2024 PROJECT PEER REVIEW

U.S. DEPARTMENT OF ENERGY
BUILDING TECHNOLOGIES OFFICE

BTO Peer Review: Field Testing & Validation - Thermal Energy Storage in Public and Commercial Buildings in Sumner County, Kansas

Demand Reduction, Flexibility, and Energy Savings

Field Testing & Validation - Thermal Energy Storage in Public and Commercial Buildings in Sumner County, Kansas

Performing Organization(s): Decent Energy, Inc; Sumner County, Kansas; Sumner County Economic Development Commission; City of Wellington, Kansas; Insolcorp, LLC; Armstrong Worldwide Industries; University of Kansas Center for Research, Inc; PlaNet Productions, Inc.; NREL

PI: Barry Dicker, President, Decent Energy, Inc.

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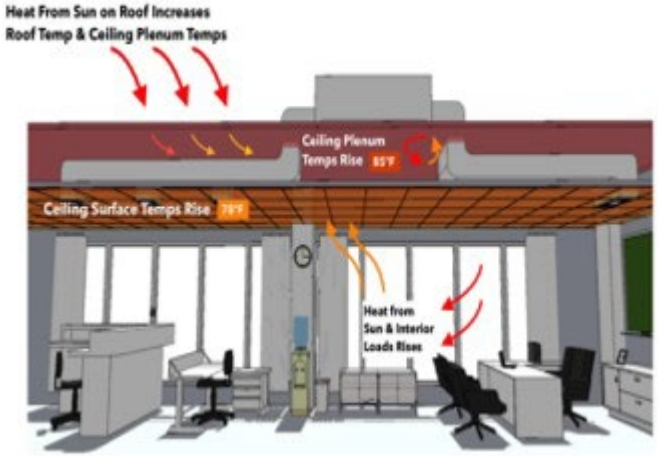
DOE Award DE-EE-0009467

Credit: Ursula Goff / 2024

Project Summary

OBJECTIVE, OUTCOME, & IMPACT

Install PCM tile in commercial buildings for load shifting and flexibility. Identify building operation and upgrades required for optimal performance of PCM tiles. Demonstrate low-cost thermal storage retrofit solutions for commercial buildings in a rural community for inclusive application development



TEAM & PARTNERS

Sumner County, KS (buildings and installers)
City of Wellington, KS (buildings, municipal utility)
Decent Energy, Inc. (PI, M&V)
Armstrong Worldwide Industries (PCM supplier)
as successor to Insolcorp, LLC
University of Kansas Center for Research, Inc. (M&V, modeling)
NREL (M&V, modeling)
Sumner County Economic Development Commission
PlaNet Productions, Inc. (media)

STATS

Performance Period: 6/1/2021 through 11/30/2024

DOE Budget: $999,835, Cost Share: $ 534,764

Budget Period 1: $634,569

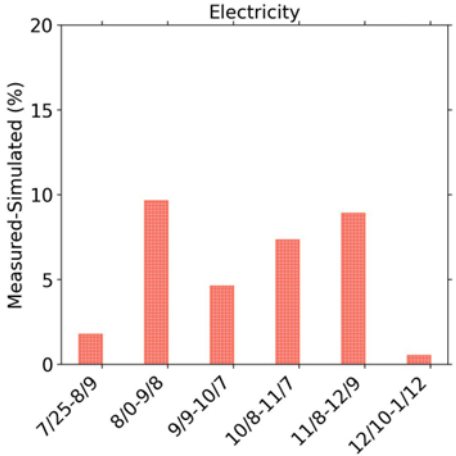
Budget Period 2: $427,371

Budget Period 3: $482,659

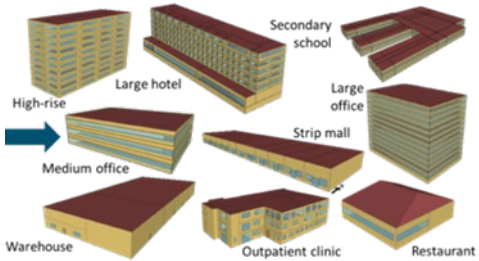
Problem

How to decarbonize buildings + enable high penetration renewables in a rural community?

- The performance, benefits, costs and process of retrofiting PCM thermal storage is not widely understood, thus limiting market adoption.
- It is also known that passive thermal storage performance is dependent on building characteristics, which makes it challenging to demonstrate broadly applicable results. Here the solution was demonstrated on multiple buildings.
- Retrofits are typically difficult – developing products specifically to address this is critical.



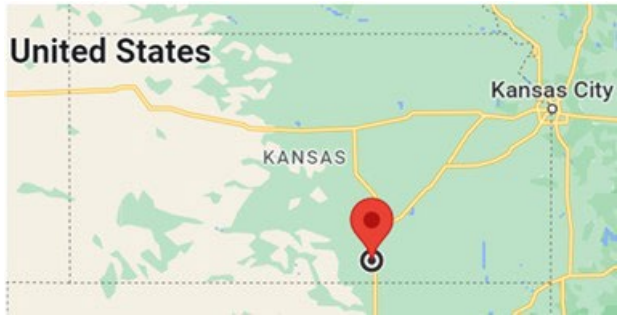
Credit: Habib Mazidi, 2022

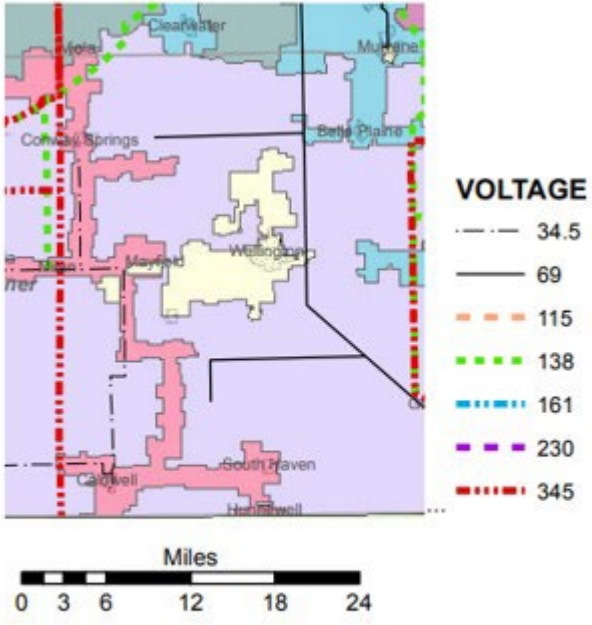


https://www.energy.gov/eere/buildings/articles/building-energy-modeling-101-stock-level-analysis-use-case

Alignment and Impact

- Grid Edge + Life Cycle Emissions
  - Thermal storage enables load shifting and renewable penetration
  - High wind and solar availability – demonstrate how to incorporate these into a rural community – need storage
  - Municipal Utility is eager to take advantage
- Affordability
  - Quantifying optimal PCM performance and cost/benefit
  - Demonstrate retrofit thermal storage solutions for low-income community





White = City of Wellington Municipal Utility
Grey = Sumner Cowley Electric Cooperative
Pink = Wheatland Electric Cooperative

SBA HUBZone

Alignment and Impact – Cont.

- Resilience
  - Storage reduces peak grid stress – especially important in rural communities with fewer services
- Equity
  - Rural community engagement
  - Demonstrate replicable pathway to reduce energy costs for LMI communities

Table 10. Flexibility for Commercial and Residential Buildings

Scope	• Commercial and Residential Buildings	
Major Drivers	• Enhance the overall facility value to the owner, operator, and the end consumer	
Success Criteria	• Storage and flexibility solutions that deliver net benefits including energy expenditures, comfort, and functionality	
Beneficiaries	• Commercial and residential building owners, operators, and occupants	
Potential Requirements	• Footprint in space-constrained installations	
Potential Cost Targets	• TOU charge reduction[50]	[Storage Cost Targets: $2–$266/kw-yr]
	• Demand charge reduction[51]	[Storage Cost Targets: $12–$269/kw-yr]

Energy Storage Grand Challenge Draft Roadmap, p. 52 (July, 2020)

Summer Peak 2x shoulder season peak – Requires much larger grid with low utilization

Previous 12 months data

2022	Peak (kW)	Peak Time	KPP Cap & Demand $
August	25,710	15:00	$395,677
September	24,191	15:00	$372,299
October	15,087	16:00	$232,189
November	13,373	9:00	$205,810
December	16,078	11:00	$247,440
2023			
January	15,013	10:00	$231,050
February	14,003	11:00	$215,506
March	12,851	11:00	$197,777
April	14,910	16:00	$229,465
May	18,663	15:00	$287,224
June	24,006	17:00	$369,452
July	25,428	16:00	$391,337

City of Wellington, Kansas Municipal Electric Utility

Approach - Community Engagement

- Team focused heavily on interactions with community organizations to create trust and demonstrate respect for local needs – including adjusting research scope to accommodate these needs
- Debriefed U.S. Sen. Roger Marshall (R-KS) on the project
- Involved city and county personnel in research whenever possible
- Regular stories with local and regional news organizations
- On-site visits for research and to meet local leaders interested in the project

Top: PI Barry Dicker meets Sen. Roger Marshall (R-KS)

Left: Chuck Booten (NREL) and Ravi Kishore (NREL) engage with Wellington Buildings Manager to discuss the project.

Approach - Buildings

- Seven municipal buildings were retrofitted with PCM ceiling tile
- Assist technology partner with scaling
- Unique challenges for each building
- Focus on one building for model development/calibration
- Developed time-accurate calibrated model to identify pathways for improved performance
- Additional efforts around active controlled tiles
- Local weather
- Leveraged utility metering infrastructure

Approach - PCM

- Three application categories
- PCM integrated ceiling tiles
  - With and Without Batt Insulation
  - Ducted and Plenum Return
- PCM layer in flat roof
- PCM integrated into duct (add on)

(A)

(B)

Credit Barry Dicker, 2022

PCM ceiling tile from above – City Hall

Credit Barry Dicker, 2022

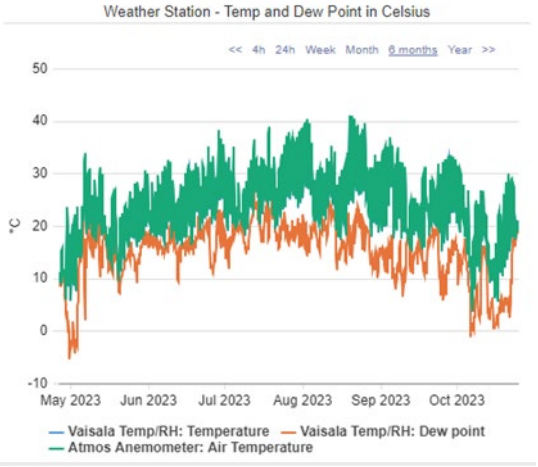
Roof repair and PCM installation – Santa Fe Bldg

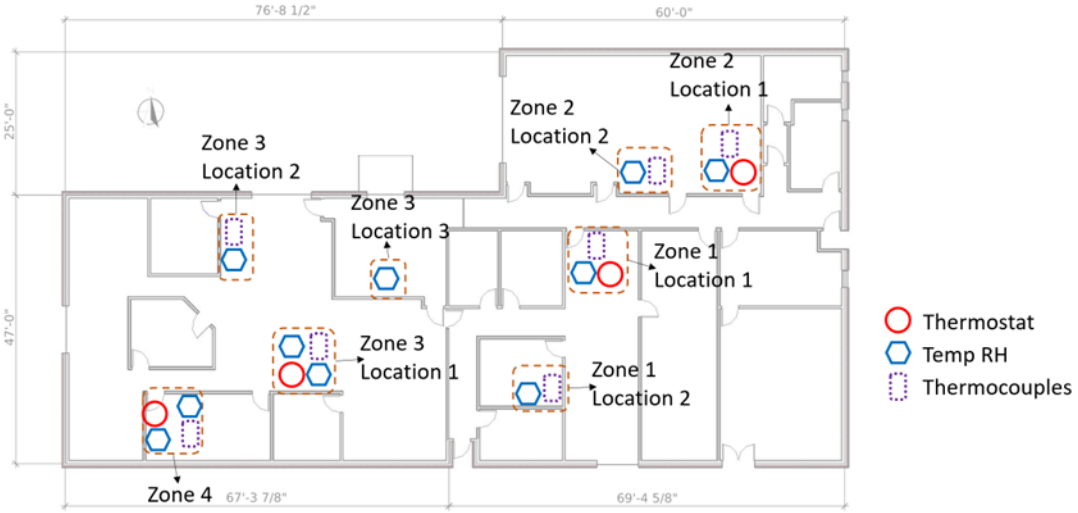
Credit Chuck Booten, 2022

PCM in ducts – Old Road and Bridge Bldg

Approach – City Hall

- Focus on one building for model development/calibration
  - City Hall
- Detailed T/RH measurements
- Energy related characteristics
- Used time-accurate calibrated model to identify pathways for improved performanc

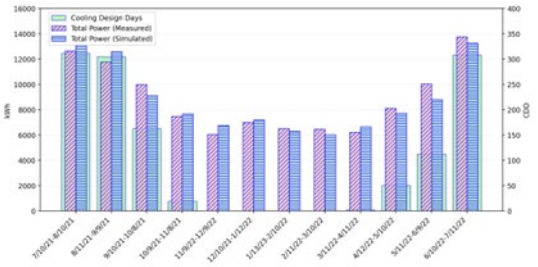




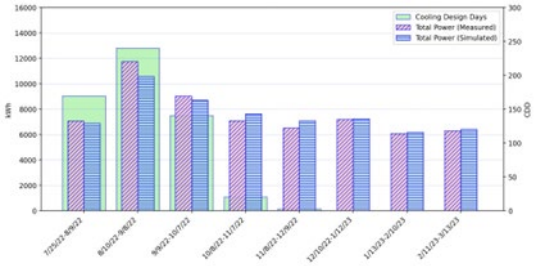
Approach – Model Calibration

- Time-accurate calibrated model to identify pathways for improved performance – time resolution is critical for modeling storage performance
- Calibration process
  - Several unknowns like duct leakage, stratification, leakage from room to plenum, heat transfer coefficients on ceiling tiles, zone infiltration, etc.
  - Summer and winter
  - Hourly and monthly
- Baseline data incomplete
  - Data Acquisition installation delays, some lost data
- Previous utility bills had irregular occupancy data due to Covid and changes in use
- Blower Door, Duct and Balometer Testing, gas demand metering

Pre-Retrofit



Post-Retrofit



Progress – Commercialization & Impact

Publications

Thermal Performance and Energy Consumption Validation of an Occupied Local Government Office Building Outfitted with Ceiling Tile Phase Change Materials, Habib Arjmand Mazidi, Sajith Wijesuriya, Mario M Medina, Chuck Booten, Barry Dicker, Ravi Anant Kishore

Validation and Parametric Assessment of Energy Performance of an Operational Government Building in a Mixed and Humid Climate Retrofitted with Ceiling Phase Change Material Tiles, Sajith Wijesuriya, Habib Arjmand Mazidi, Ravi Anant Kishore, and Chuck Booten

Armstrong World Industries Introduces Innovative Energy Saving Solution

December 18, 2023 at 07:31 am EST

Share

Ultima® Templok® ceiling panels address demand for solutions that reduce energy use and carbon emissions in buildings

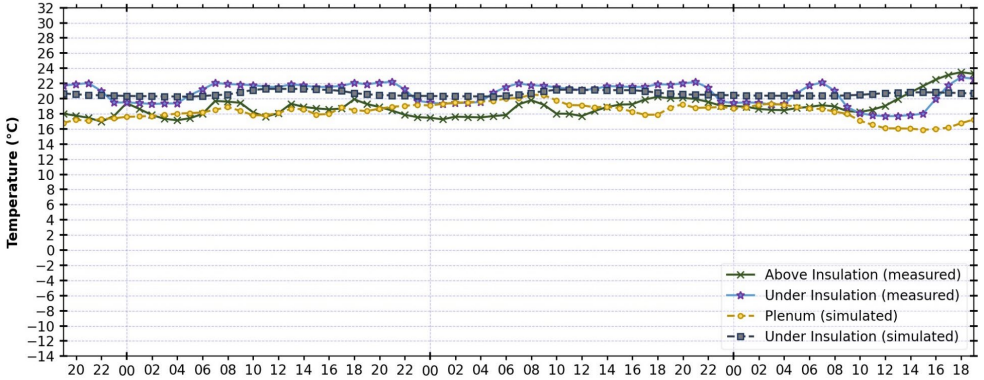
Armstrong World Industries, Inc. (NYSE: AWI), a leader in the design, innovation and manufacture of ceiling and wall solutions, announced today that it has launched a new, innovative ceiling product that can reduce energy usage in commercial buildings. The new Ultima® Templok® solution features AWI mineral fiber ceiling panels with integrated phase change material (PCM) that can reduce building energy costs and consumption while also enhancing thermal comfort.

AWI Selected by GSA and DOE for Green Proving Ground Program

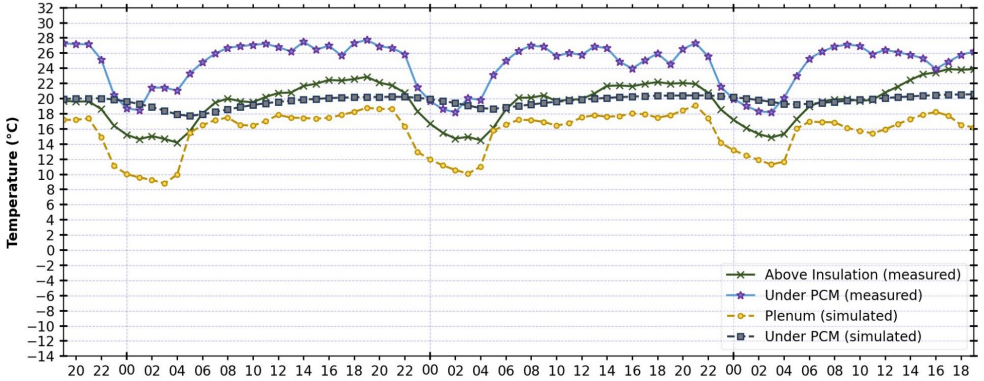
Calibration - City Hall

- Measured and simulated temperatures in and above drop ceiling in City Hall
- Trends captured well both before and after retrofit
- Useful for simulation comparisons
- Predicting absolute temperature/energy requires a more “ideal” building
- Optimal charge/discharge of PCM is difficult with small dT and several degrees of glide in the phase change
- Spatial temperature variation in the ceiling is problematic

Pre-Retrofit



Post-Retrofit

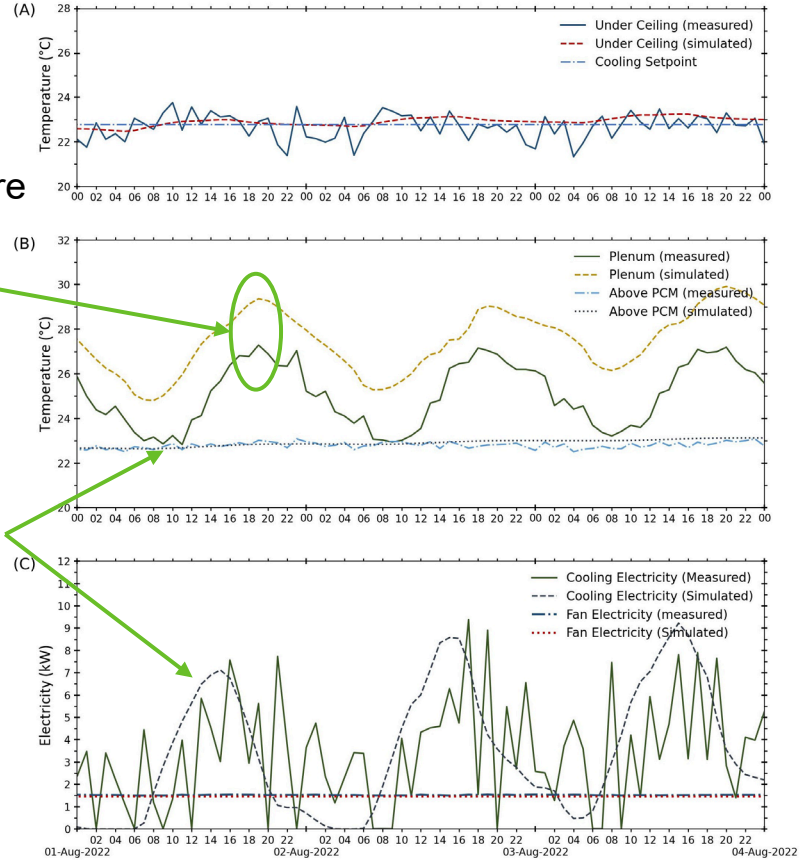


Calibration - Time-Resolved

- Accurate predictions of TES systems require time-resolved calibration
- Much more difficult than annual or even daily calibration
- Requires heavily instrumented building – focus on one building for this project to control cost
- Plenum above ceiling (with HVAC equipment) was problematic
  - Trend modeling good, true temperature modeling hard
  - Due to zone complexity and real-world condition of the building
  - Rely more on accuracy of pre/post PCM modeling comparison

Calibration of absolute temperature of plenum difficult

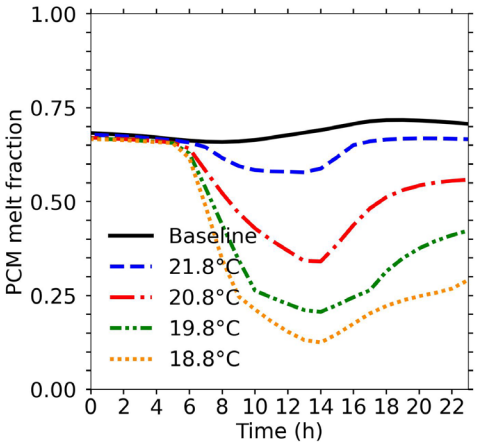
Time-resolution of trends is accurate



Using the Calibrated Model - Parametric Analysis

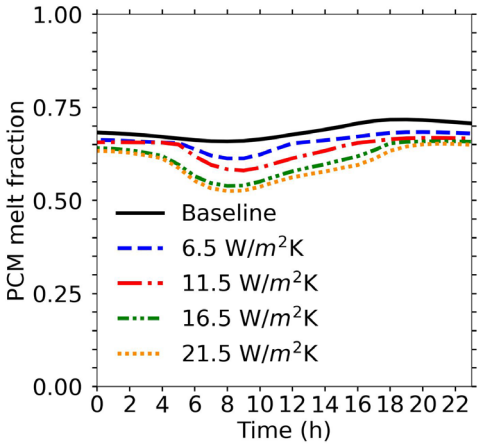
- PCM activation is complex
  - Temperature distributions in the room such as stratification, buoyancy, infiltration, and heat from light troffers impact state of charge (SoC)
- Parameter interactions are non-linear
  - HTC has marginal benefit on its own even with very high airflow
  - Pre-cooling + HTC shows complete discharge with moderate airflow

Pre-cooling



+

HTC



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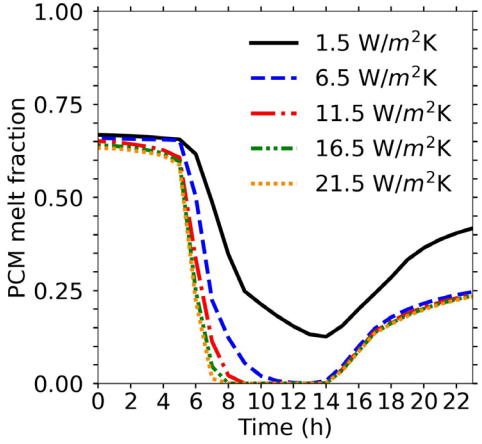
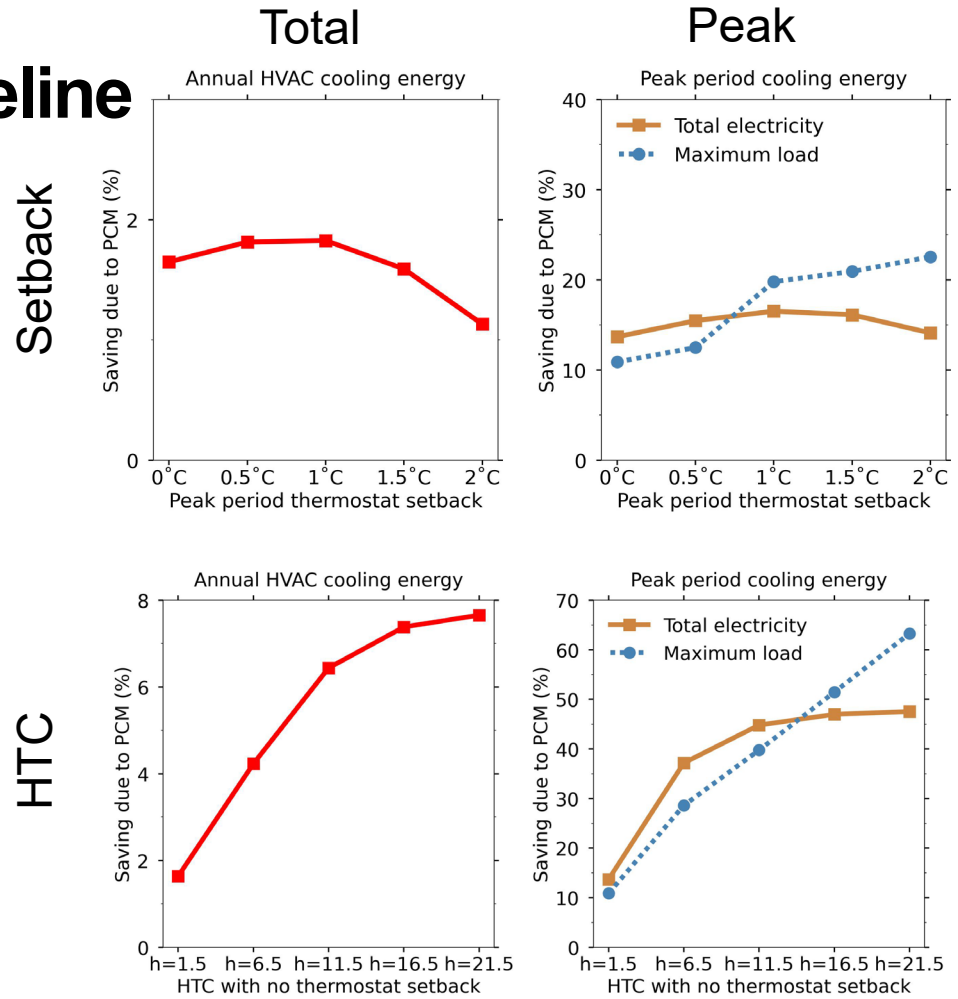
Pre-cooling + HTC



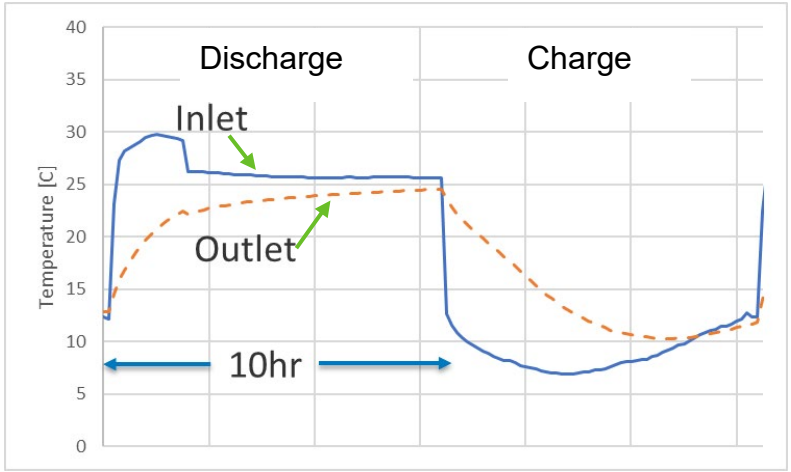
Modeling: PCM vs. Baseline

- Assumes building has been updated
  - Control infiltration
  - Uniform insulation
  - Reduced duct leakage
- Setback control is useful for peak savings – not total savings
- PCM energy benefit is mostly from increased heat transfer coefficient (HTC) – means faster charge/discharge
- Moderate increase in HTC can save total energy and peak power



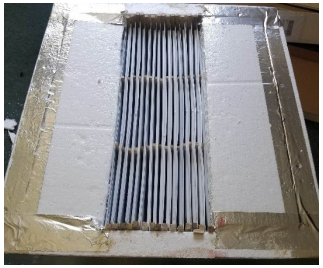
Duct-Integrated PCM

- Proof of concept duct integrated storage
- Retrofit-friendly solution
- Universal form factor – 2x2 ceiling registers
- Same PCM tiles as used in ceiling
- Focus is on active control of charge / discharge
- Shows promise



Replace This

With this PCM HX



Proof of concept

Thank you

Partners:

Decent Energy, Inc;
Sumner County, Kansas;
Sumner County Economic Development Commission
City of Wellington, Kansas;
Insolcorp, LLC;
Armstrong Worldwide Industries;
University of Kansas Center for Research, Inc.;
PlaNet Productions, Inc.;
NREL

PI: Barry Dicker, President, Decent Energy, Inc.
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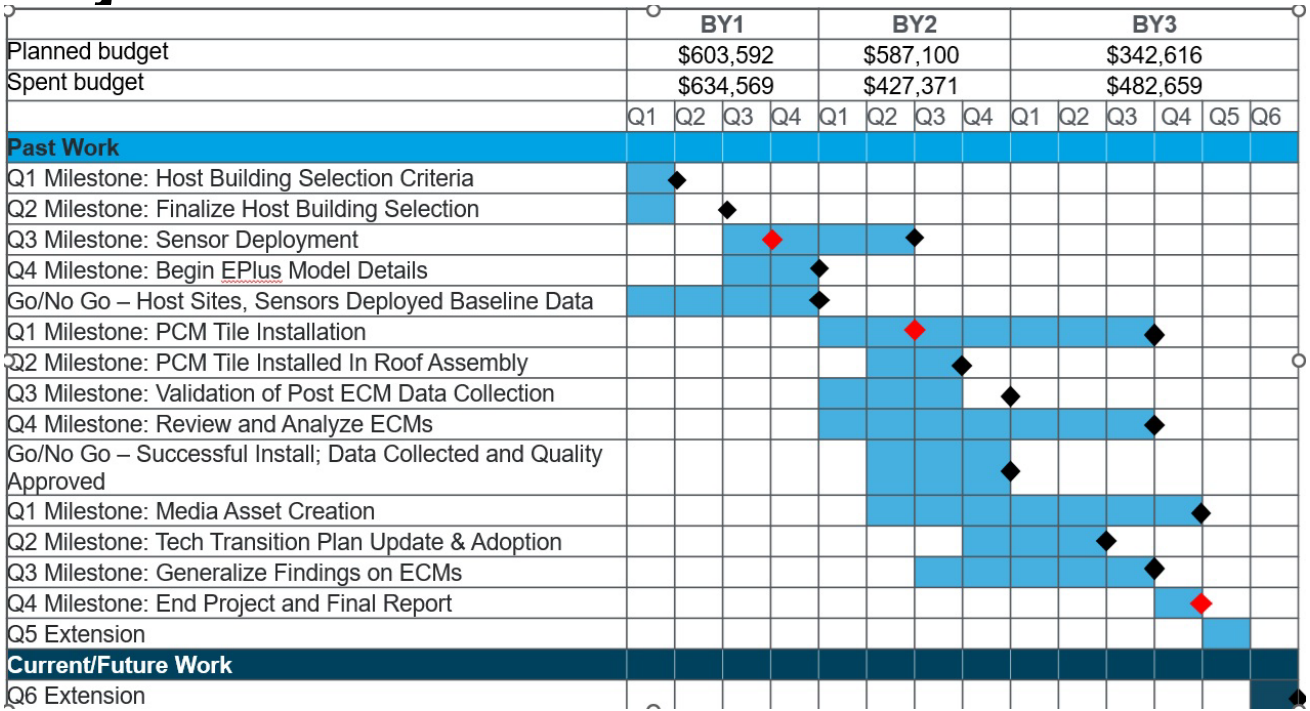
Reference Slides

Project Execution



	BY1				BY2				BY3					
Planned budget	$603,592				$587,100				$342,616					
Spent budget	$634,569				$427,371				$482,659					
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q5	Q6
Past Work														
Q1 Milestone: Host Building Selection Criteria														
Q2 Milestone: Finalize Host Building Selection														
Q3 Milestone: Sensor Deployment														
Q4 Milestone: Begin EPlus Model Details														
Go/No Go – Host Sites, Sensors Deployed Baseline Data														
Q1 Milestone: PCM Tile Installation														
Q2 Milestone: PCM Tile Installed In Roof Assembly														
Q3 Milestone: Validation of Post ECM Data Collection														
Q4 Milestone: Review and Analyze ECMs														
Go/No Go – Successful Install; Data Collected and Quality Approved														
Q1 Milestone: Media Asset Creation														
Q2 Milestone: Tech Transition Plan Update & Adoption														
Q3 Milestone: Generalize Findings on ECMs														
Q4 Milestone: End Project and Final Report														
Q5 Extension														
Current/Future Work														
Q6 Extension														

Q3 BY1 - Additional Sensors and Collection Nodes Added to Enhance Data Quality

Q1 BY2 – Installation extended to accommodate true replacement tile/AWI involvement

End Project- Extension of data collection to accommodate AWI involvement and complexity

Team

Sumner County Kansas

CITY OF WELLINGTON

Sumner County Economic Development

Barry Dicker
President, Decent Energy, Inc.

Mick Dunn
Technical Sales Manager, Armstrong Ceilings

Dr. Chuck Booten
Senior Engineer, NREL

Dr. Habib Mazidi
Assistant Professor, MSOE

Dr. Sajith Wijesuriya
Research Engineer, NREL

Dr. Ravi Kishore
Senior Engineer, NREL

Laura Lombardi
President, PlaNet Productions, Inc.

Dr. Mario Medina
Professor and Director of Architectural Engineering. Texas A&M