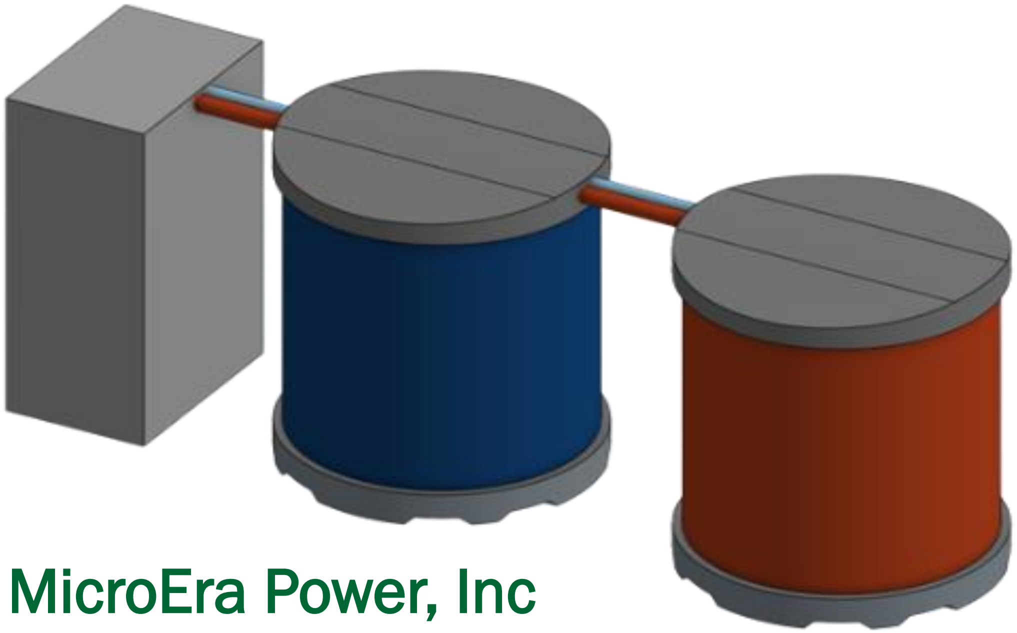
THERMAplus

TES Optimized for Integration with Chillers & Heat Pumps



MicroEra Power, Inc
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SBIR Phase I, Award Number DE-SC0022856
DOE Manager: Sven Mumme

Project Summary

Objectives and outcomes

1. Show ability to tune the melting point of active material at 5 target formulations with lab scale and engineering scale samples, and modeling
2. Model and test process to cycle between formulations (responding to weather, occupancy, grid parameters, renewables, etc.)
3. Develop design tools &requirements for heat exchanger sizing and materials, tank geometry, heat pump integration, and potential pilots

Team and Partners

MicroEra Power, Inc, Rochester, NY

James Grieve, PI

Smith College, Northampton, MA

Prof. Denise McKahn, Controls/Dynamic Systems

Stats

Performance Period: **6/27/2022 – 6/26/2023***

DOE budget: **$200K** Cost Share: **N/A**

Milestone 1: **Validation of tunable PCM formulations**

Milestone 2: **Analysis/Design of TES modules**

Milestone 3: **Physics-based models for controls**

Milestone 4: **Planning for potential pilots**

* with no cost extension

Problem: Cost-Effective Storage

1. Thermal Energy Storage (TES) is an important technology for decarbonizing buildings and transitioning to renewables. Without TES, heating costs for heat pumps tend to be higher than using natural gas
2. Current products are not tunable, so lack flexibility to store heat or cooling at different temperatures as weather and HVAC loads vary
3. Current systems which store both cooling and heat have a very large footprint and are hard to site in urban applications

Market Opportunity:

- Building HVAC is a $600B/year global business
- USA market POTENTIAL for TES for buildings is in the range of 1200 – 4500 GWh [1]
- At $40/kWh, 2000 GWh = USA market opportunity of $4B/year (2030 to 2050)
- Early market of $170M/year in 2026: areas with high electric rates and HVAC loads

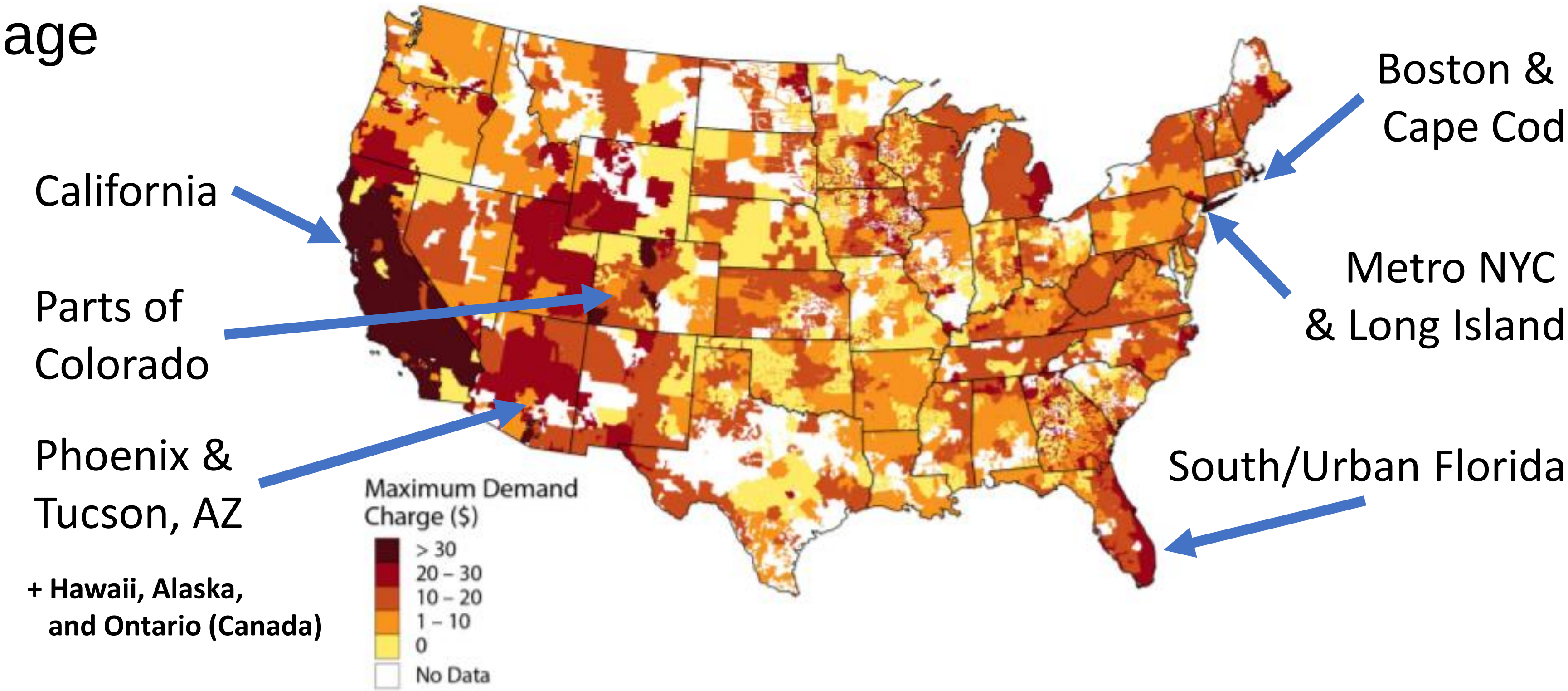
[1] Odukomaiya, Mumme et al, Addressing Energy Storage Needs at Lower Cost via On-site Thermal Energy Storage in Buildings, RSC 9/2021

THERMAplus – Early Markets

<u>Criteria for TES:</u>

1. **High Demand Charges**
2. High Renewable Usage
3. High HVAC loads
4. Demand Growth
5. Receptive Utilities
6. Mandates & Incentives

Areas with high Demand Charges - source: NREL[2]



Economic Driver = Peaky Air Conditioning
Environmental Driver = Decarbonization of Heat

[2] see link

Alignment and Impact

THERMAplus has 3X the capacity as current products in the same footprint, for stored heat and cooling

Baseline:

- Buildings consume about 40% of primary energy and about half of this is for Thermal Loads
- Air Conditioning is currently carbon-intensive, driving the use of peaker plants using natural gas or oil.
- Heating is currently even more carbon-intensive, dominated by the use of natural gas, oil or propane

THERMAplus enables:

(1) Shifting thermal loads from peak to off-peak/renewable-intensive saving up to 50% on air conditioning and reaching cost-parity with natural gas heating now in many markets.

(2) Boosting heat pump efficiency by about 20%, by operating in most efficient load and ambient conditions (e.g. freezing our PCMs slowly at night, when cooler ambient boosts COP)

(3) Downsizing of HP equipment by 30 - 50%, sized closer to the average load, rather than peak load

(4) Downsizing of geothermal ground loop by up to 80%, in a hybrid system with TES sized for the daily storage (4-14 hours), ground loop sized for 7-10 days of storage, and a small air source capacity

Load Shifting: Long Island Building with HPs

THERMAplus shifts HVAC loads off-peak

- 150,000 ft^2 building
- Electrified w/ heat pumps
- HVAC is the largest and peakiest electrical load

Electric Bill	Baseline	+ THERMAplus	Savings
Annual Total Electric Cost	$200K	$129K	$71K (35% saved)

THERMAplus shifts energy usage to Off Peak

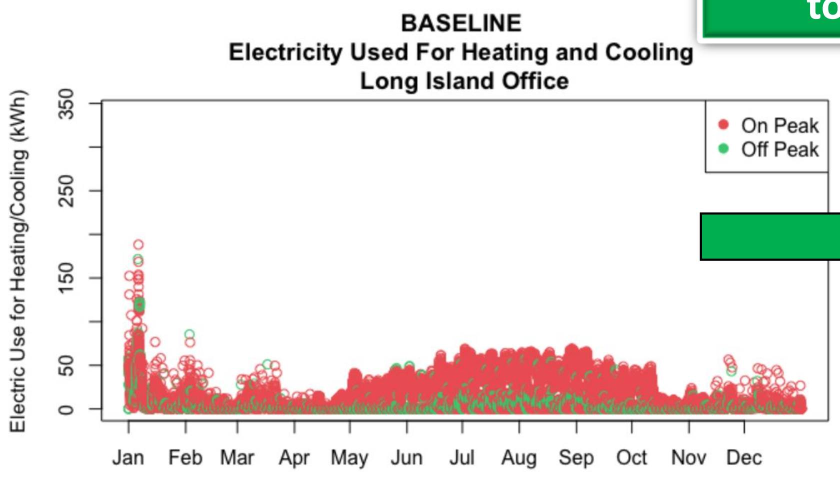


Fig. 1: Baseline, electricity used for heating and cooling before THERMAplus

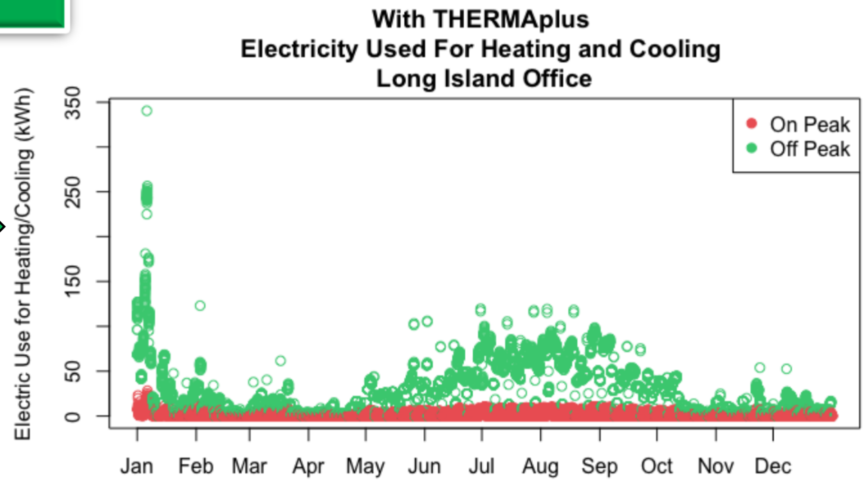


Fig. 2: Electricity used for heating and cooling with THERMAplus

Approach: Ph1 SBIR focused on Hardware + Material

Hardware

- Modular Tanks
- Novel Heat Exchanger

Material

Tunable PCMs

- Low-Cost
- Energy Dense
- Fire Safe

Integration

Heat pumps:

- Air Source
- Geothermal
- Hybrid

Fuel Cells

Software

Smart controls

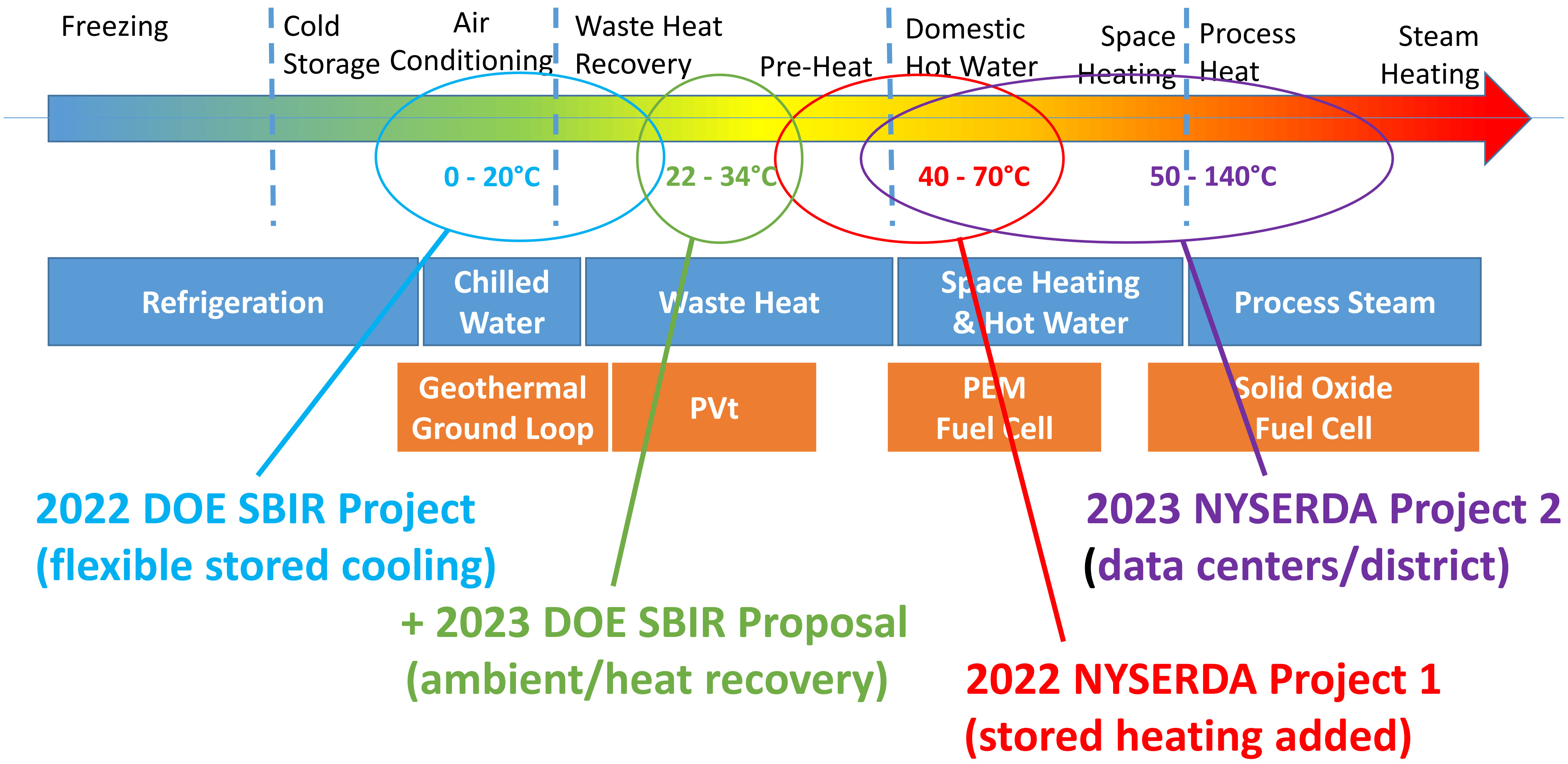
- Load shifting
- Predictive
- Adaptive

Service

- Remote Monitoring
- Optimization

Energy-as-a-Service

Tunability Ranges for MicroEra Power PCMs



Note: Tunable Ranges confirmed experimentally & with modeling tool (also used by ZAE Bayern)

Incumbent Technology: Limitations of Ice Storage

(1) Only useful for Cooling Energy

- energy density as a hot water tank is very low

(2) Requires Ice-making Chiller @ -10°C evaporator temp

- much lower COP than @ +2°C (humid) or +12°C (desert)
- breakeven efficiency (at best)
- retrofits are very expensive

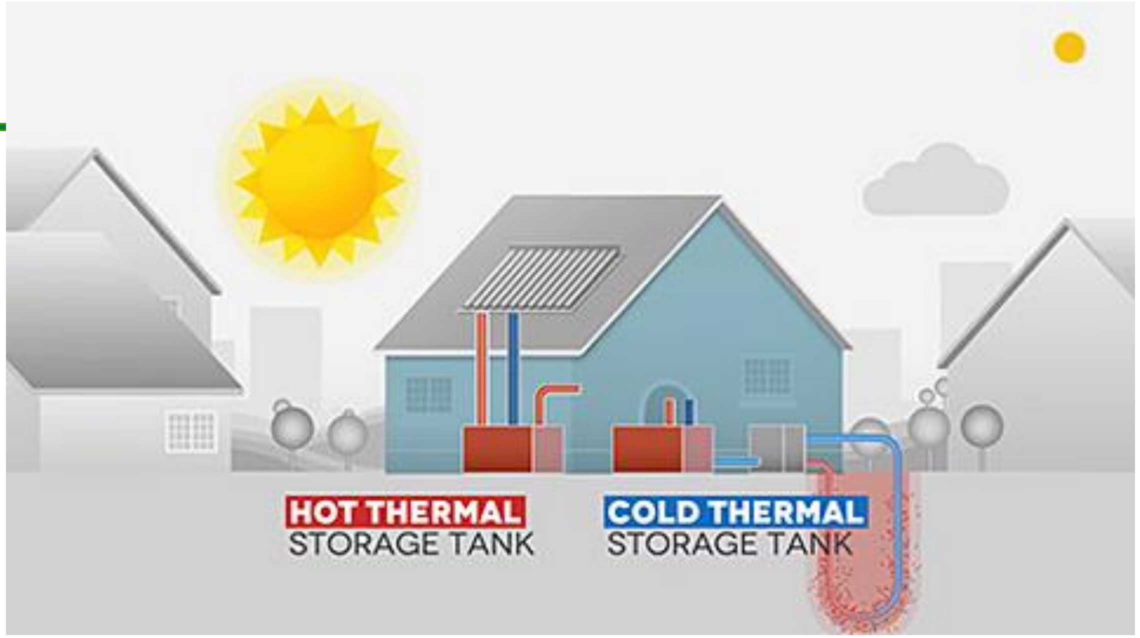
(3) Requires Glycol Antifreeze

- cost, environmental, service impact
- 8% efficiency penalty (heat capacity, viscosity)

Alternative Energy Storage Technologies

	LITHIUM Battery System	THERMA*plus* Smart TES	Fuel Cell
Stores	Electricity	Cooling and Heat 0 - 20°C and 40 - 70°C	Fuel: H_2 or NH_3
Duration	1 - 4 hours	4 – 24 hours (7-10 days paired with geothermal)	1 - 10 weeks
System Cost (installed)	$600/kWh	$3-$5/kWh PCMs $80/kWh early target	$1000/kW?
Round-Trip Efficiency	Fair (~80%) Resistive, Chemical, Electronic losses	Excellent (~120%) lower lift increases COP	Poor (~50%) + Purification, Compressor Losses
Durability	5 – 10 years	20 – 30 years	5 – 10 years
Safety	Challenging	Excellent	Unproven/New
Carbon reduction	Good	Excellent	Excellent

BENCHMARK from Europe



TESSE2B project (Completed in 2019)

- useful integration work and demos, but:
  - (a) separate hot/cold tanks
  - (b) relatively low energy density
  - (c) high cost organic PCMs used, and
  - (d) low seasonal utilization

	TESSE2B supplier	MicroEra Power
Stored Latent Cooling	39 kWh/m3	96 kWh/m3
Stored Latent Heat	52 kWh/m3	170 kWh/m3
Thermochemical Mode	-	477 kWh/m3

MicroEra's low cost tunable materials and system have about 3X the energy density in the same total tank volume, with high seasonal utilization.

Our goal is to develop low-cost, practical systems with high volume market potential

THERMAplus Novel & Promising Features

Proven:

Tunable Materials allow optimal peak load reduction and efficiency improvement as loads, temperature and humidity vary. Market pull from many utilities and EPRI:

0, 6, 13 and 16°C (in SBIR Ph1), 40 - 70°C and 50 - 140°C (in NYSERDA projects)

Promising:

A novel heat transfer approach avoids low performance of current systems due to a thick layer of frozen material on the heat exchanger

In Process:

(1) Predictive/Adaptive algorithms developed to optimize cost savings, CO_2 reduction and grid benefits. Implementation partner in hand, with real-world experience.

(2) Two high-volume sources identified for welded plastic heat exchangers

THERMAplus Barriers, Technical Challenges & Risks

Cheap natural gas, and relative cheap electricity

Conservative HVAC/Real Estate Industries, slow to change

Heat Pumps much more widely deployed in Europe and Asia

Our active materials are stable, low volatility and fire safe, but more corrosive than water, so long term durability of materials must be validated. Robust containment, in a sealed system should mitigate any risk

HP requirements for THERMAplus need a wider operating range. Available in Europe, and coming to the USA, but not commercialized yet

Commercialization – thermal energy storage

- To address the "where has this been done before" issue, we have pilots planned at an Alfred Univ. linked facility (NY) and at Smith College (MA)
- Smith College is implementing a $220M decarbonization plan, with the potential for $50M in capital cost savings by downsizing the ground loop and adding THERMAplus TES. Jamestown, NY BPU has similar motivation.
- Like with Tesla's PowerWall, a sale or lease will be the building owner, but local utility will have influence on how THERMAplus is optimally managed
- EPRI has made introductions to APS, Central Hudson, ConEd, Entergy, NYPA, PG&E, Portland General and Xcel. Strong market pull for tunable TES in all climates, for large building, campus and district applications

Pilot Sites

Rochester, NY R&D Site (hot/chilled water)

Smith College Field House (geothermal HP)

Smith College Campus Geothermal Plan (net zero by 2027)

Progress (1of2)

1. Melting point tunability in targeted stored cooling range (0 – 20°C) confirmed with DSC, 400 ml scale and modeling showing same results

2. A custom rapid cycling apparatus has been designed, built and tested. It currently cycles the 100 ml samples every 3 hours and we are targeting every 1 hour by June, 2023 (with better insulation and layout).

3. Process for fine-tunability (with tunable stored cooling) has been modeled and analyzed, and is on test.

4. Process for wide-tunability (with stored heat in winter and stored cooling in summer) has been modeled and analyzed. Plan to build and test during SBIR Phase2.

Progress (2of2)

5. Developed design tools and requirements for heat exchanger sizing and materials, tank geometry, heat pump integration and potential pilots, led by Professor Bernie Fischer (RIT-Mechanical Engineering)

6. Met 7 of 10 metrics. Expect to meet all 10 by end of SBIR Ph1 (6/2023)

7. Trained 5 interns, and hired a Chemical Engineer with 5 years of research experience with latent heat and thermochemical materials

8. Developed lab controls and data acquisition, including understanding temperature and flow measurement requirements for product

9. CFO Hired, with renewable project financing and real estate experience

Future Work

1. Full Speed Ahead to a Phase2 SBIR project, which will include hardware scale-up for lab testing and first pilots, longer-term material compatibility and PCM performance testing, planning and implementation of pilots

2. Software development including TES controls and data acquisition, heat pump integration, building integration, and grid aggregation partnered with Smith College, the Schatz Energy Research Center (Arcata, CA) and Gridworks Consulting (Cambridge, MA)

3. Complementary product development focused on higher temperature TES and heat pump integration (supported by NYSERDA)

4. Third Party Validation of tunable PCMs, through a small project with EPRI

Key Learnings

1. Developed robust methods, for storing, handling, mixing and disposing of PCM materials in our lab

2. Commissioned equipment and lab infrastructure to cool and heat small samples and lab prototypes from -20 to + 80°C

3. Developed wiring, circuit board, and microcontroller systems for testing

4. Proved that our active materials are not prone to phase separation, and appear to have essentially unlimited life.

5. Proved the ability to manage supercooling and control crystallization

Thank You

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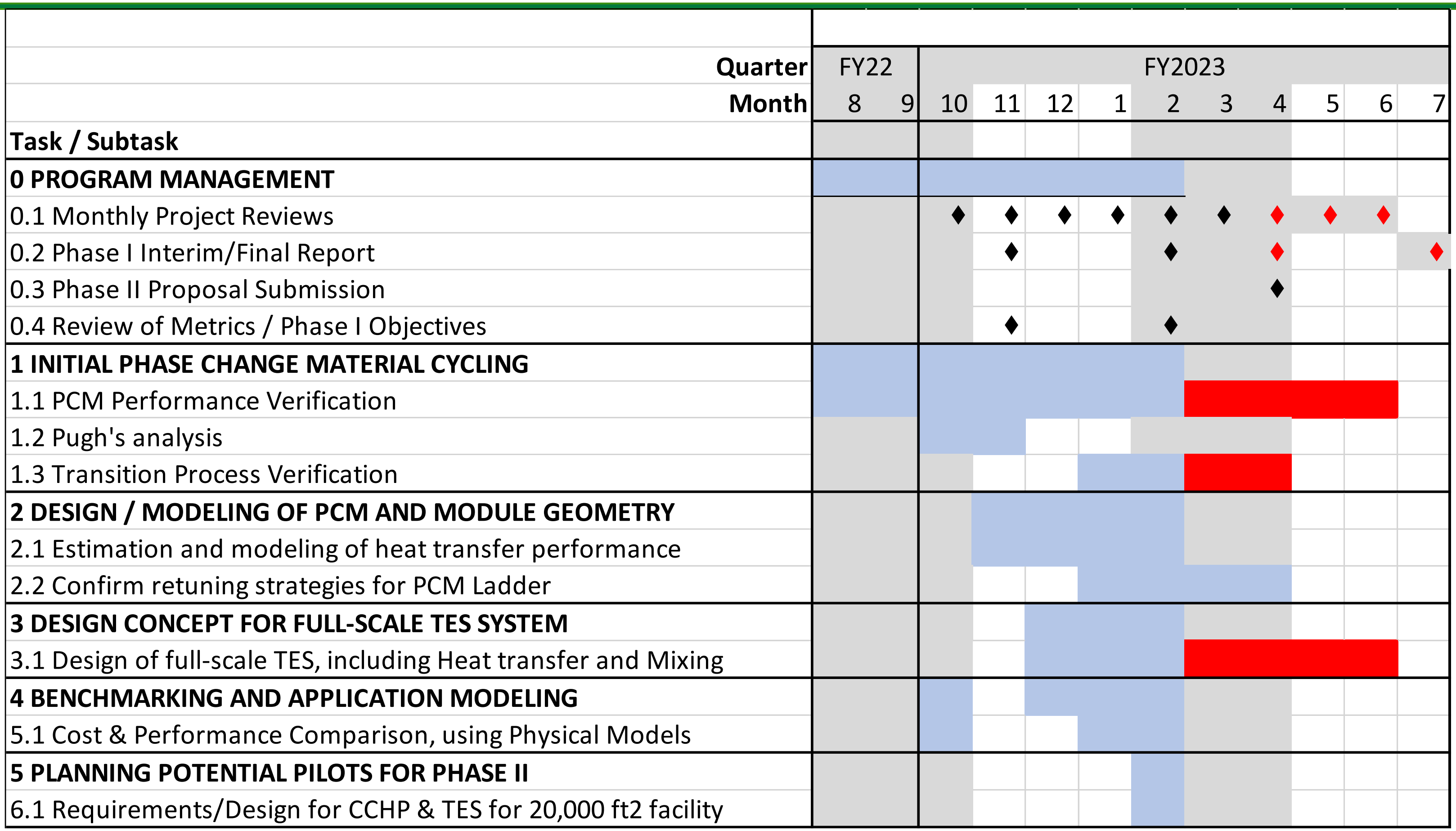
SBIR Phase I, Award Number DE-SC0022856

Topic 54-10c Integrated Thermal Energy Storage in HVAC&R Systems

REFERENCE SLIDES

Project Execution



- Project started 2 months late, due to delay in contract signing, release of funds, and issues setting up the lab
- Stretched timing to 12 months with no-cost extension
- Rapid cycling of PCMs will continue until June, with ongoing upgrades to custom equipment
- Design work is leveraging lessons learned on heat exchanger and temperature measurement from NSYERDA project
- All deliverables will be met by the end of Phase1. About $50K remains to be spent of the original $200K budget

Technical Team

James Grieve, PE - CTO MicroEra Power (PI)
Former Chief Scientist at Delphi Automotive, with >40 patents and extensive experience related to systems engineering for complex powertrain, fuel cell and thermal systems

Molly Over, MSc - Design Engineer MicroEra Power
3 years of experience in TES product design and development

Alexander Dyall, Chem Eng and Environmental Eng (dual major), 5 years research experience

Bernie Fischer, PhD - Research Engineer MicroEra Power, Professor of Mech Eng (RIT).
Industry experience at Delphi, GE and Pratt&Whitney

Denise McKahn, PhD - Systems & Controls, Engineering Prof at Smith College.
PEM FC systems expert from Univ of Michigan and Schatz Energy Research Center

Jessica Millar, PhD - former Math Professor, partner at Gridworks Consulting (New Addition)
Microcontroller and cloud software, and grid aggregation for thermal systems