High-Efficiency Solid-State Heat Pump Module

2016 Building Technologies Office Peer Review

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U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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Project Summary

Timeline:

Start date: September, 2015

Planned end date: August, 2017

Key Milestones

1. Phase 1: Demonstrate >8 °C material-level calorimetric performance that enables an electrocaloric module COP > 6.0
2. Phase 2: Demonstrate TRL3 solid-state heat pump module

Budget:

Total Project $ to Date (through Sept. 2016):

- DOE: $700,692
- Cost Share: $233,564

Total Project $:

- DOE: $1,093,845 ($679,393 Phase I)
- Cost Share: $364,615 ($226,464 Phase I)

Key Partners: (none)

Project Outcome:

United Technologies Research Center shall demonstrate a solid state (refrigerant-free), high efficiency, compact, zero direct global warming heat pump which has the potential to replace refrigerant-based vapor compression systems.

TRL 3 demonstration of solid-state heat pump that has the potential to provide seasonal COP > 6.0 at full commercialization.

Purpose and Objectives

Problem Statement:

- Current regulations (both US and European) and market needs, are driving us to systems with lower global warming footprint and higher efficiency
- Electrocaloric heat pumping is a refrigerant-free technology that has the prospect of being more efficient, compact and quieter than current vapor compression systems

Target Market and Audience: The target market is residential and small commercial buildings. Residential heating/cooling uses >4.5 quads annually, and small-commercial uses >1 quads for a total of ~5.5 quads.

Impact of Project:

- ≥25% system efficiency improvement and ~2000x direct GWP reduction enabled through:
  - TRL 3 heat pump module demonstration
  - Electrocaloric heat pump with COP > 6.0
  - Elimination of working fluids with global warming potential, and reduction of noise and maintenance costs

Approach

Approach:

- Leverage UTRC micro-electrocalorimetry capability to demonstrate material performance over required operating envelope
- Leverage UTRC electrocaloric modeling tools for module design
- Demonstrate module performance on a test bed
- Analyze system level performance using tested materials and UTRC dynamic modeling tools
- Collaborate with Carrier to assess techno-economic impact

Key Issues:

- Scale-up of electrocalorimeter for module scale films
- Module construction and integration

Distinctive Characteristics:

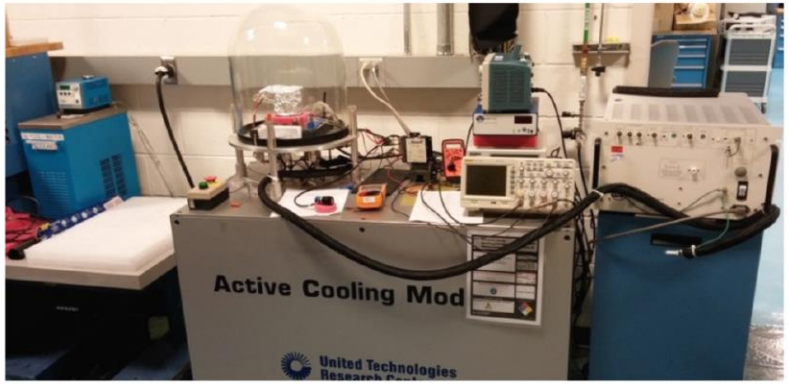
- Novel electrocalorimeter
- Innovative electrocaloric module concept

Progress and Accomplishments

Accomplishments:

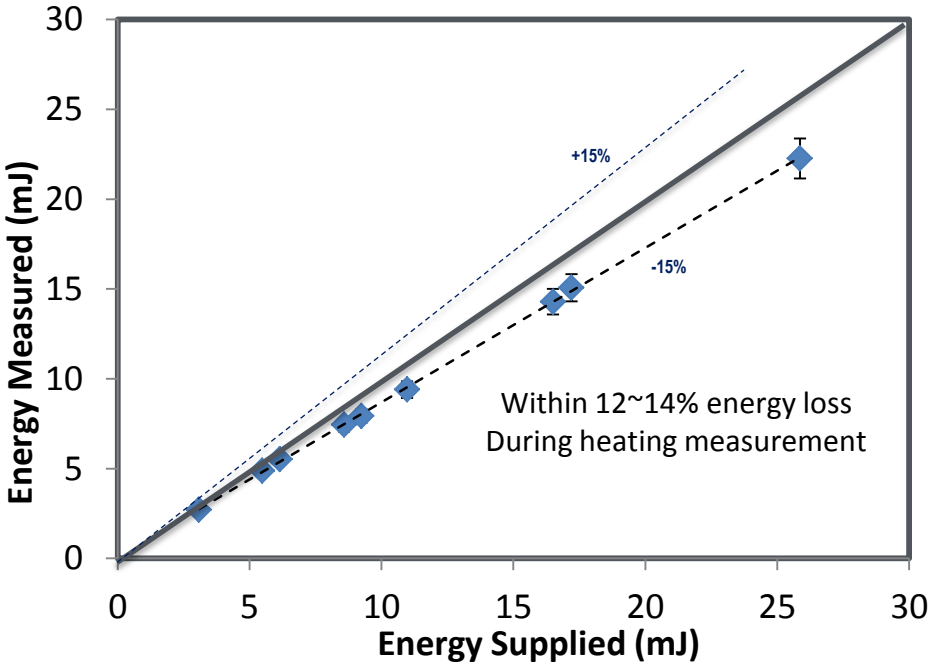
- Project is in early stages of development (start Sept 2015)
- Demonstrated new calorimeter capable of measuring performance over a large temperature envelope 3 - 80 °C and electric fields up to 2000 V

Electrocaloric Calorimeter



Capability of Calorimeter

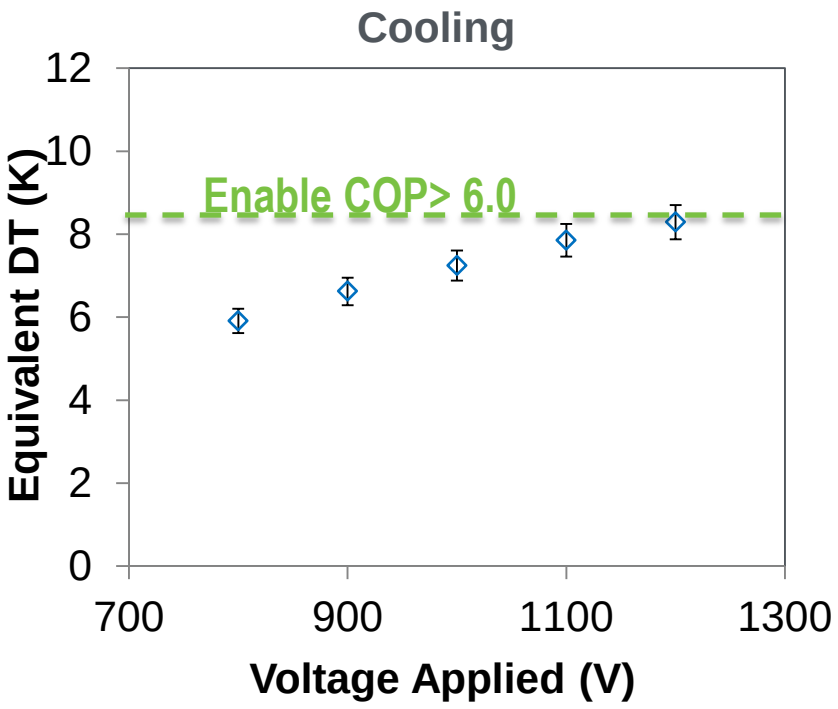
Parameter	Capability
Operating temperature range	3 ~ 80 °C
Operating temperature control	± 0.2 °C
Electric field capability	< 2000 V
Calorimeter least count	> 0.2 mJ

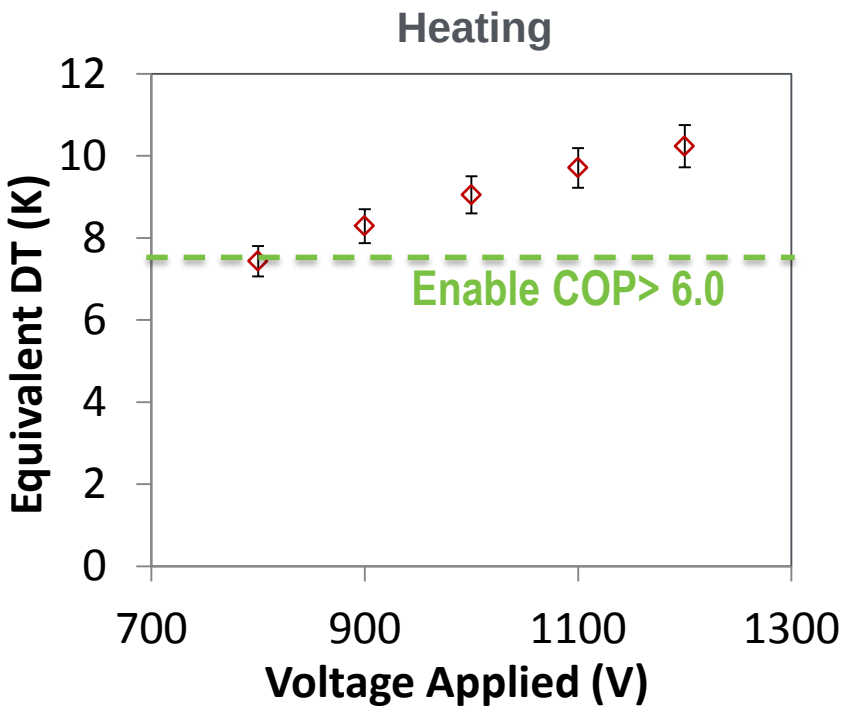


Progress and Accomplishments

Accomplishments:

- Demonstrated > 8 °C temperature lift using micro-electrocalorimetry at room temperature using sub-scale material





Project Integration and Collaboration

Project Integration:

- Carrier is the world's largest manufacturer and distributor of HVAC&R equipment and has a long history of developing successfully commercialized products

- Carrier Corporation commercialized HVAC technologies and concepts developed at UTRC

- UTRC project team is advised by Carrier product and engineering teams to ensure metrics are met during conceptualization and testing phases

Partners, Subcontractors, and Collaborators: None

Communications: Project is in early stages of development

Next Steps and Future Plans

Next Steps and Future Plans:

- Phase I: (Sept. 2015 – Aug. 2016)
  Demonstrate material-level electrocalorimeter performance of module-scale films which can enable COP> 6.0.
  - Demonstrate sub-scale material performance at broader temperature range (~10-40 °C)
  - Demonstrate module-scale (~10x bigger) material performance
  - Design electrocaloric heat pump module
  - Phase I Go/No-go review in July 2016

- Phase II: (Sept. 2016 – Aug. 2017)
  - Prototype 1 and prototype 2 calorimeter testing
  - System performance analysis
  - Techno-economic assessment

REFERENCE SLIDES

Project Budget

Project Budget: $1,458K
Variances: none
Cost to Date: $934,256 (FY15-FY16)
Additional Funding: Cost Share 25% UTRC.

Budget History					
Sept. 4, 2015 – FY 2015 (past)		FY 2016 (current)		FY 2017 – Aug. 31, 2017 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$12,028	$4,009	$688,665	$229,555	$393,153	$131,051

Project Plan and Schedule