, Fall 2021

Budget:

- DOE: $3050k
- Cost Share: $
  - Sunamp (TES) $20k (equipment) 30k (support)
  - Aermec (heat pump) $10k (equipment) 10k (support)
  - LG (heat pump) $10k (equipment) 10k (support)

Key Partners:

Team	Industry
UC Davis WCEC	LG
UC Berkeley	Aermec
Emanant	Sunamp

Project Outcome:

- Package designs of thermal energy storage integrated with efficient heat pumps that can respond to supply and cost signals.
- Modeled and pilot physical installations to demonstrate feasibility.
- Demonstrate minimum peak load reduction of 20% and 30% annual HVAC energy cost savings, compared to state of the art all electric.

Challenge

Problem Definition :

Decarbonizing building energy use requires both electrification and load shifting to align with renewable generation. Thermal loads of space heating and cooling and hot water particularly important. Thermal storage offers advantages but needs to be packaged with efficient equipment for scale-up.

Solution

Grid-interactive HVAC and HW systems, with integrated active thermal energy storage:

- enable electrification of heating and DHW
- advance grid-interactive efficient building systems
- support broader use of renewables
- improve grid and building resilience
- reduce energy costs & emissions

Team

Lawrence Berkeley National Laboratory

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Jonathan Woolley

NestWorks

Michael Woodcox







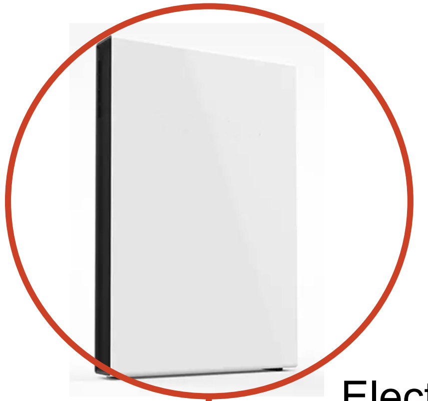






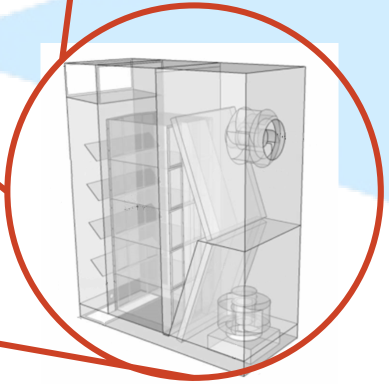



Approach: Inception



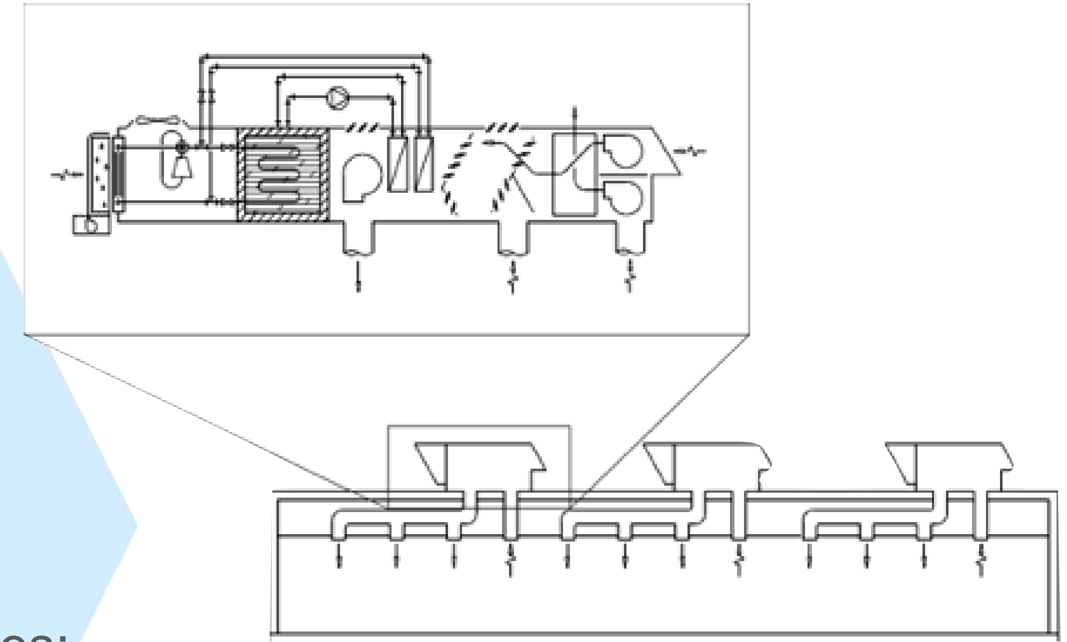
Electrochemical energy storage

Phase change materials thermal energy storage



DOAS with heat recovery + indirect evaporative cooling

Advanced heat pumps



Opportunities:

- Lower cost (heading to below $50/kWh, high density)
- non-toxic, non-flammable, >60k cycles.

Challenges:

- Lack of performance data
- Lack of / models / system models
- Control of complex systems
- Cost / physical constraints

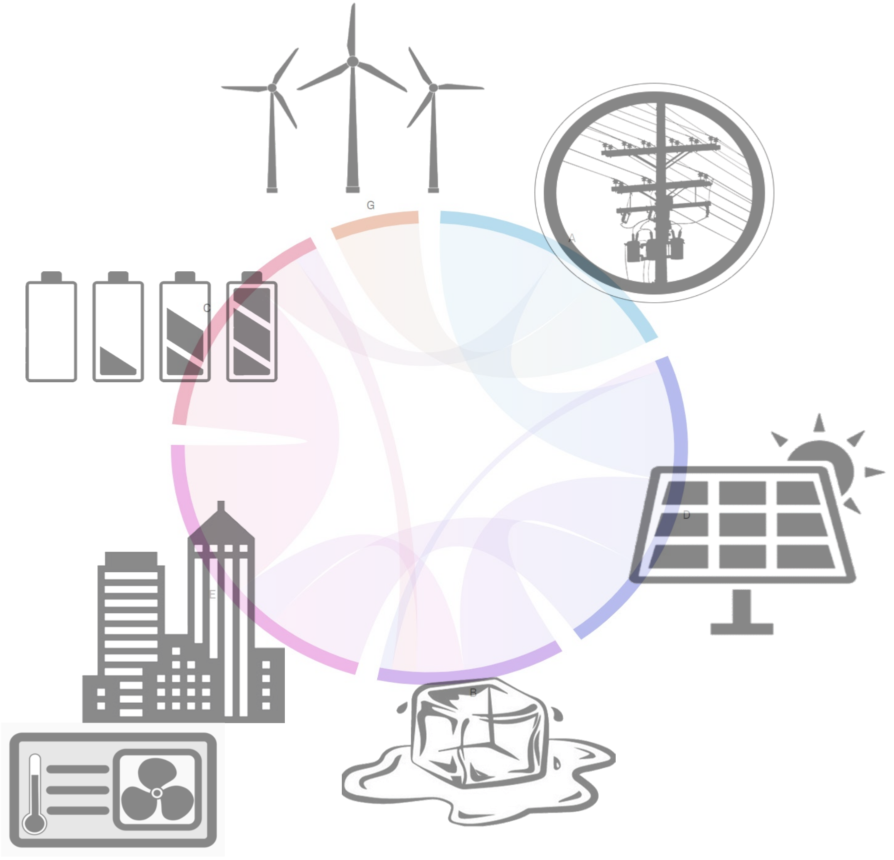
Approach: Objectives

Develop and demonstrate packaged system designs :

- high performance air-to-water heat pumps
- thermal and electrochemical energy storage
- evaporative cooling and energy recovery
- grid-interactive, model predictive control strategies

Tools to accelerate implementation

Work with industry partners for commercialization



Approach: Key Steps

<u>Foundational technology development</u>

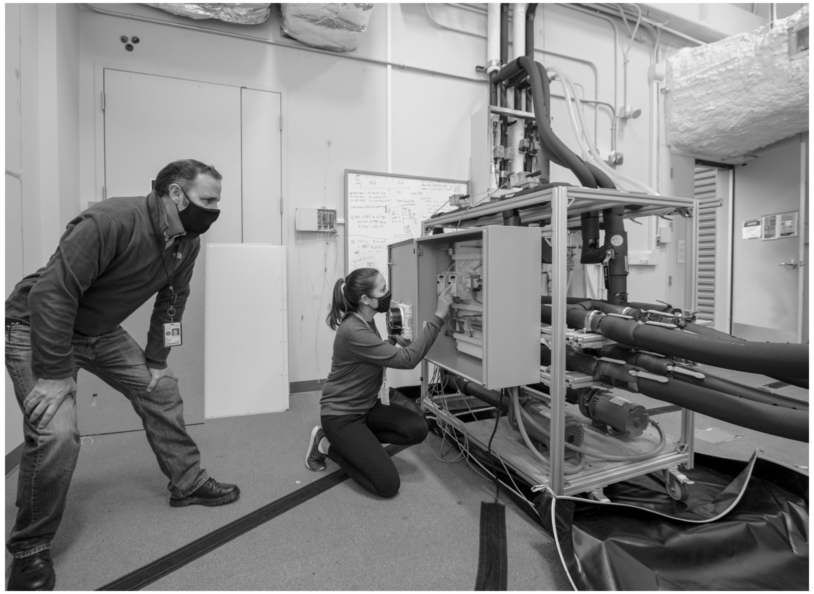
- **Lab characterization** of component technologies
- **Simulation** tools enable evaluation of techno-economic potential.

<u>Techno-economic evaluation of market application</u>

- **Market viability** analysis (DOE iCorps)
- Active **industry partnerships**
- Simulated designs for **three applications** and **model-predictive controls**

<u>Demonstration of prototype</u>

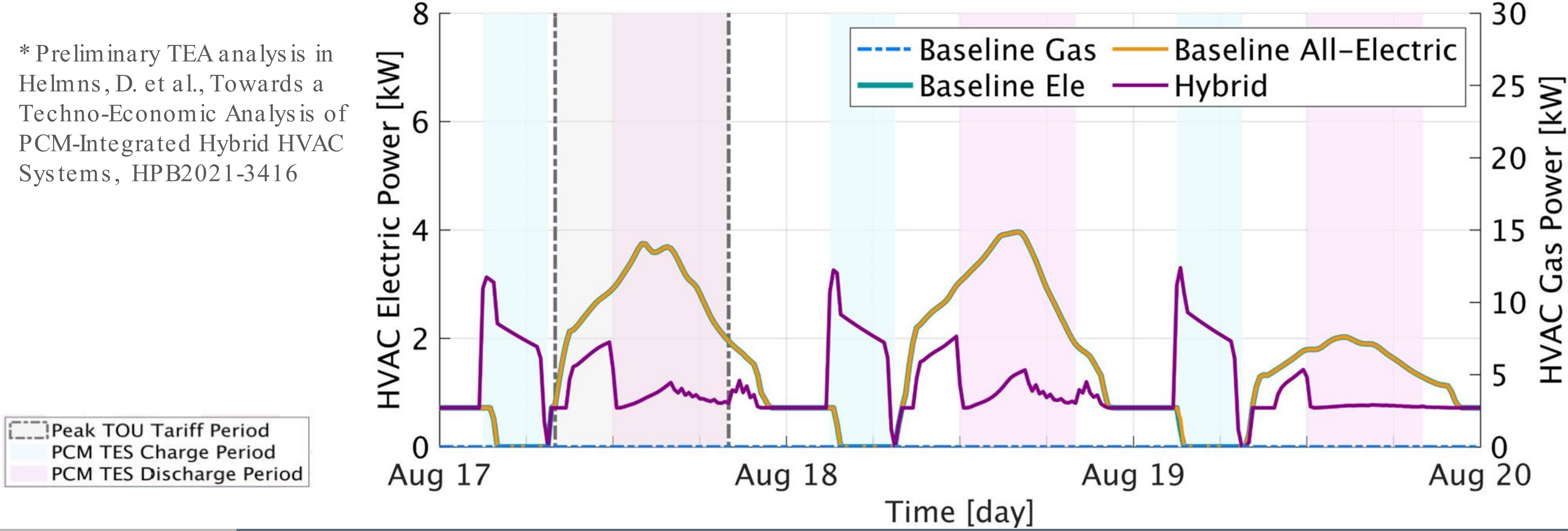
- **Shovel ready** commercial building prototype
- Plan for field **demonstration** as next step
- Installation in cold climate **residence**



Impacts: Simulations demonstrate savings

- Advance grid-interactive efficient systems through **demos** and **tools**
- **Enable electrification** of heating and DHW
- Simulated peak load reductions of: 58%, 44%, 55% for BBR, PSP and MFR respectively
- Simulated 20-50% energy cost* savings 3 simulated applications

* Preliminary TEA analysis in Helmns, D. et al., Towards a Techno-Economic Analysis of PCM-Integrated Hybrid HVAC Systems, HPB2021-3416



Impact: Advanced real -world demonstrations

Current projects continuing development of technologies, follow -on projects

Hybrid HVAC with TES

Shovel ready prototype

Demo in residence

MPC tested in simulation

Rule based hardware control

Hardware in the loop

PCM TES model testing in virtual plant

Cal Flex HUB

Laboratory testing

Hardware control based on dynamic pricing signal based hardware control

HP Flex

Field demonstration of PCM based TES

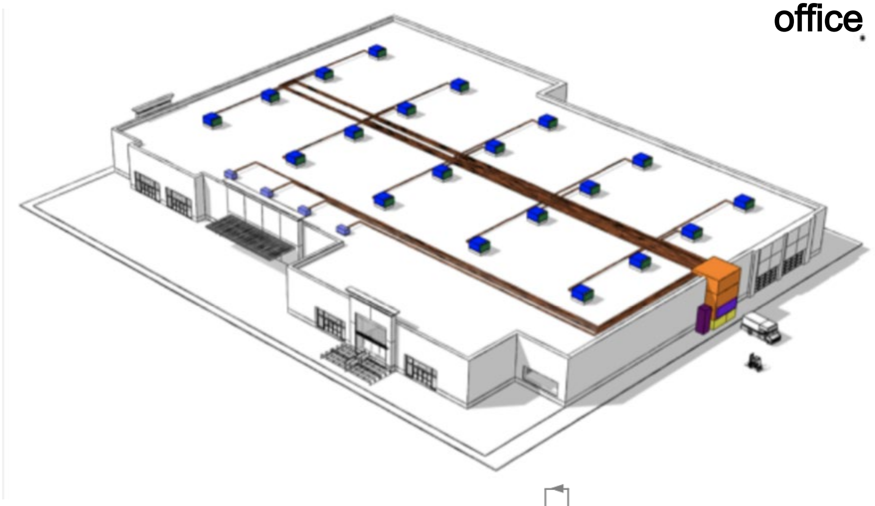
Hardware MPC

New funding proposals

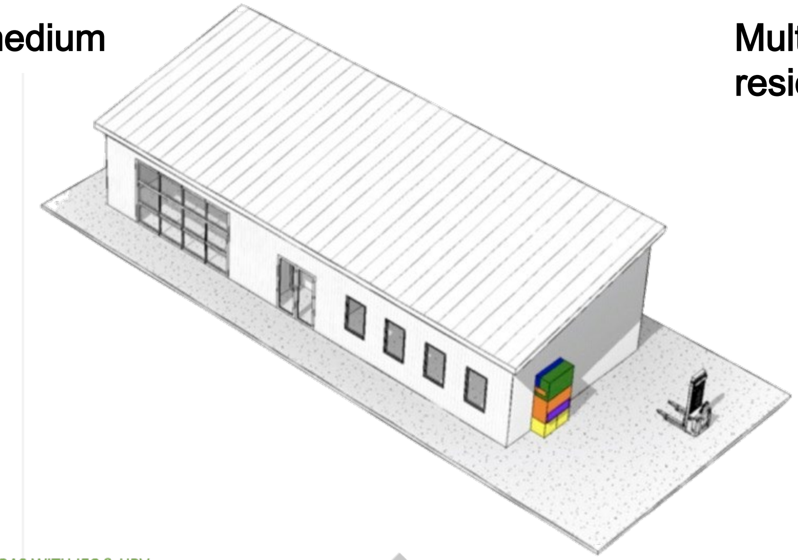
BENEFIT “Thermal Energy Storage Research and Demonstration for Multifamily Hot Water”

Progress: System Designs

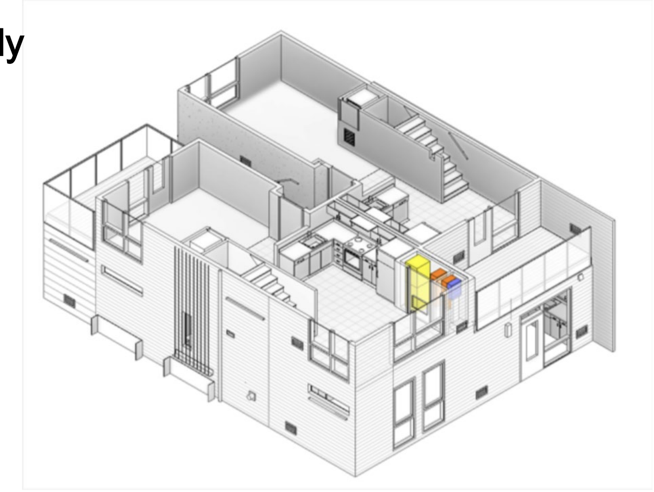
Big box retail

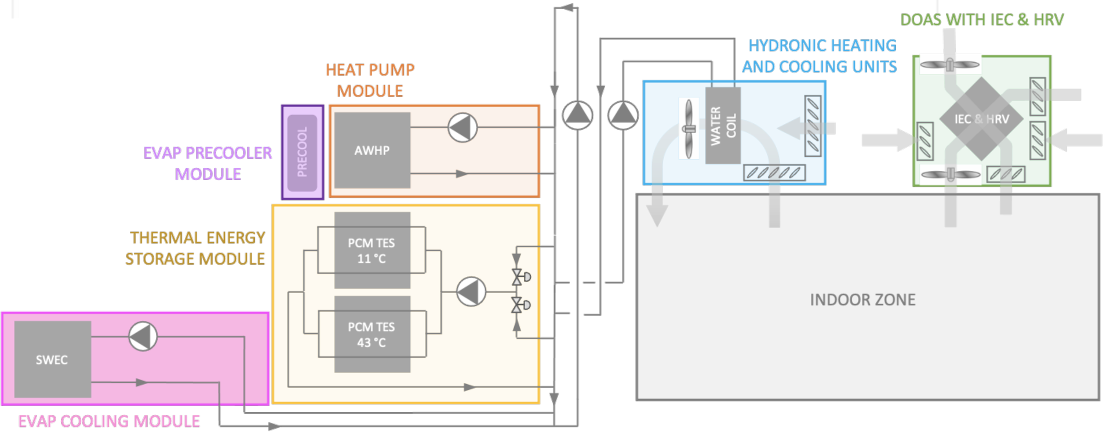


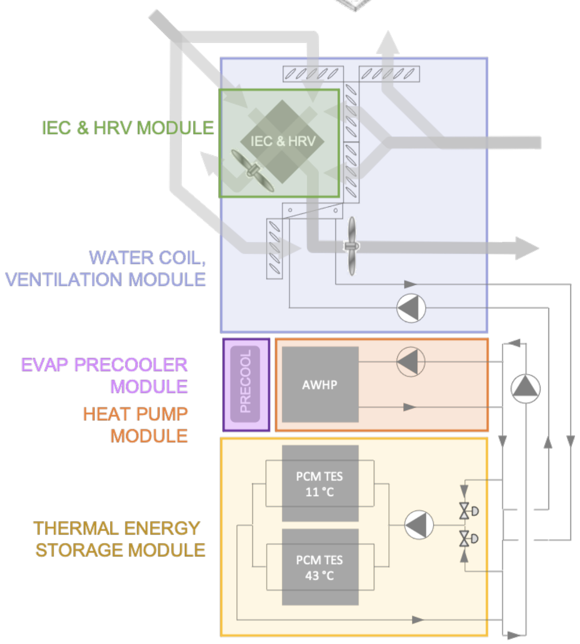
Small/medium office

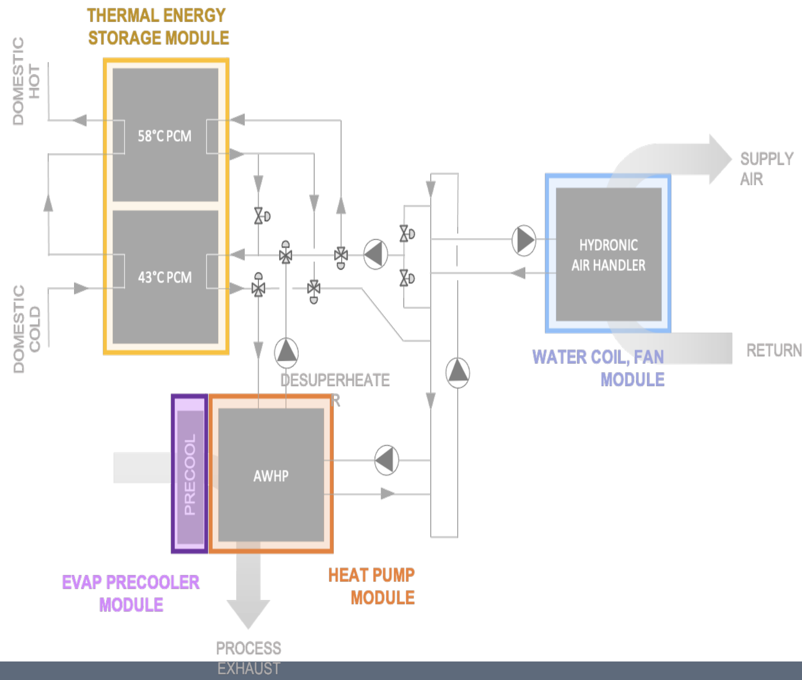


Multi -family residential





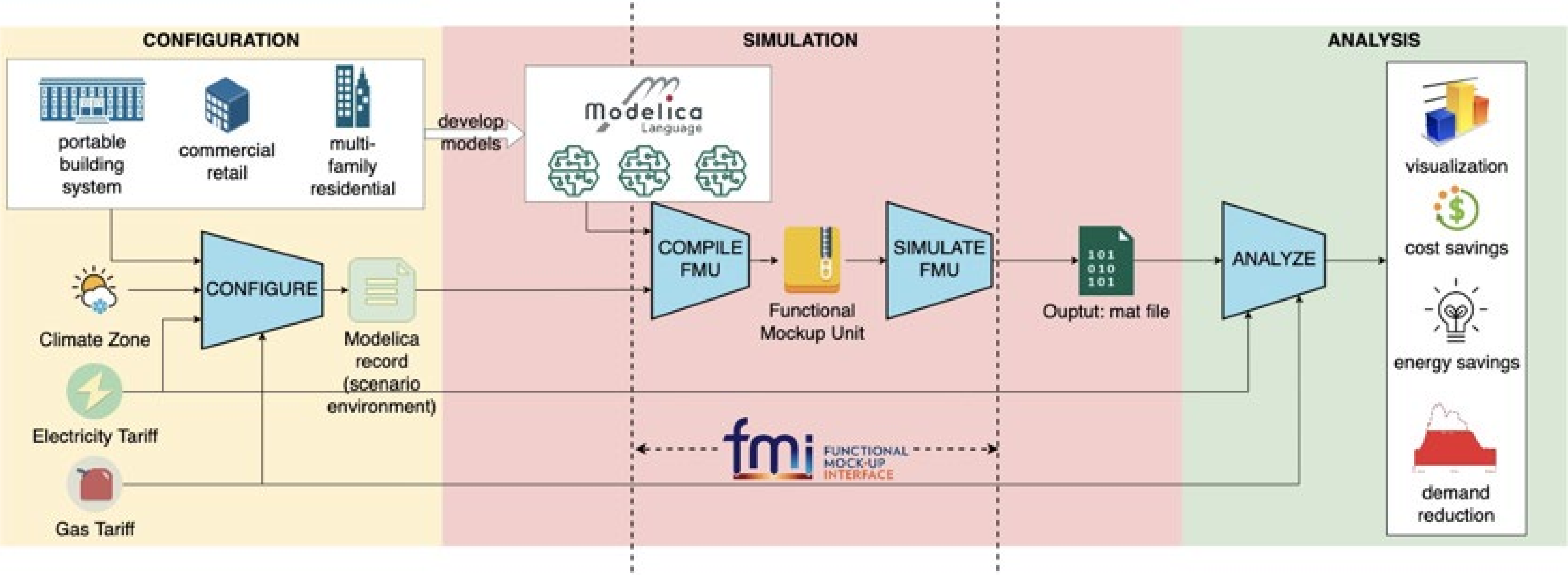




(Add citation for published paper)

Progress: Parametric Simulation Tool

Parametric simulation framework developed to **easily configure different scenarios**
Uses time series data to **analyze demand reduction and operating cost savings**



System model contains **subsystems**, **devices**, and **unit cells** in physics-based objects
Spawn of EnergyPlus ready

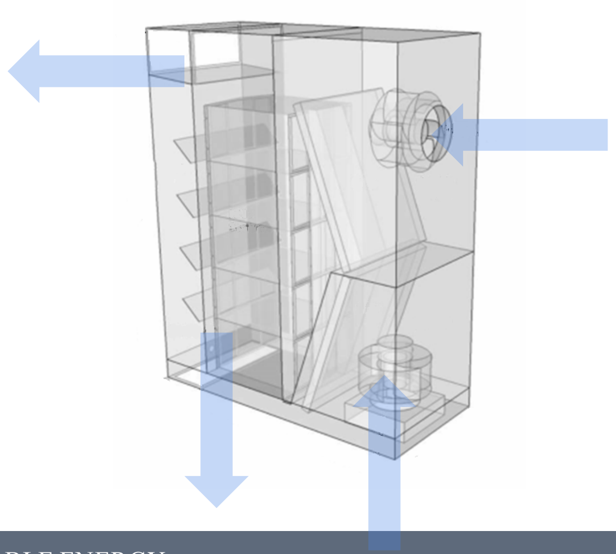
Progress: Laboratory and field testing

Evaluating three core component technologies

- Thermal batteries that use phase change materials
  58°C (136°F), 48°C (118°F), 43°C (109°F), 11°C (52°F) ✓
- Heat recovery ventilator with indirect evaporative cooling ongoing
- High temperature air-to-water heat pump ongoing

Sunamp

SEELEY INTERNATIONAL



LG

Engagement of market actors

Manufacturers

- AERMEC
- Carrier
- LG
- Sunamp
- nyle systems
- neothermal energy storage

Deployment

- OAKLAND UNIFIED SCHOOL DISTRICT — Community Schools, Thriving Students
- ROCKY MOUNTAIN INSTITUTE
- ASSOCIATION FOR ENERGY AFFORDABILITY INC.
- REDWOOD ENERGY

Integrated Design

- harvest thermal
- Otherlab
- SMITHGROUP
- EMANANT

Codes & standards

- STATE OF CALIFORNIA ENERGY COMMISSION
- ASHRAE®

Technology Transfer

- **Tag meetings with industry partners + joint DOE iCorps**
- **Two ASHRAE seminars**
  - *"Phase Change Materials and Batteries for Energy Storage in Small HVAC Systems– Design Considerations and Life Cycle Cost Comparisons"*
  - "Integrated HVAC Systems for Small and Medium Commercial Buildings"
- **Peer -reviewed papers**
  - Development and Validation of a Latent Thermal Storage Model Using Modelica , 2020
  - Towards a Techno-Economic Analysis of PCM-Integrated Hybrid HVAC Systems, 2021
- **Papers under development**
  - Development and lab validation of a numerical model for PCM thermal energy storage.
  - Model development and lab validation of M -cycle type indirect evaporative cooler with heat recovery.
  - Techno-Economic Analysis of PCM-Integrated Hybrid HVAC Systems Using Modelica.

Monitored field evaluation of integrated system

Project details

- Residential installation (Massachusetts)
- Cold climate evaluation (–5°F heating design)

System and functions

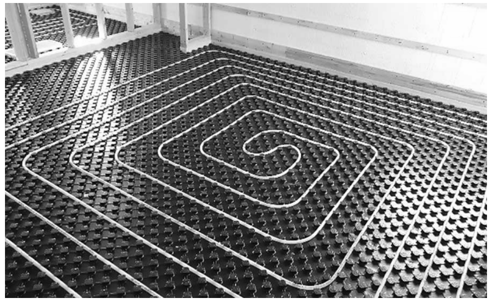
- Air to water heat pump (R32)
- PCM thermal energy storage
- Heating, cooling, and DHW
- Fan coil units and radiant floors

Objectives

- Characterize HP
- Measure integrated system efficiency and demand reduction
- Validate simulation models
- Evaluate real world system behaviors
    - Intermittent performance at extremes
    - Defrost cycle

KEY HIGHLIGHTS

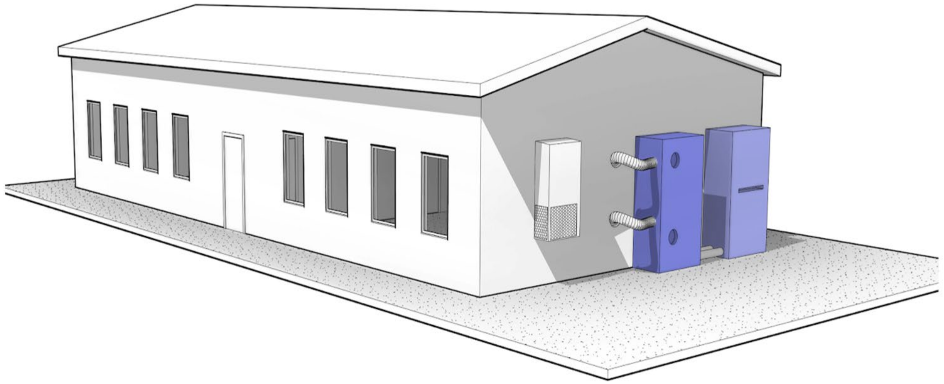
- *All-electric heating and DHW in a cold climate without electric resistance*
- *Reduced heat pump size*
- *Reduced footprint for storage*
- *Monitoring real world performance*

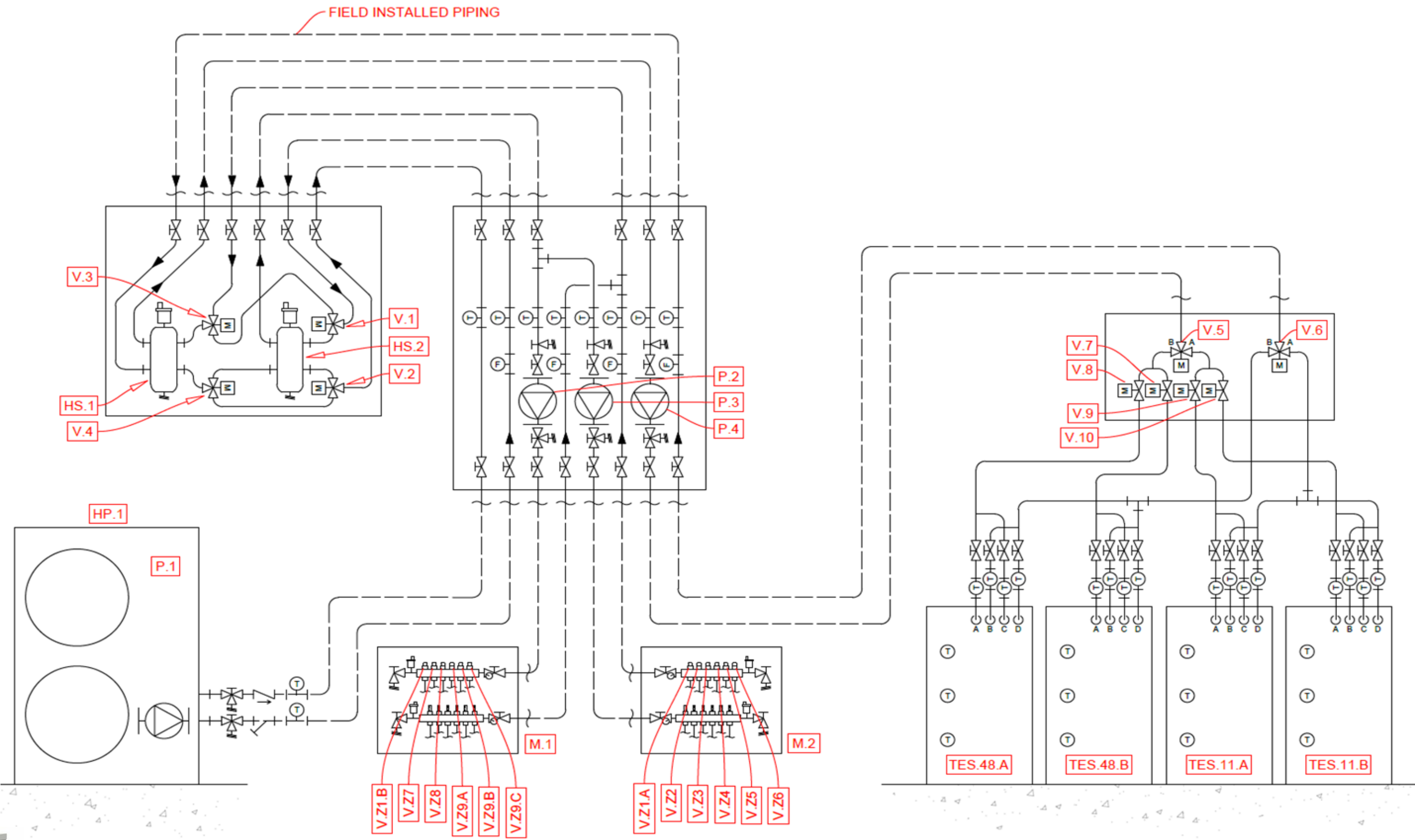


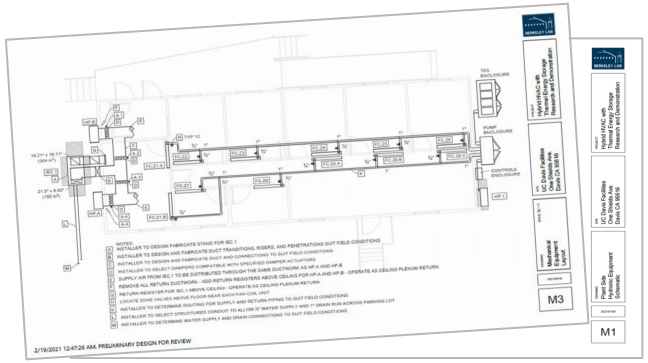
Next Steps : Field Installation & Demonstration

Objectives:

- Prove integrated system functions
- Demonstrate strategic controls
- Measure energy performance and savings
- Validate models and simulation tools







Thank You

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Project Budget

Project Budget : Original budget $3504k, Total now expected $3005k
Variances : Scope adjusted in Y3 to postpone field installation to follow on funding.

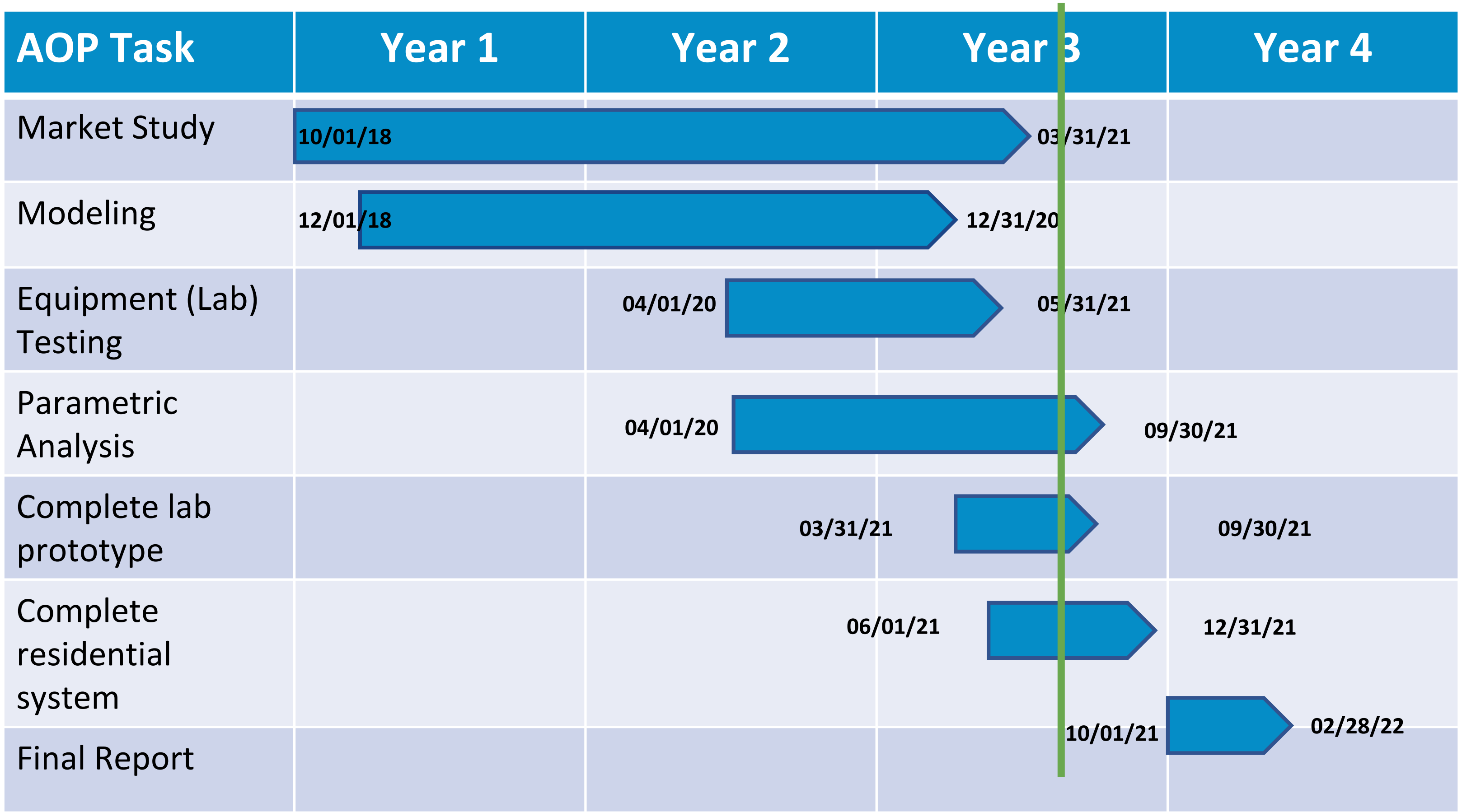
Cost to Date : Full funding received
Additional Funding : Proposals for follow on funding in process.

FY18-FY19 (past)		FY 19 - FY20 (past)		FY20 - FY21 + 6 months (current +extension)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$900k	$0k	$1250k	$45k	$900k	$45k

Project timeline

Major corrections to original plan

- Continue simulation modeling of all three building applications.
- Build proto-type system in house to retain knowledge and enable rapid changes
- Perform parallel development of simulation models and hardware prototype
- Perform LG heat-pump characterization in a home (reduce cost and facilitate follow-on projects)



Milestones

3/29/2019->12/31/2019	M1.1 -> M1.5: Simulation tool development milestones resulting in simulated performance for one system with at least 30% annual HVAC energy cost savings and 20% peak load reduction.	Completed on schedule (all)
3/30/2020	M2: Webinar presenting system performance results, and economic analysis.	Completed on schedule
6/30/2020	M3: System designs achieve 30% annual HVAC energy cost savings and 20% peak load reduction. M4: Completed detailed TES characterization testing plan. M5: Complete initial techno economic analysis.	Completed on schedule
9/30/2020	M6: Begin TES characterization experiment in FlexLab	Completed on schedule
12/31/2020	M7: Complete development test plan for chamber testing of the IEC-HRV	Completed on schedule
3/30/2021	M8: Complete SWEC testing	Completed on schedule
5/30/2021	M9: Competed hardware component characterization of TES	Completed on schedule
9/30/2021	M10: Complete parametric simulations M11: Competed hardware component characterization of IEC-HRV	ongoing
12/31/2021	M12: Complete “shovel ready” prototype suitable for commercial building	ongoing
12/31/2021	M13: Complete installation and begin data collection for residential system	ongoing
2/31/2022	M14: Final report draft	ongoing