DLR Group

Thermal Mass 2.0

Innovative Phase Change Materials for High Performance Design

Mile High Motivation
Innovate.Integrate
RMA 2018

Rocky Mountain APPA
RMA
Networking. Mentorship. Professional Development.

listen.DESIGN.deliver

presenting today

Prem Sundharam AIA, LEED AP, CEM

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DLR Group

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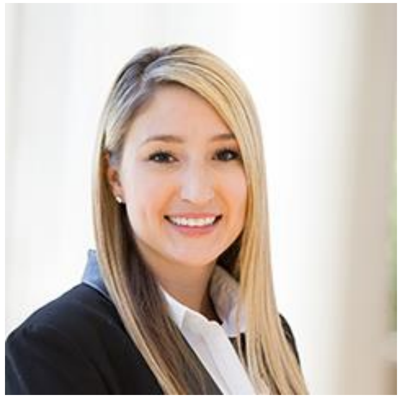
Professor, Research Scientist
at Julie Ann Wrigley, Global Institute of Sustainability

ASU SCHOOL of SUSTAINABILITY
ARIZONA STATE UNIVERSITY



Liz Brack EIT, Structural Designer

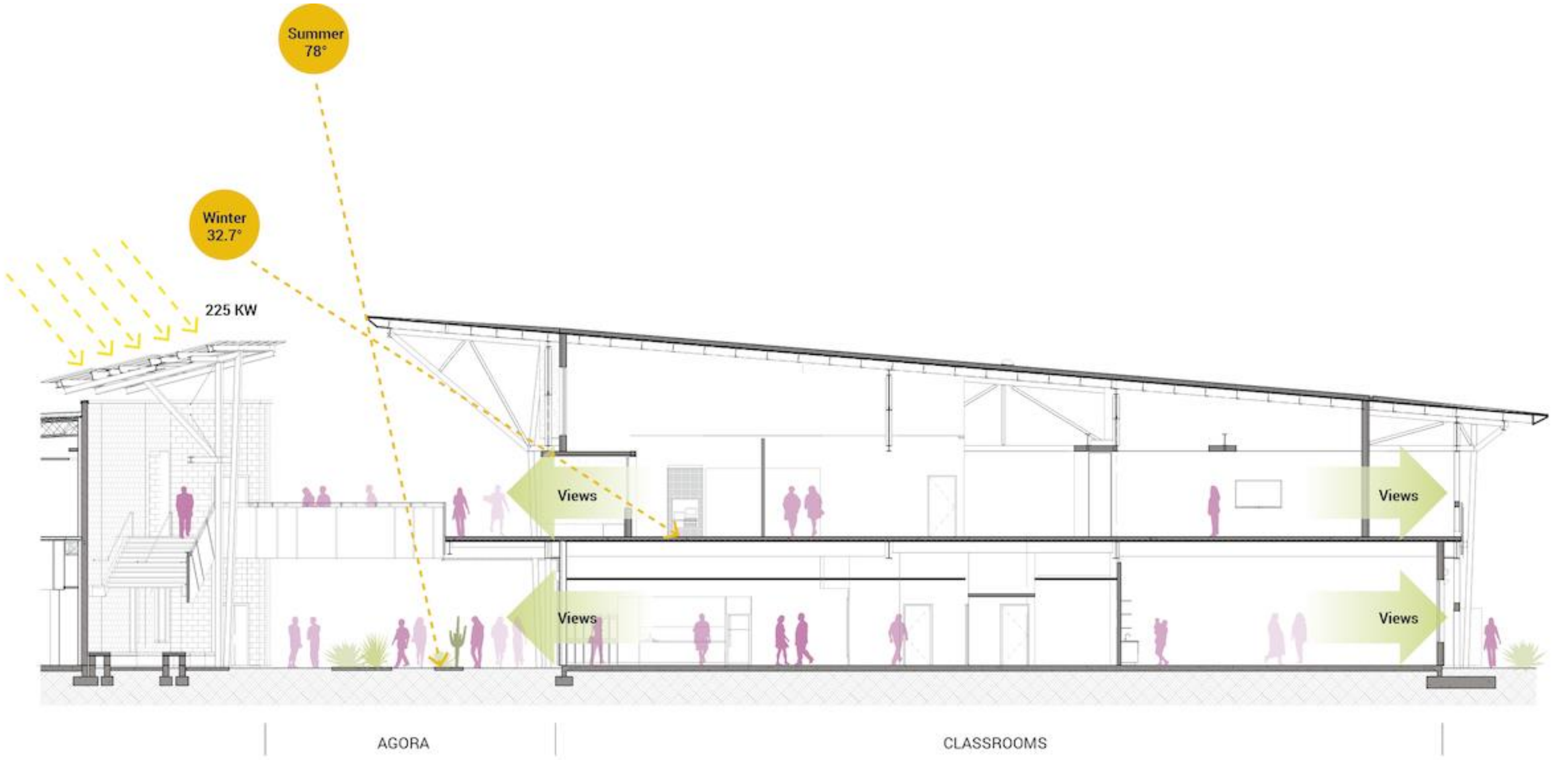
Associate, Adjunct Faculty at ASU

DLR Group

Course Description

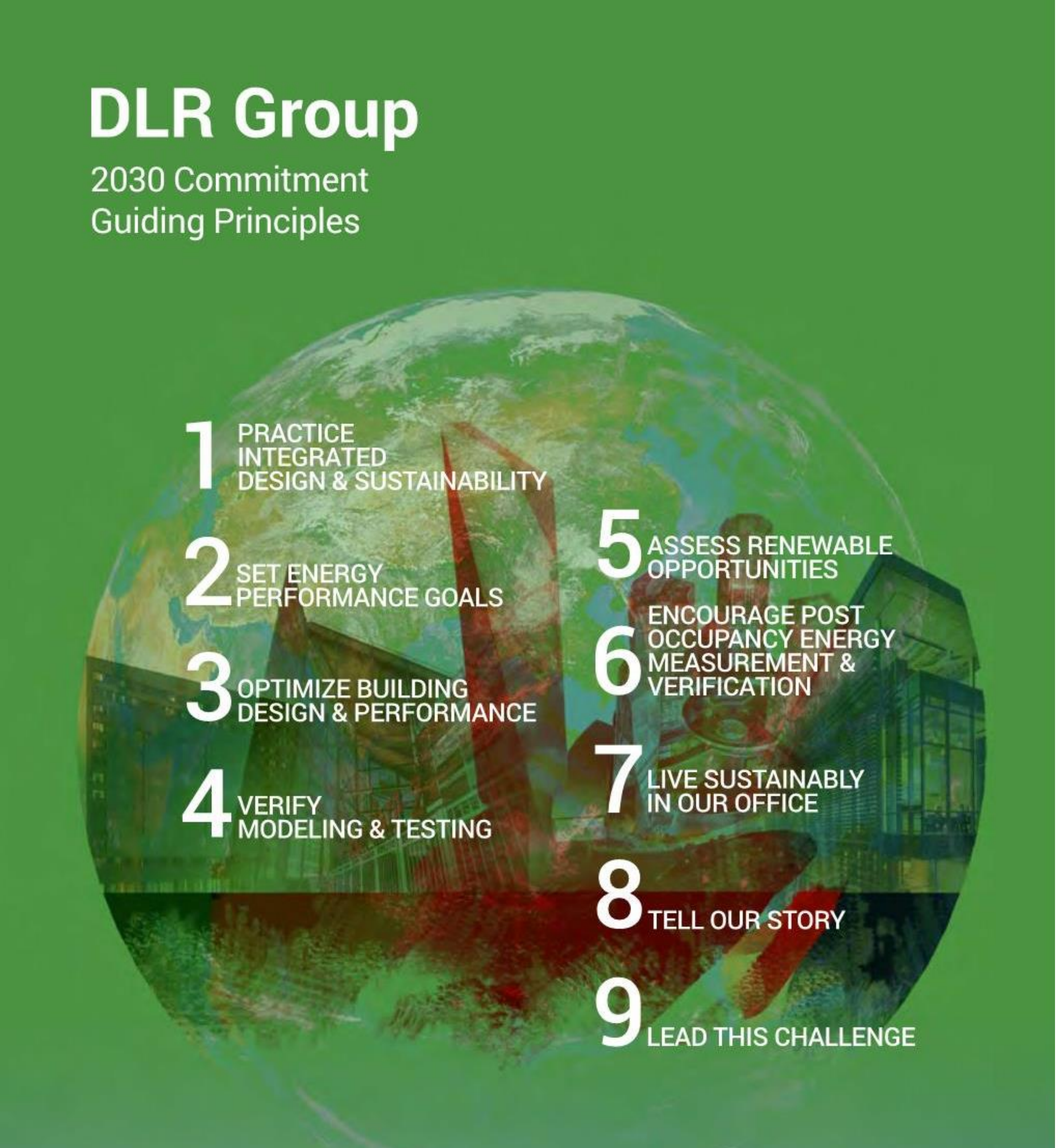
Storing thermal energy in building materials such as concrete, stone, etc. has been used as an effective passive design strategy for high performance buildings in years past.

What's new with thermal mass?
Learn about the research and application of phase change materials in steel frame construction through compelling case studies.



Learning Objectives

1. Attendees will learn the history of Phase Change Materials and basic building science concepts.
2. Attendees will be able to compare PCM technology against other high performance strategies from a performance and economics standpoint and apply integrating PCM into design
3. Attendees will learn about applying research to curriculum integration for students as they take advantage of the advanced metering and sensing equipment installed.

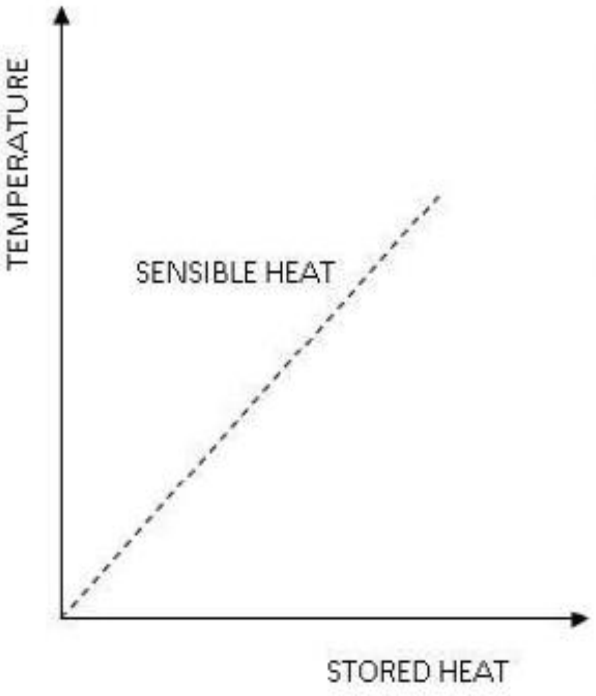


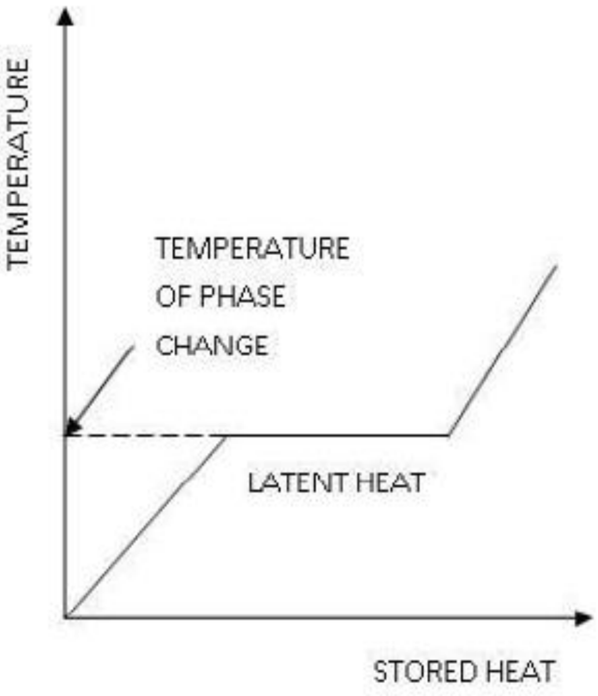
1. **HISTORY OF PHASE CHANGE MATERIALS (PCM)**
2. **INNOVATIVE BIO-PCM**
3. **THERMAL MASS 2.0 DLR GROUP RESEARCH**
4. **RESEARCH CURRICULUM INTEGRATION**
5. **THERMAL COMFORT RESEARCH**

1

HISTORY OF PHASE CHANGING MATERIALS

Phase Change Materials (PCM)

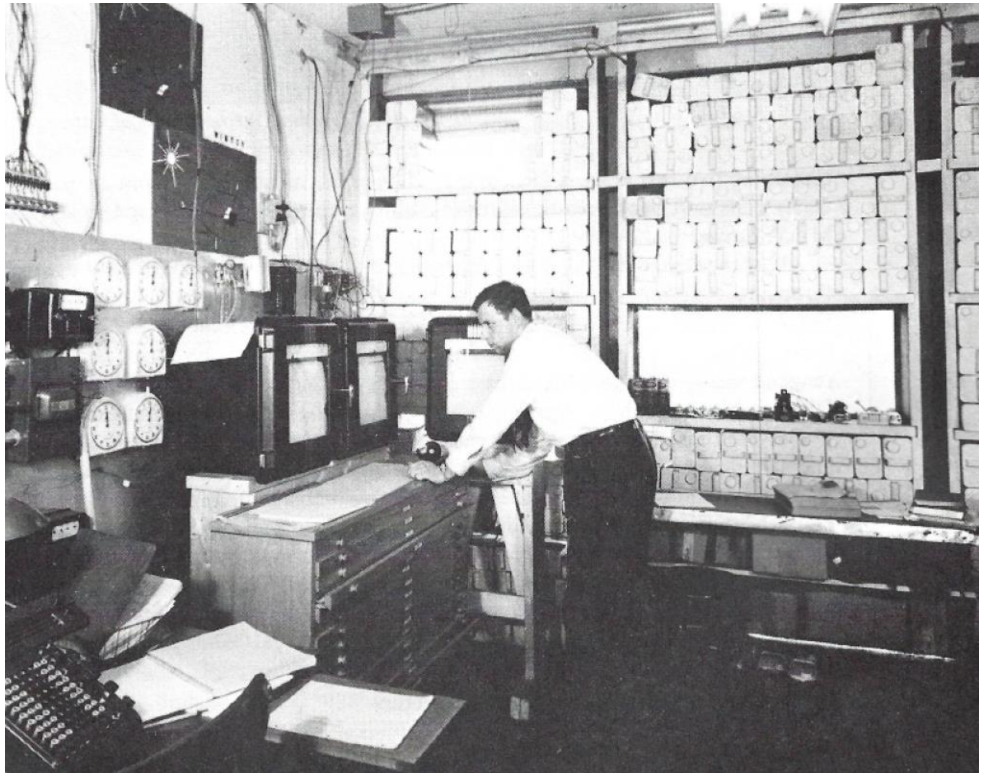




What is Phase Change Material (PCM)?

Early Examples of Phase Change Materials (PCM)

MIT Solar House II (Hottel 1947)



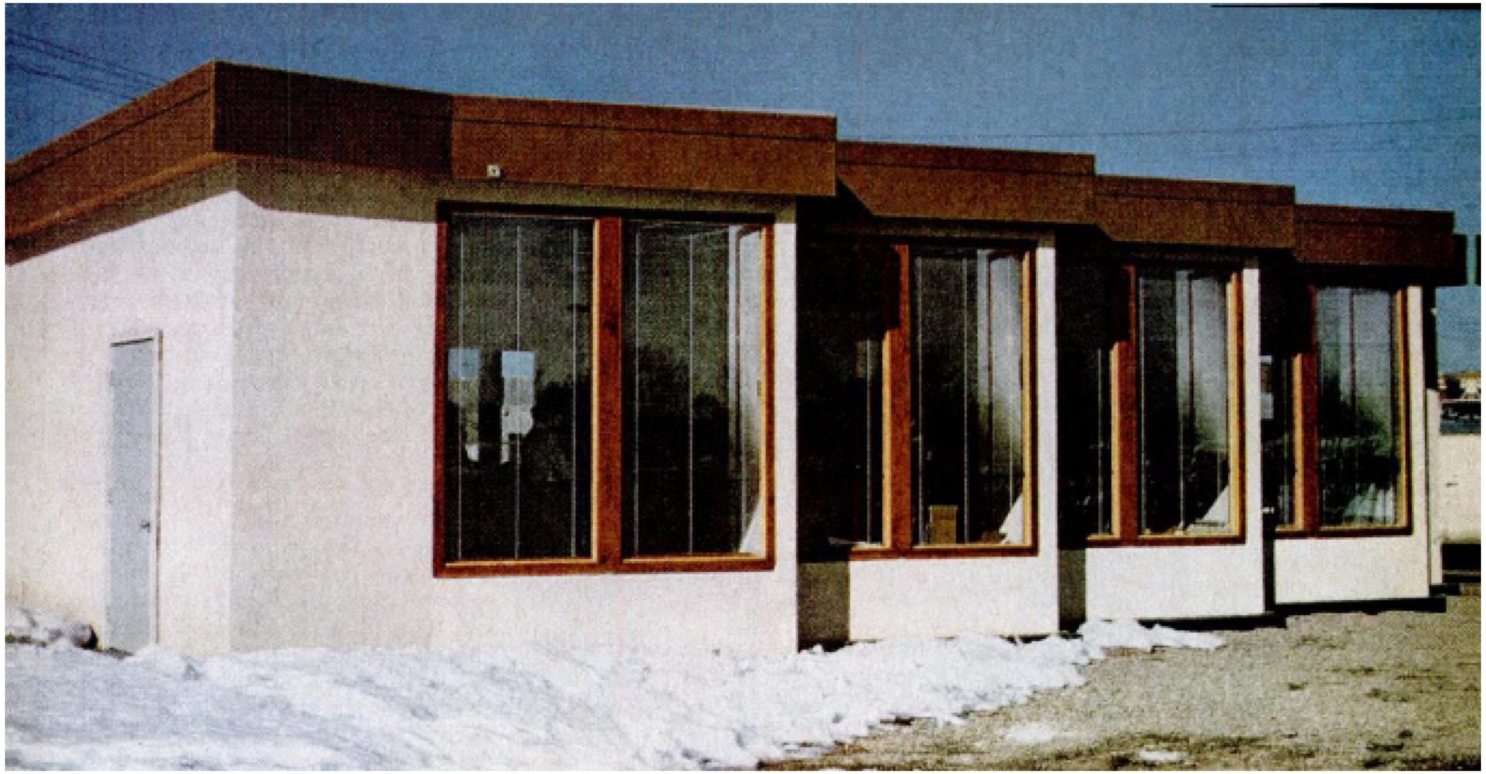
Interior of One of the Test Cells

Early Examples of Phase Change Materials (PCM)

Dover House, Dover MA., 1948

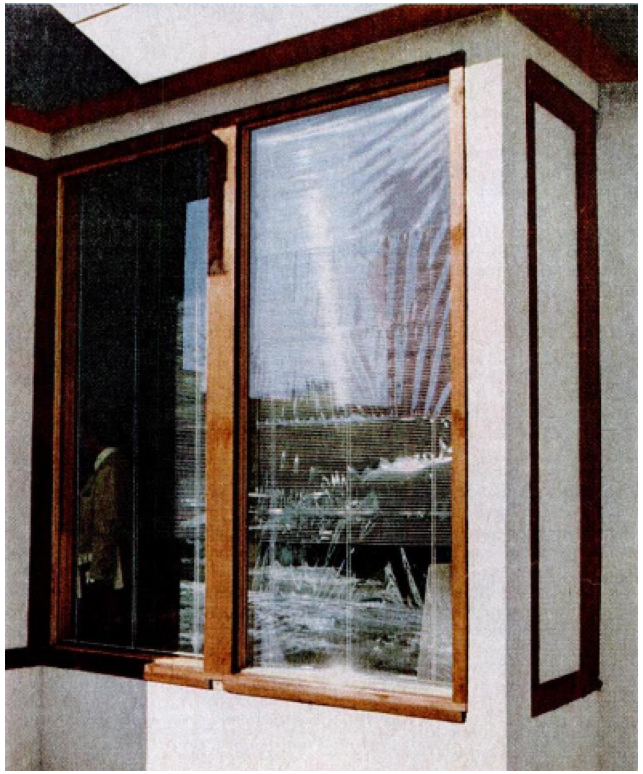
Eleanor Raymond & Maria Telkes at House in 1948

Early Examples of Phase Change Materials (PCM)

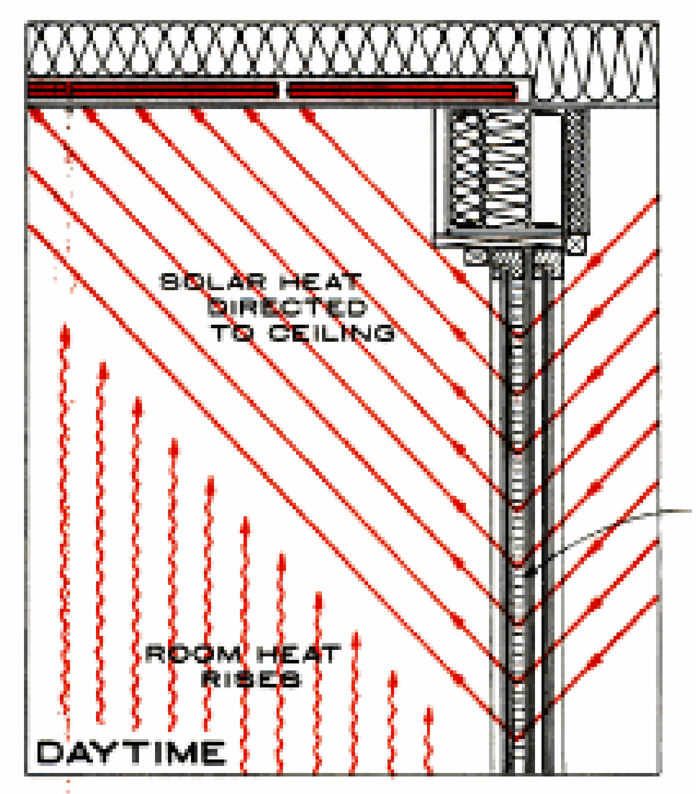


MIT Solar House V (Johnson 1978)

Early Examples of Phase Change Materials (PCM)

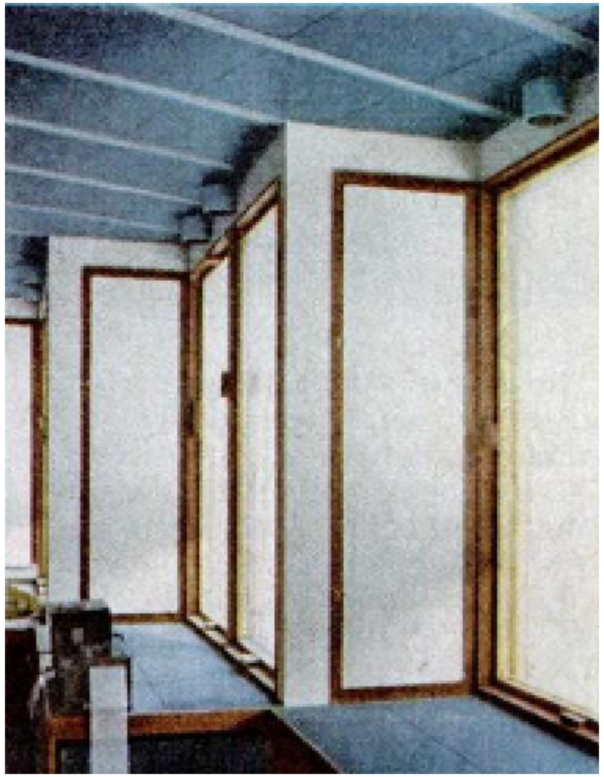


Mirror Blinds Reflect Sunlight to the Ceiling

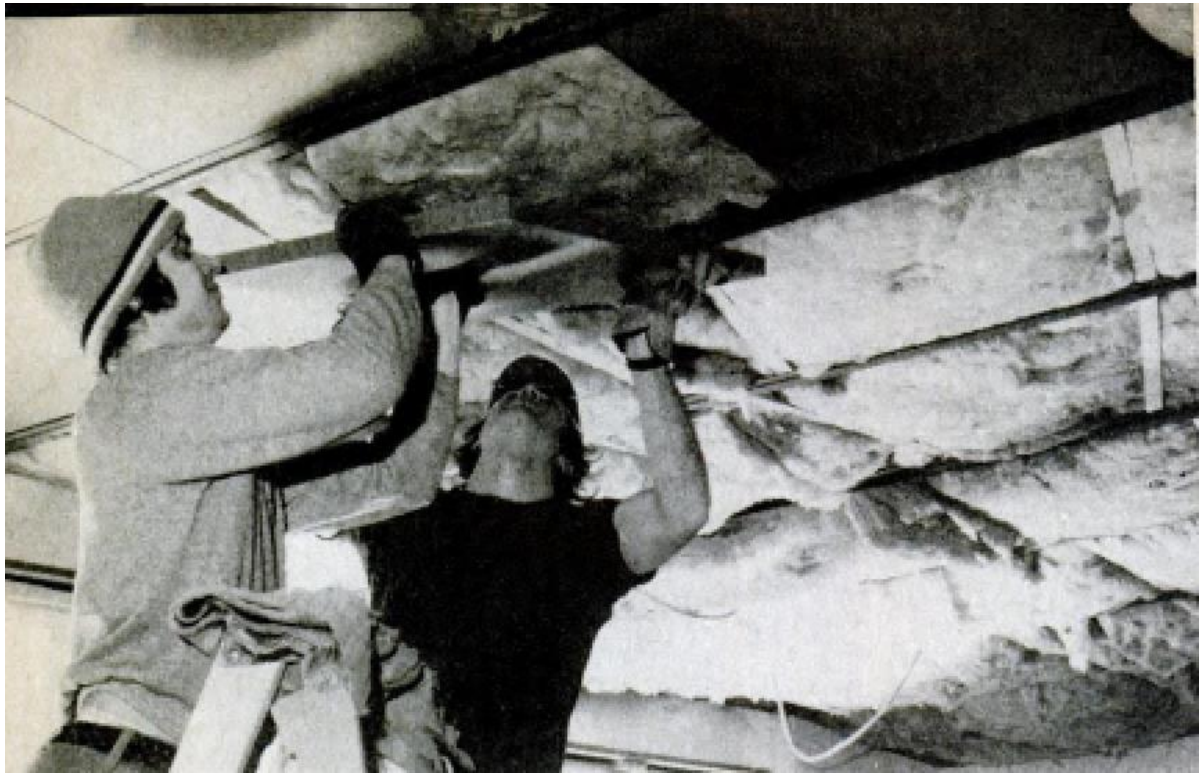


PCM was Placed in the Ceiling and Charged by the Reflected Sunlight

Early Examples of Phase Change Materials (PCM)



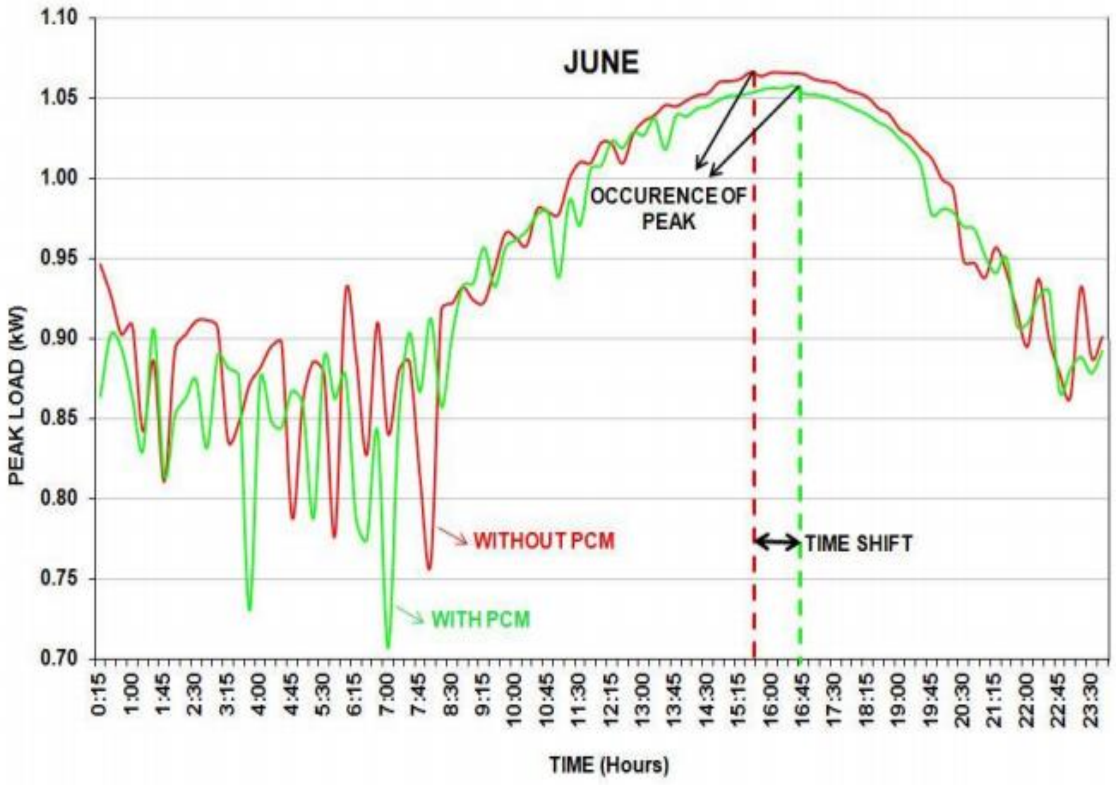
Interior of the Solar House V



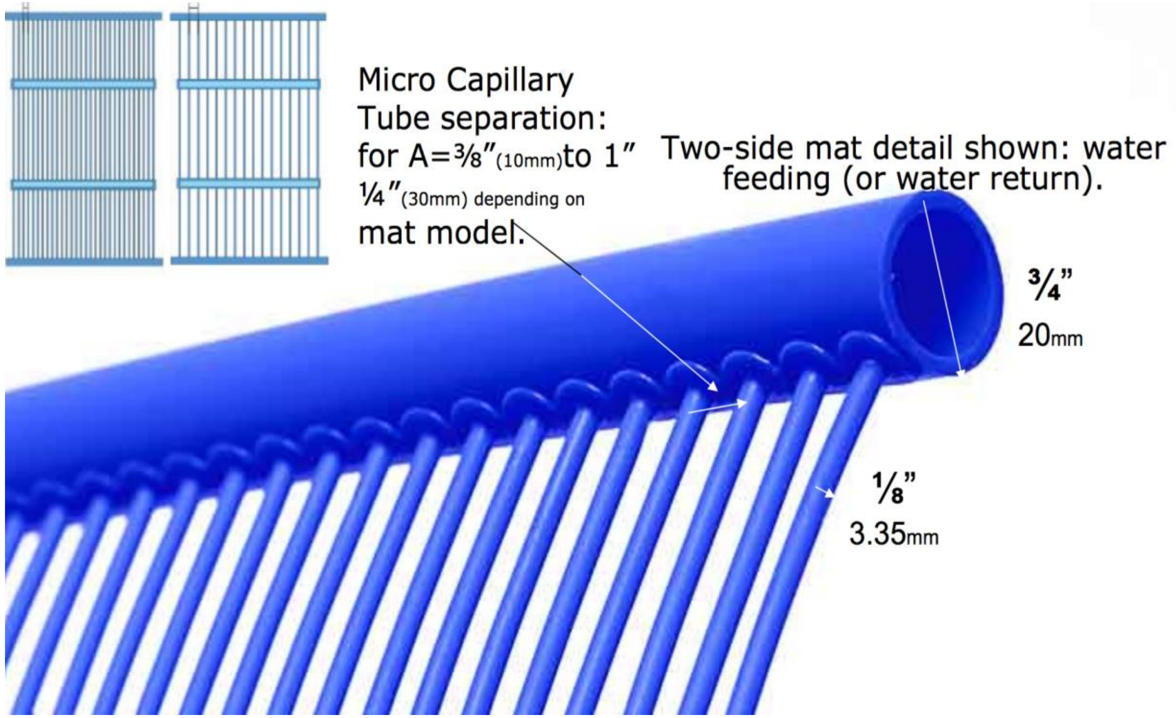
Installing the PCM in the Ceiling

ASU's PCM Test Structures

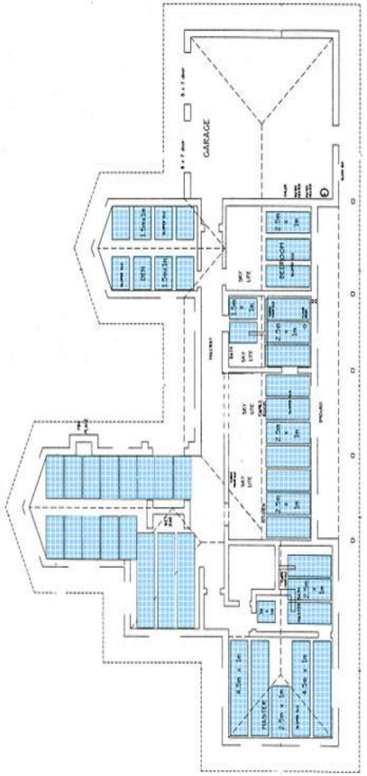
Muruganathan, Tempe AZ., 2010



Capillary Hydronic Charging

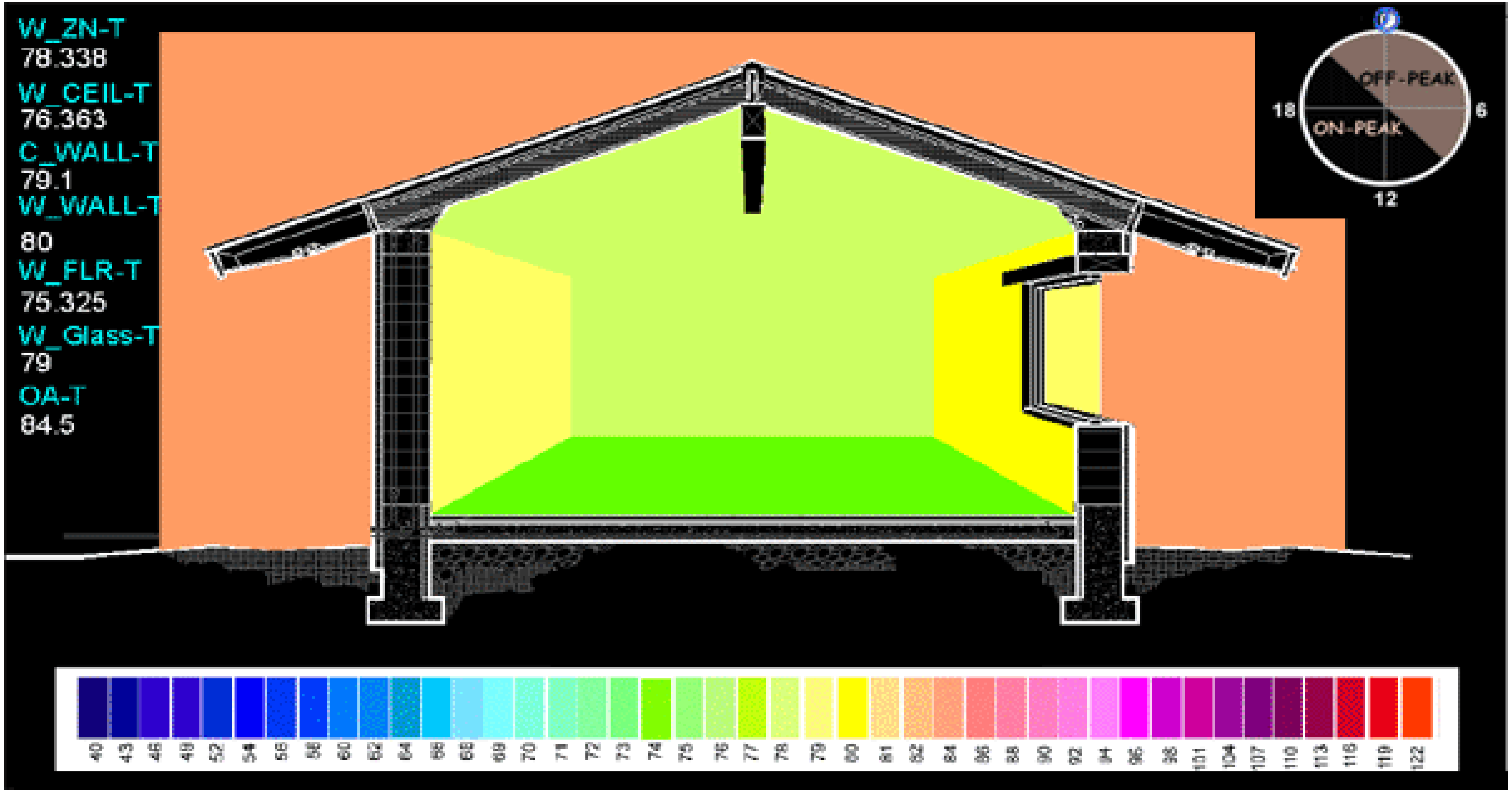


www.bekausa.com

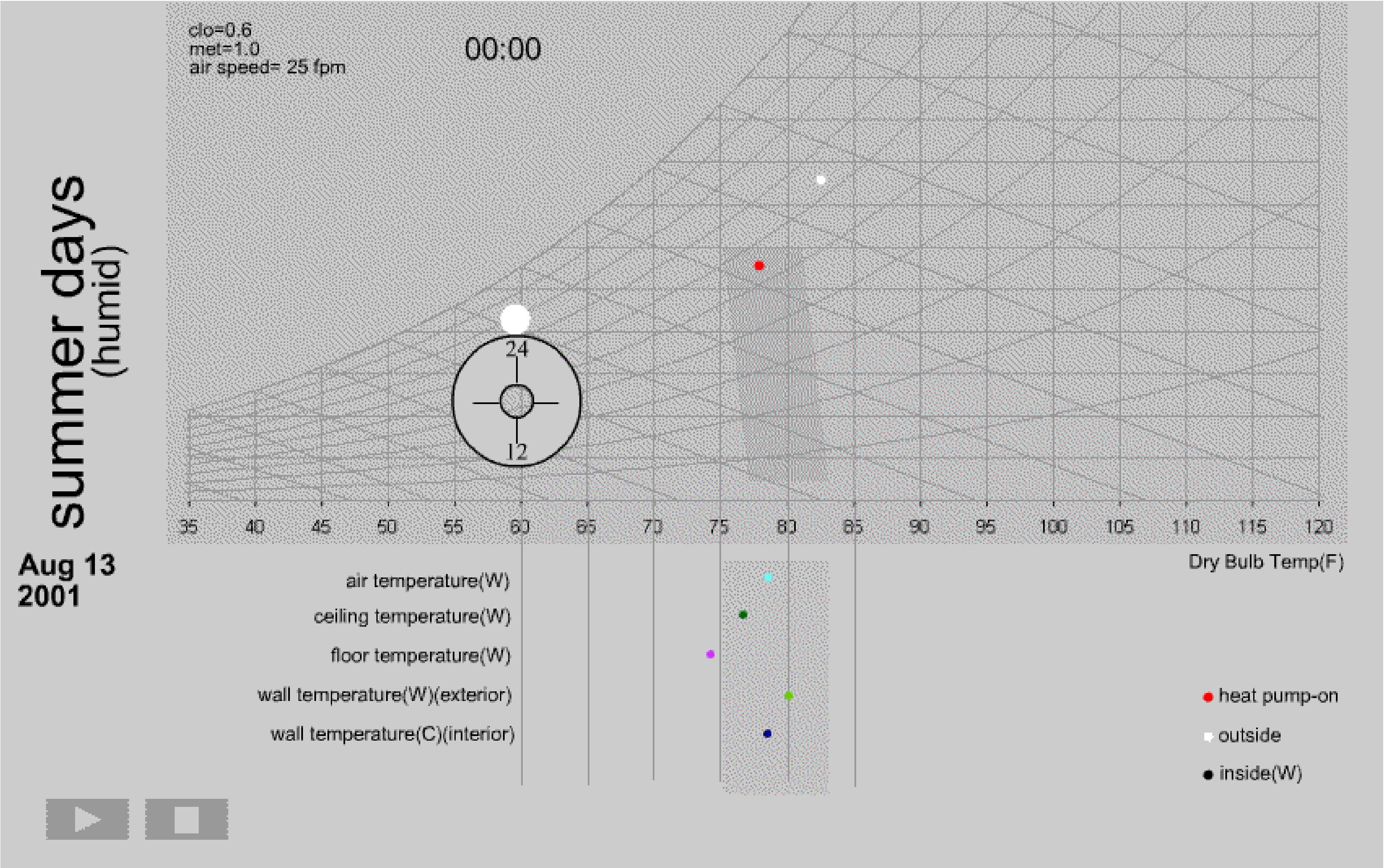


Carefree, AZ., 2001

Animations


W_ZN-T
78.338
W_CEIL-T
76.363
C_WALL-T
79.1
W_WALL-T
80
W_FLR-T
75.325
W_Glass-T
79
OA-T
84.5
OFF-PEAK
ON-PEAK
18
6
12
40 43 46 49 52 54 56 58 60 62 64 66 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 84 86 88 90 92 94 96 98 101 104 107 110 113 116 119 122

Animations



clo=0.6
met=1.0
air speed= 25 fpm
00:00
summer days
(humid)
24
12
35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120
Dry Bulb Temp(F)
Aug 13
2001
air temperature(W)
ceiling temperature(W)
floor temperature(W)
wall temperature(W)(exterior)
wall temperature(C)(interior)
heat pump-on
outside
inside(W)

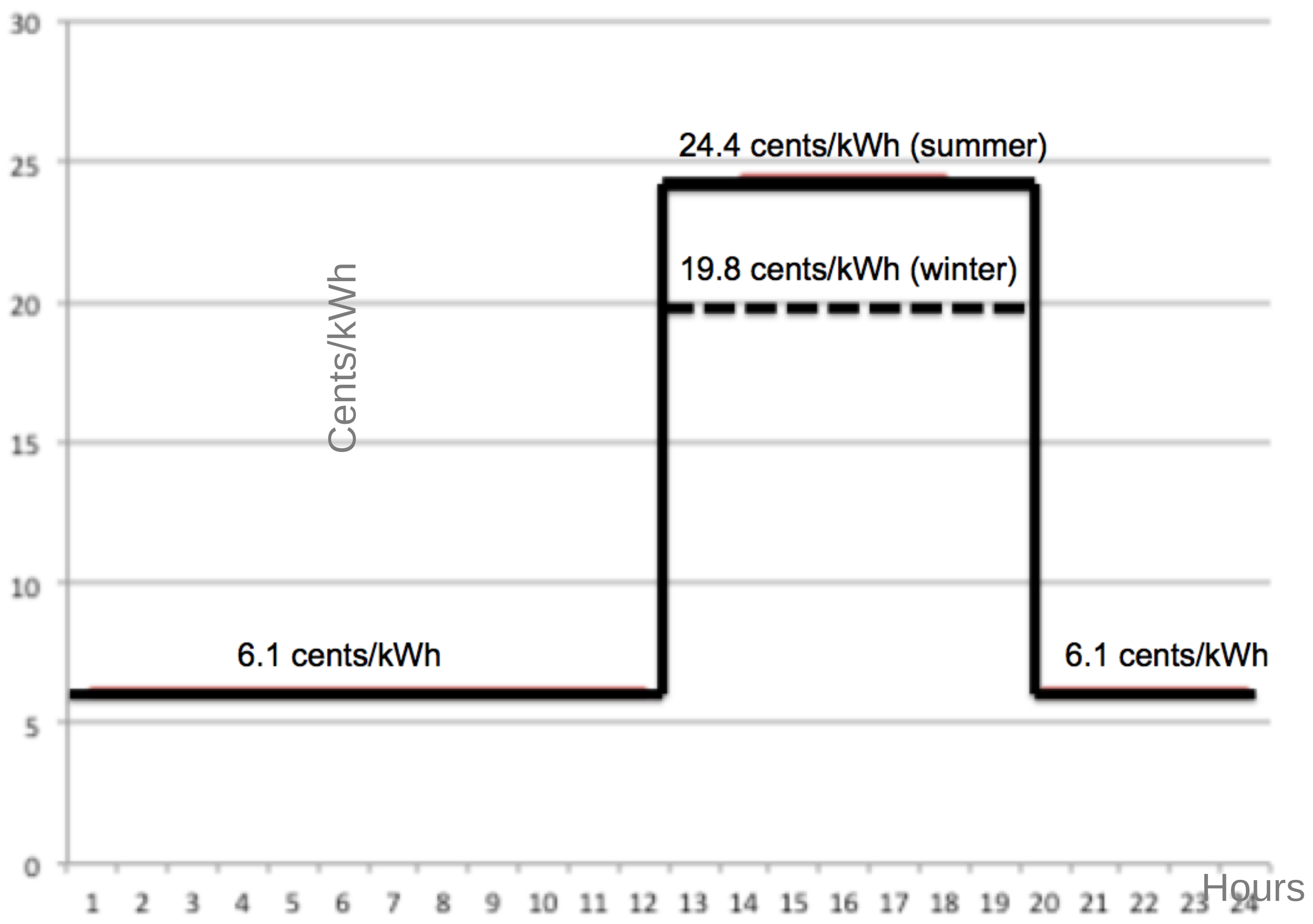
Mock-Up Model on Ceiling System

SHADE – ASU 2013 Solar Decathalon House

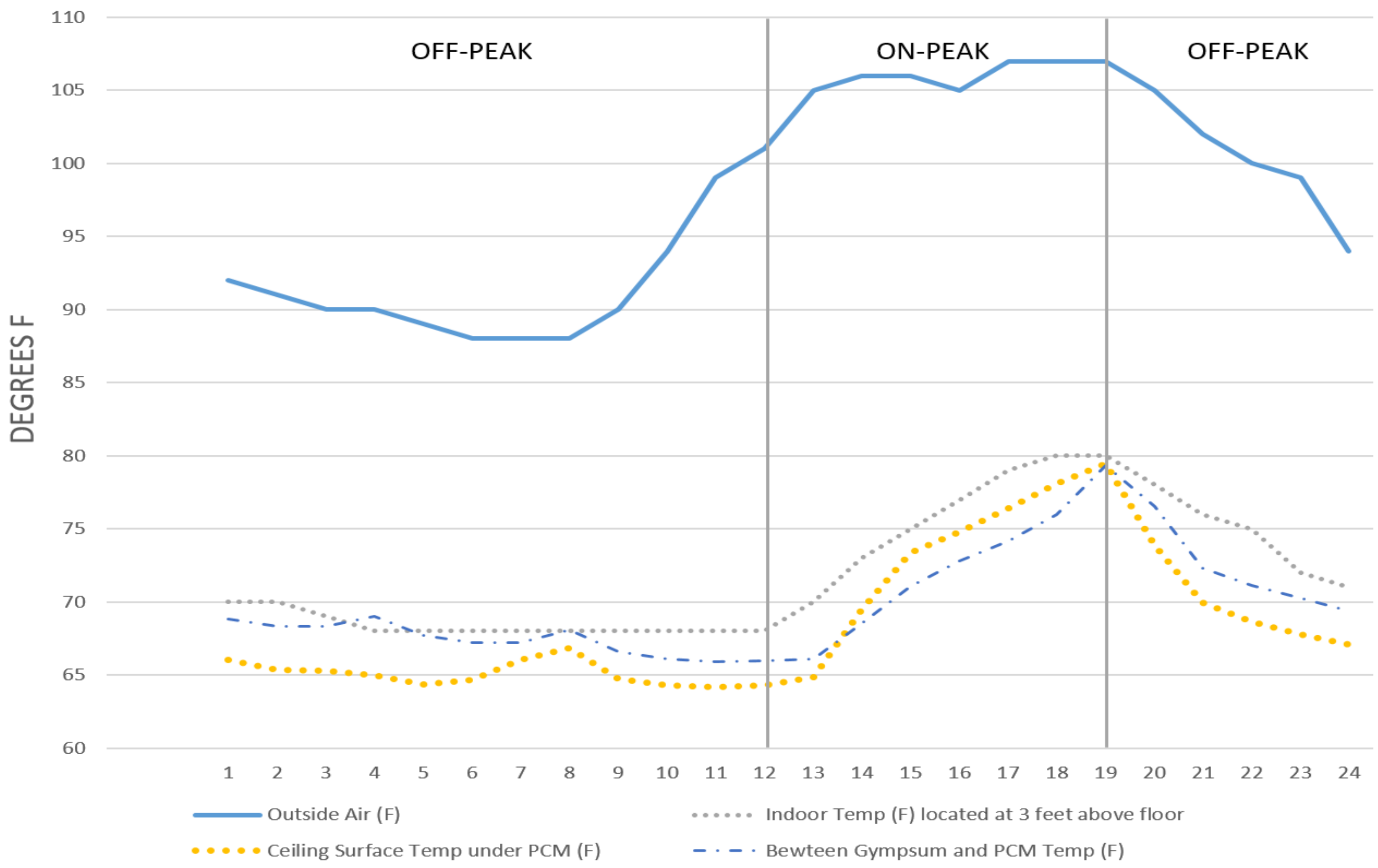
In Irvine, CA (2013)

In Phoenix, AZ (2015)

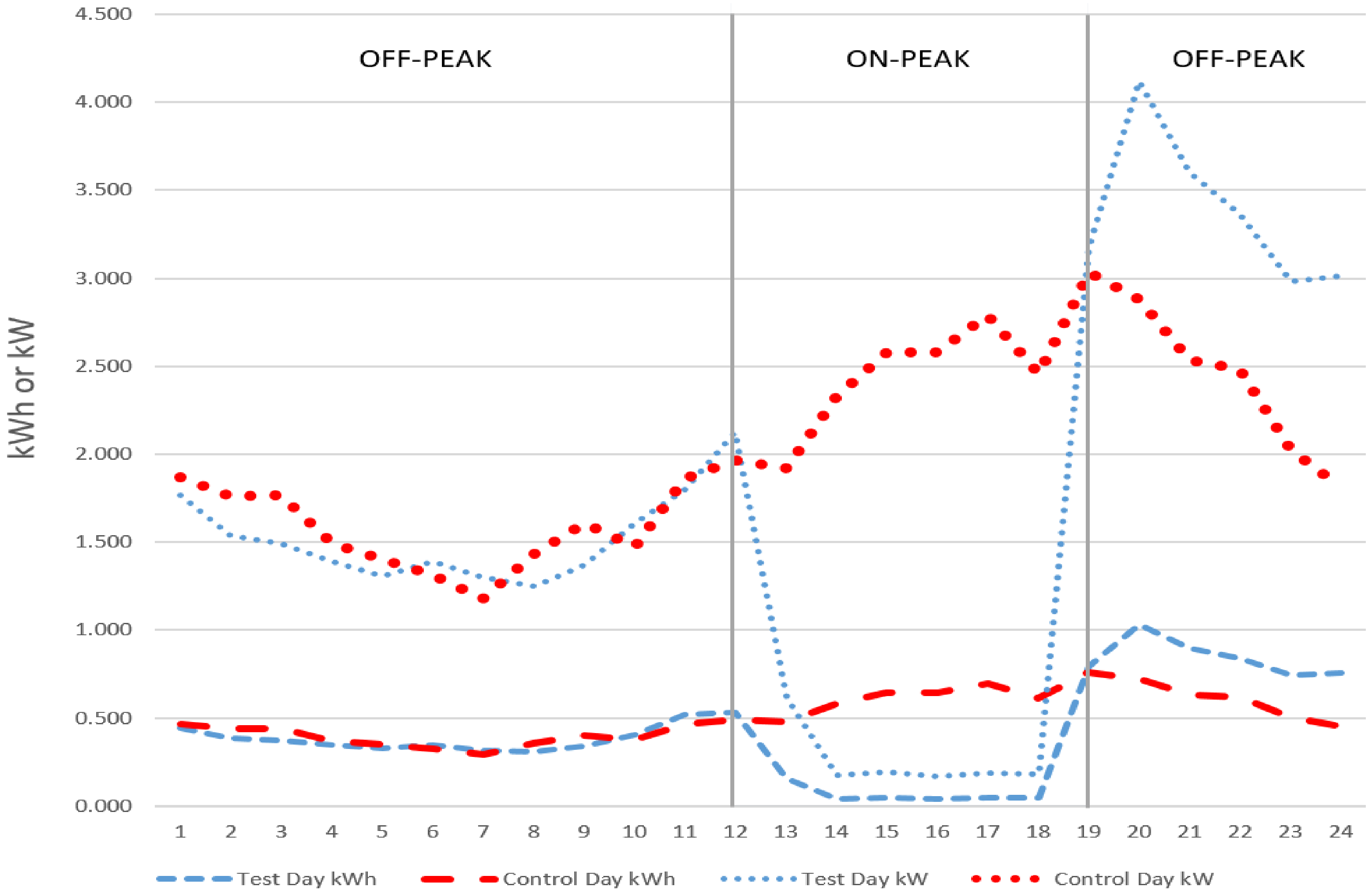
APS ET-2 TOU Rate



Typical Temperature Profiles



Typical Energy Profiles



Findings

- Hydronic Radiant Cooling coupled with PCM can be a very effective distributed energy storage strategy
- SHADE meet 6 hours of passive performance (APS later changed their TOU window to 3 – 8pm now a 5 hour window)
- Achieve 30% energy savings (kWh)
- Achieved 90% demand (KW) reduction during on-peak, but had a 25% demand increase during off-peak
- With further modifications SHADE can achieve even better performance

Future Work

- Explore the use of other TOU and Demand rate plans
- Explore the integration with the 9.5 KW photovoltic system
- Develop an model (based on the SHADE data) to be used to stimulate Radiant/PCM strategies for other building types
- Explore which Demand/Storage technologies can be embedded in the building itself versus those that can be managed by operational changes
- Energy and Demand savings have been proven, the next item to look at are comfort issues – that is what we are proposing for the Canyon View H.S. project

2

INNOVATIVE BIO-PCM

Benefits for Using PCMs in Buildings

A Proven, Cost Effective, Long-Term, Maintenance Free Means to Reduce HVAC Power Consumption While Maintaining Desired Ambient Temperature.

Reduces HVAC Power Consumption

Reduces building HVAC power consumption by 25-35% and cycling frequency by 10-15%

Attractive Payback Period

In most locales, power savings will return fully-installed cost in 3 years or less

Extends HVAC Equipment Lifetime

Reduced runtime & compressor cycling extends equipment lifetime

Reduces Carbon Footprint

1,000 telecom shelters with ENRG Panel reduces annual power consumption by more than 10,000,000 kWh – a CO_2 emissions equivalent of 7.5 million pounds of coal burned

No Operating Cost, Long Lifetime

Operates passively, requiring no power and no maintenance

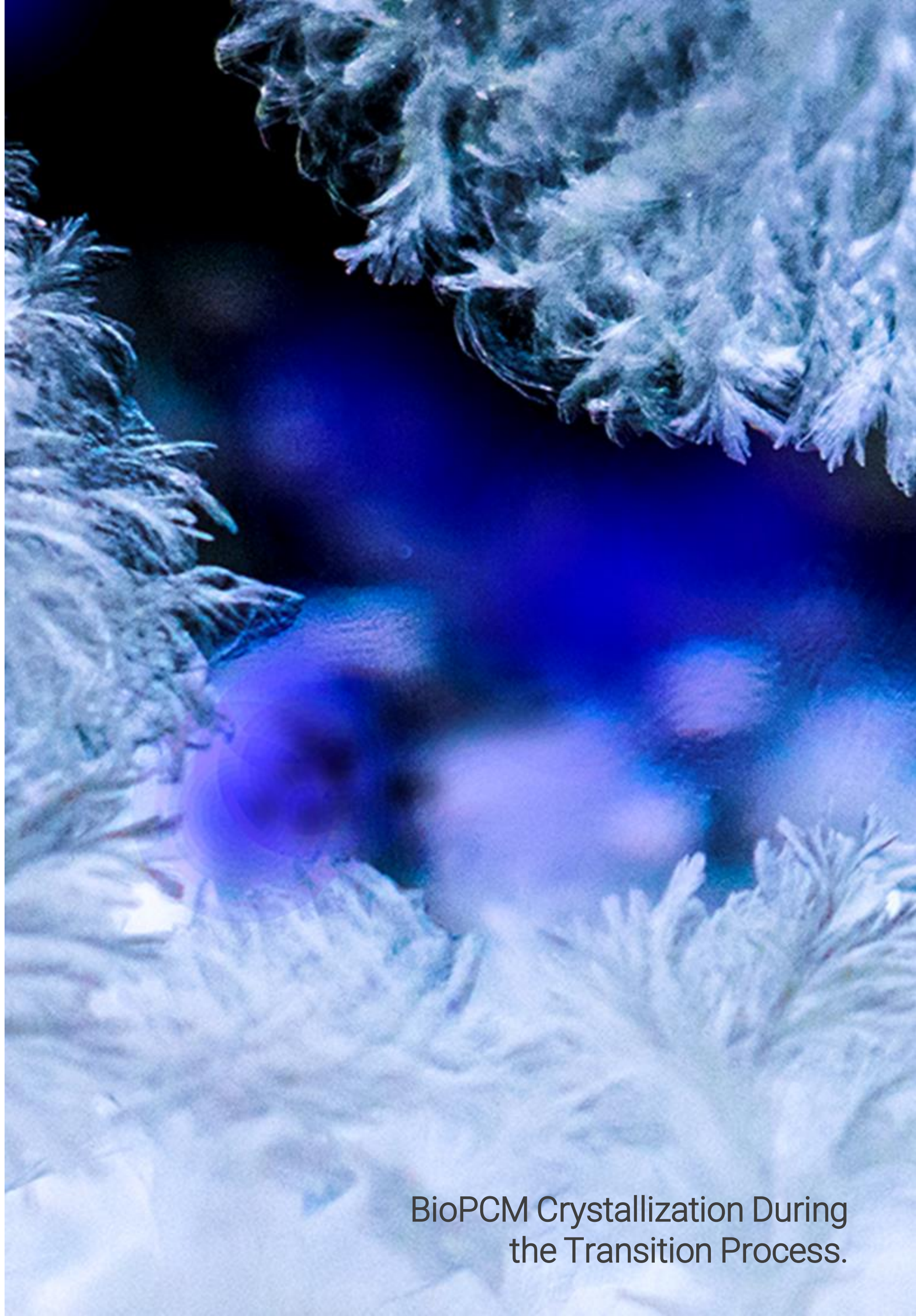
Types of Phase Change Materials

	Low enviro impact	Tunable Transition Temps	High-energy density (BTU/lb.)	Long lifetime (Years)	Low cost of production ($/ft^2)	Solid-to-gel & Solid-to-solid	Non-toxic	Non-corrosive	Non-flammable
BioPCM	✓	✓	✓	✓	✓	✓	✓	✓	✓
Paraffin PCMs	✗	✗	✓	✗	✗	✗	✗	✓	✗
Salt hydrate PCMs	✓	✗	✗	✗	✓	✗	✗	✗	✓

What is Bio-Based PCM?

Bio-Based PCM has the Following Characteristics

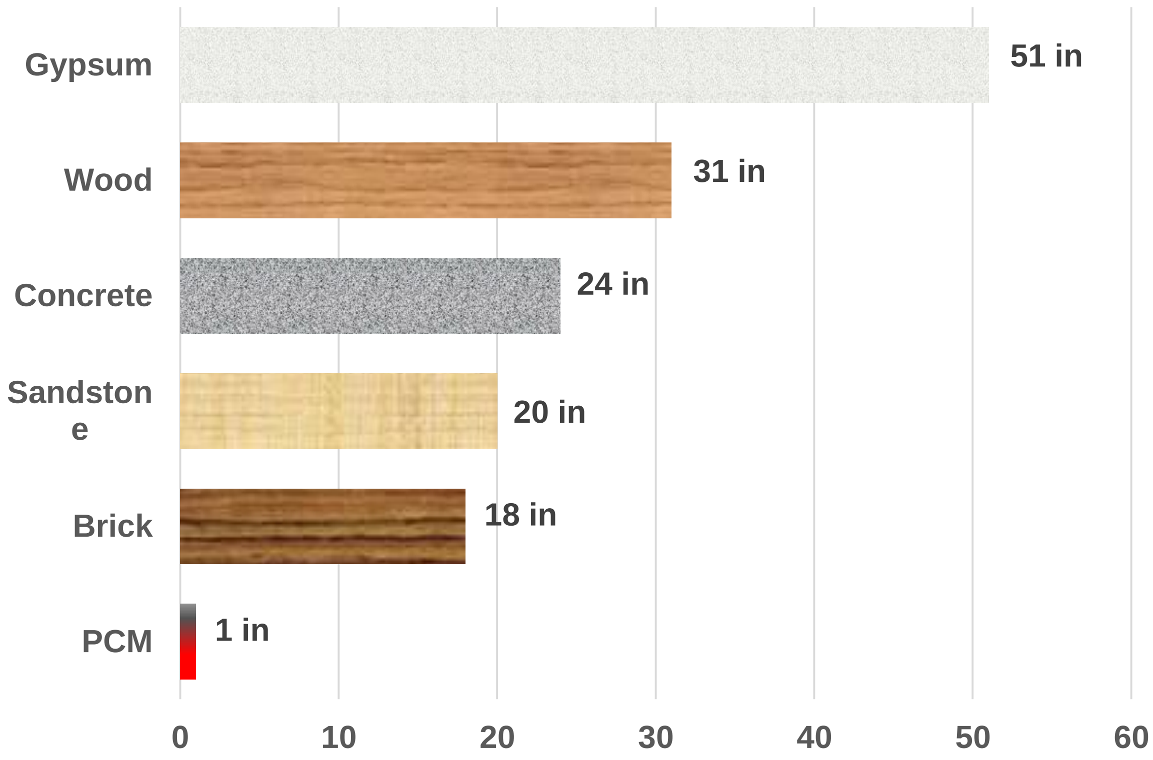
- Renewable – made from sustainably-sourced, renewable plant based by-products
- Engineered melting and freezing temperature ranges
- Maintenance free, passive
- Long life > 85 years, outlives the average building
- Stable and repeatable chemical and physical properties
- Fire-resistant tested to meet IBC and CBC requirements
- Non-toxic, 100% biodegradable & recyclable



BioPCM Crystallization During the Transition Process.

PCMs & Conventional Thermal Mass

- Conventional thermal mass has been used for centuries. High mass design provides thermal comfort in extreme climates. Thermal mass retains cool night temperatures during the heat of the day. Conversely, it retains the heat of the day during the cool of the night.
- PCMs provide the benefits of high mass design without the cost of a high mass design.

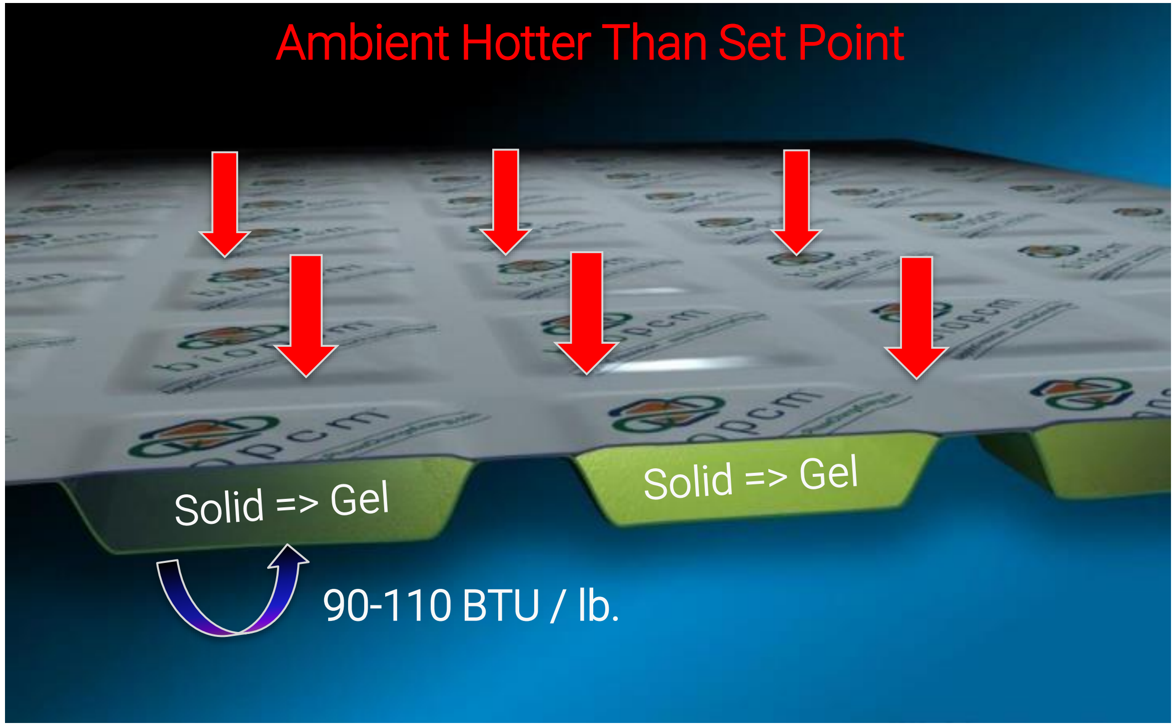


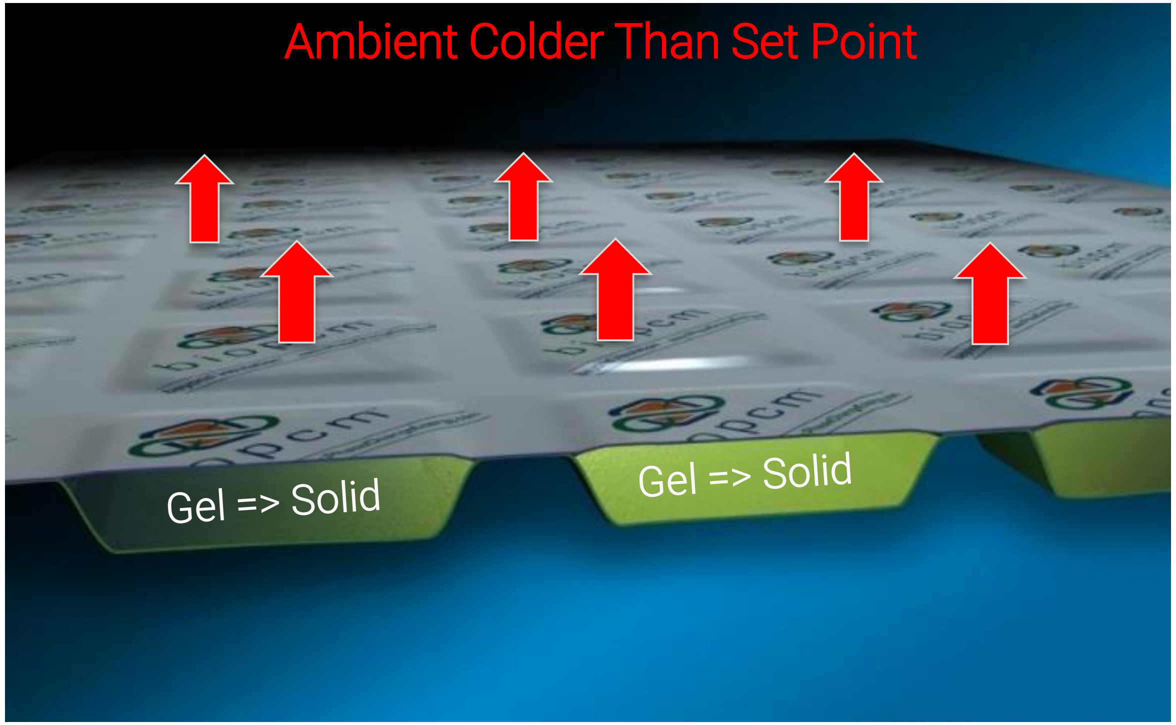
Equivalent thickness of conventional materials to match 1 inch thick layer of BioPCM.

How Do PCMs Work?

PCMs act like a thermal sponge, as the temperature becomes warmer they melt and become a gel, absorb and store heat.

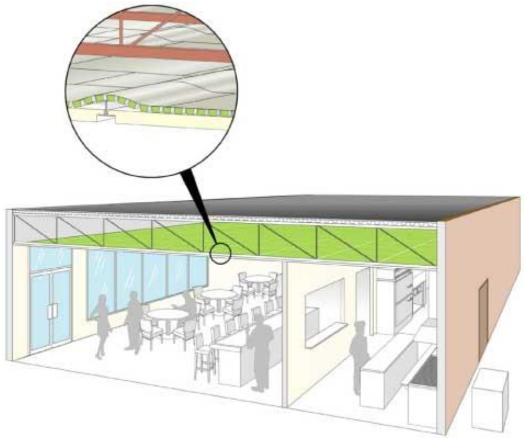
PCM stays within its engineered temperature range when in between phases (latent).





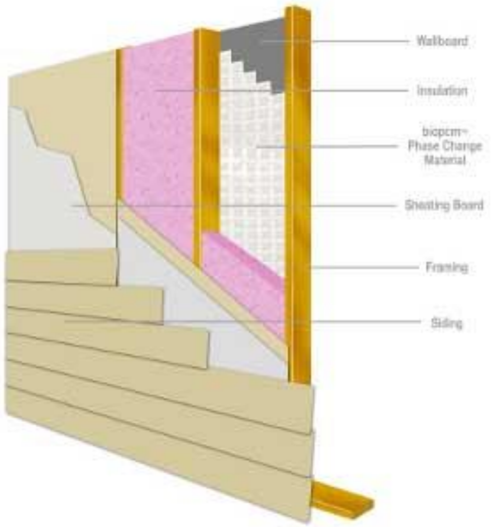
Bio-Based PCM Application Types

Above Dropped or TGrid Ceiling



- Simplest Installation &/or Retrofit
- Allows benefits to be applied to existing buildings
    - Good fit for energy upgrade market
    - Good fit for building retrofit
    - Good fit for repurposed buildings/spaces

In Walls

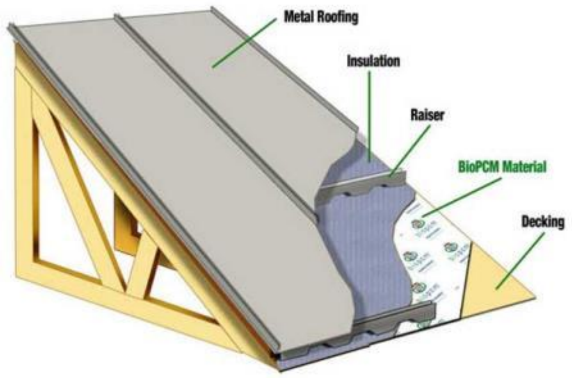


- Typically new construction
- Allows for strategic placement in space based on building orientation
- PCM is made to fit standard width stud bays with flanges for easy attachment

Bio-Based PCM Application Types

Roof

- Installed with furring above sheeting or below roof deck
- Can be below insulation or above insulation
- Can be applied to existing buildings



Custom

- Applications challenging spaces
  - Back up cooling applications
  - Industrial processes
  - Telecomm/Data Center

3

THERMAL MASS 2.0
DLR GROUP RESEARCH

PCM Application
in New Construction

Guiding Principles

Canyon View

Values Framework

Key Performance Indicators (KPIs)

1. Students: Academic Achievement with College and Career Readiness.
2. Students: **Engagement** – attendance rate, capture rate, out-of-boundary attendance.
3. Staff: Retention.
4. Staff: **Collaboration.**
5. Staff: Participation, **extra-curricular** after school activities.
6. Community: Facility **utilizations** including accelerator.
7. Community: Business partnerships.
8. Administration: **Total cost of ownership.**

Students and Staff Experience

Community Experience

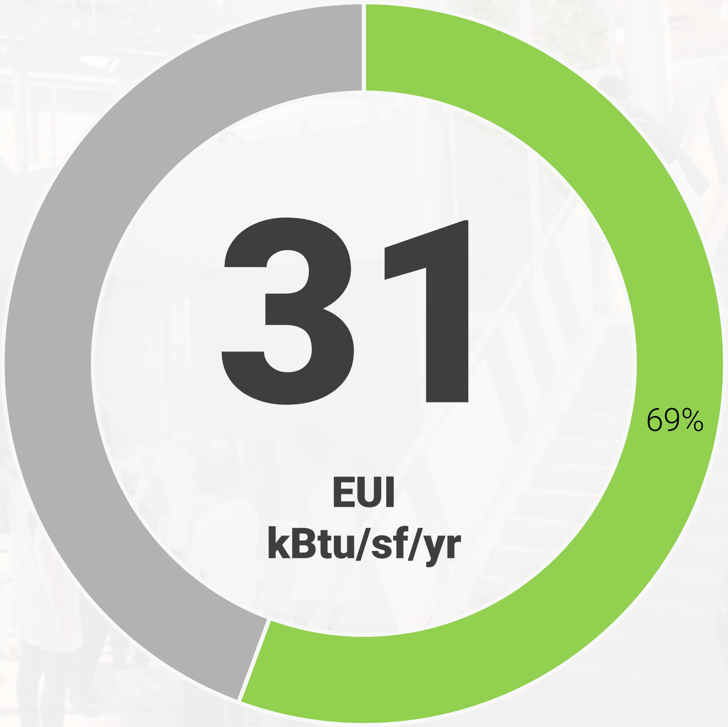
Administration Experience


Energy Performance Goal
50%
Better than Code
28
EUI Goal
kBtu/sf/yr
72%

LEED Integrative Process | Optimize Energy

Designed to meet Code – 30%
Design Best Practices – 60%
Strategies with a Premium – 10%

- Building envelope above code minimum
- LED light fixtures
- Magnetic bearing chillers
- Energy recovery systems
- Demand control ventilation
- Daylighting controls



LEED Integrative Process | Optimize Energy

Challenge with PCM technology

- Energy modeling software – prediction capabilities not satisfactory
- Savings and ROI calculations were rule of thumb based – hard to justify first cost.

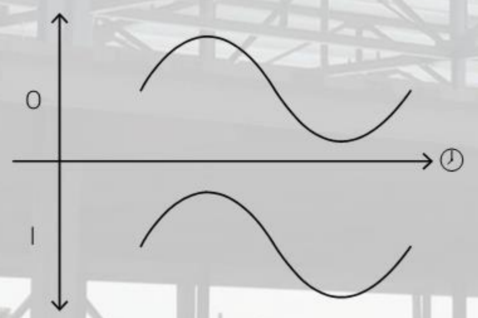
LEED Innovation in Design

Opportunity for Curriculum

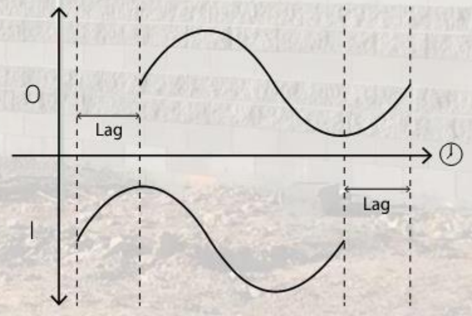
- Phase Change Material Technology
- Applied to one of the learning suites
- Indoor ceiling fans
- Applied to one of the learning suites – 2nd floor

(design) R&D

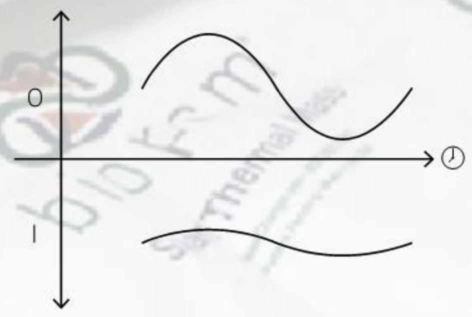
Thermal Mass 0



Thermal Mass 1.0



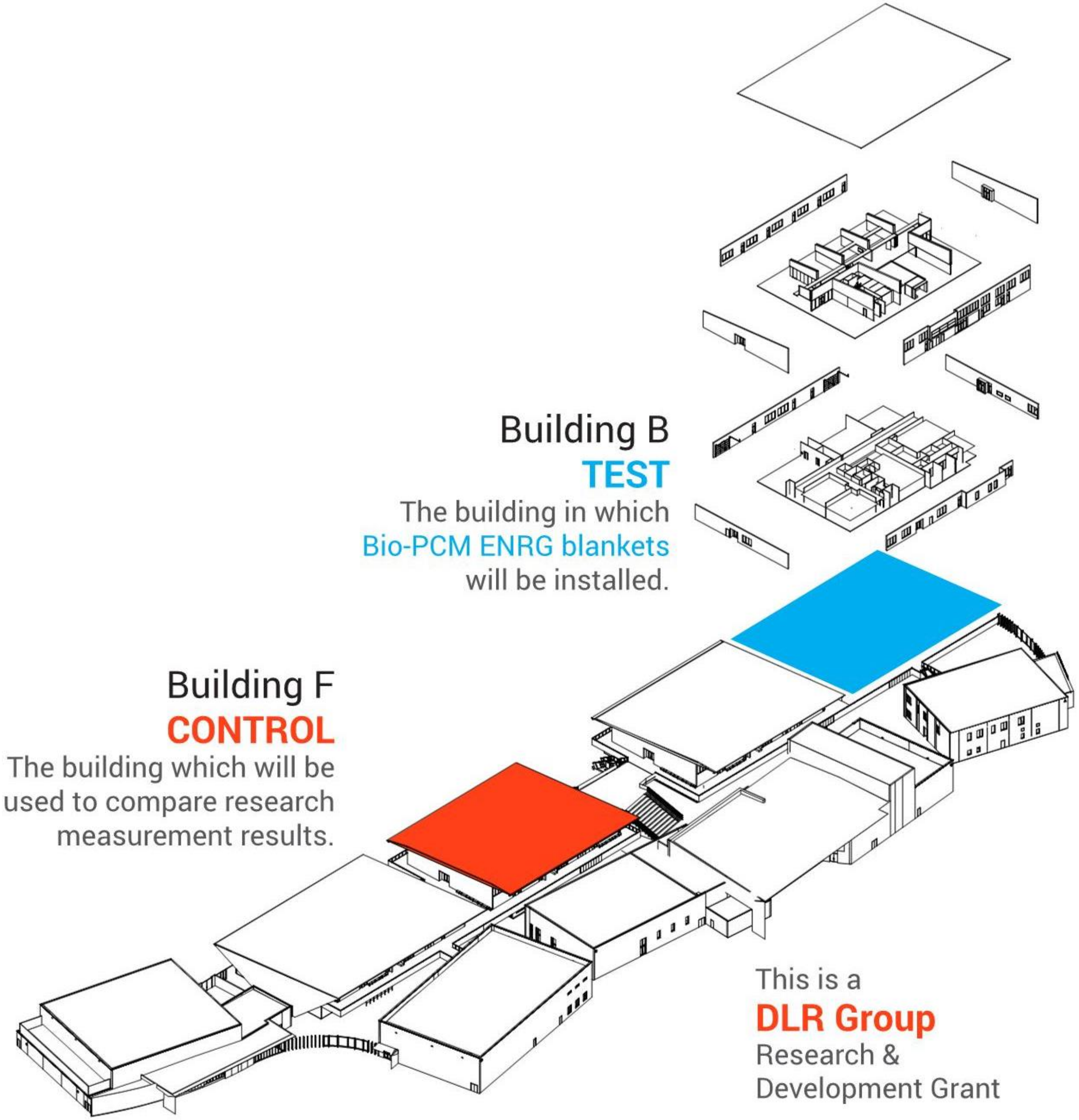
Thermal Mass 2.0



Thermal Mass 2.0

Proving thermal storage for heating and cooling buildings through phase change materials.


Canyon View
High School
ACCELERATOR



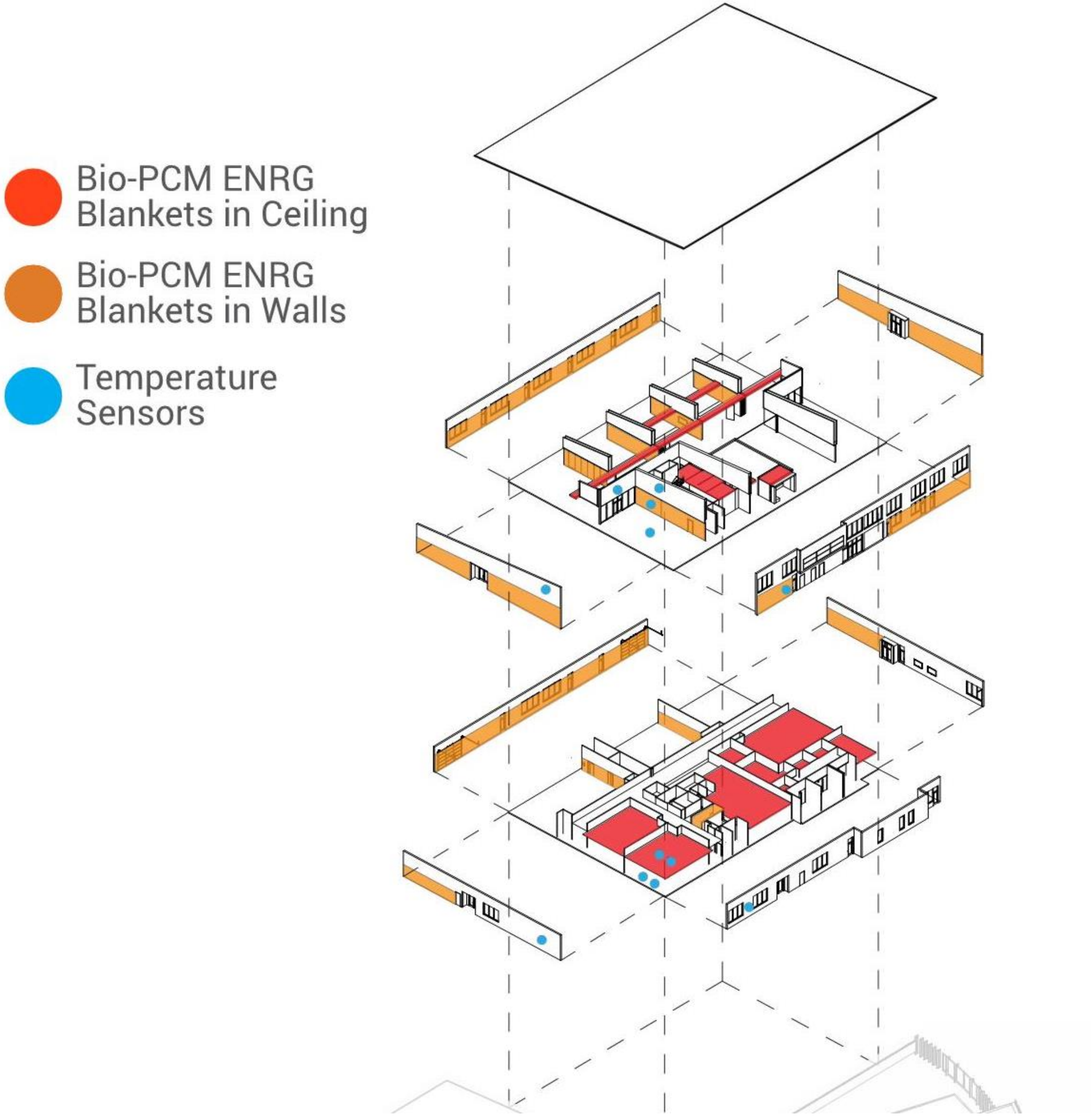
Building B
TEST

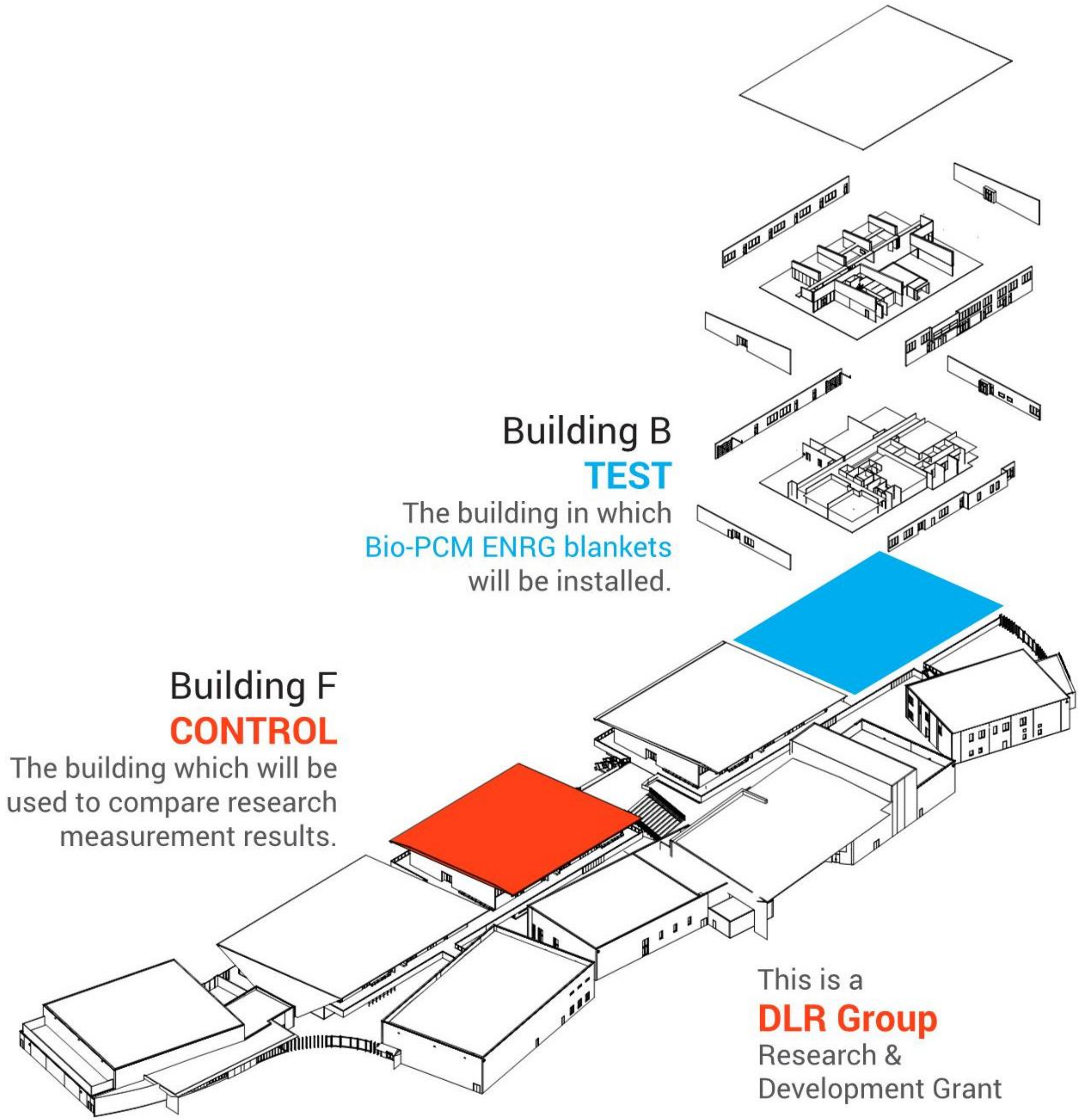
The building in which Bio-PCM ENRG blankets will be installed.

Building F
CONTROL

The building which will be used to compare research measurement results.

This is a **DLR Group** Research & Development Grant


Bio-PCM ENRG Blankets in Ceiling
Bio-PCM ENRG Blankets in Walls
Temperature Sensors



Advanced Energy Metering

- **HVAC**
  - Flow Meters (CHW)
  - Air Flow Temp. Sensors (FCs)
- **Electrical**
  - Current Transducers (CTs)

PCM Application
in New Construction

BLDG B – 1ST FLR

15,000 SQR FT

STUDS 16" O.C.

PHASECHANGE ENERGY SOLUTIONS
120 E. PRITCHARD ST.
ASHEBORO, NC 27203
1-336-629-3000
WWW.PHASECHANGE.COM

PHASE CHANGE MATERIAL SCHEDULE

Tag	PCM-1	PCM-2	PCM-3	PCM-4	PCM-5	PCM-6
Make	ENRG BLANKET	ENRG BLANKET	ENRG BLANKET	ENRG BLANKET	ENRG BLANKET	ENRG BLANKET
Model	Q23M27_24	Q23M27_18.5	Q23M27_14.5	Q23M51_24	Q23M51_18.5	Q23M51_14.5
M Value	27	27	27	51	51	51
PCM Area (Sqr Ft)	2,426	4,415	4,965	0	4,781	4,243

PHASE CHANGE ENERGY SOLUTIONS – ENRG BLANKET, CLASS A, INSTALLED ABOVE T-GRID & HARD LID CEILINGS

HATCHED AREAS INDICATE PCM ABOVE CEILING

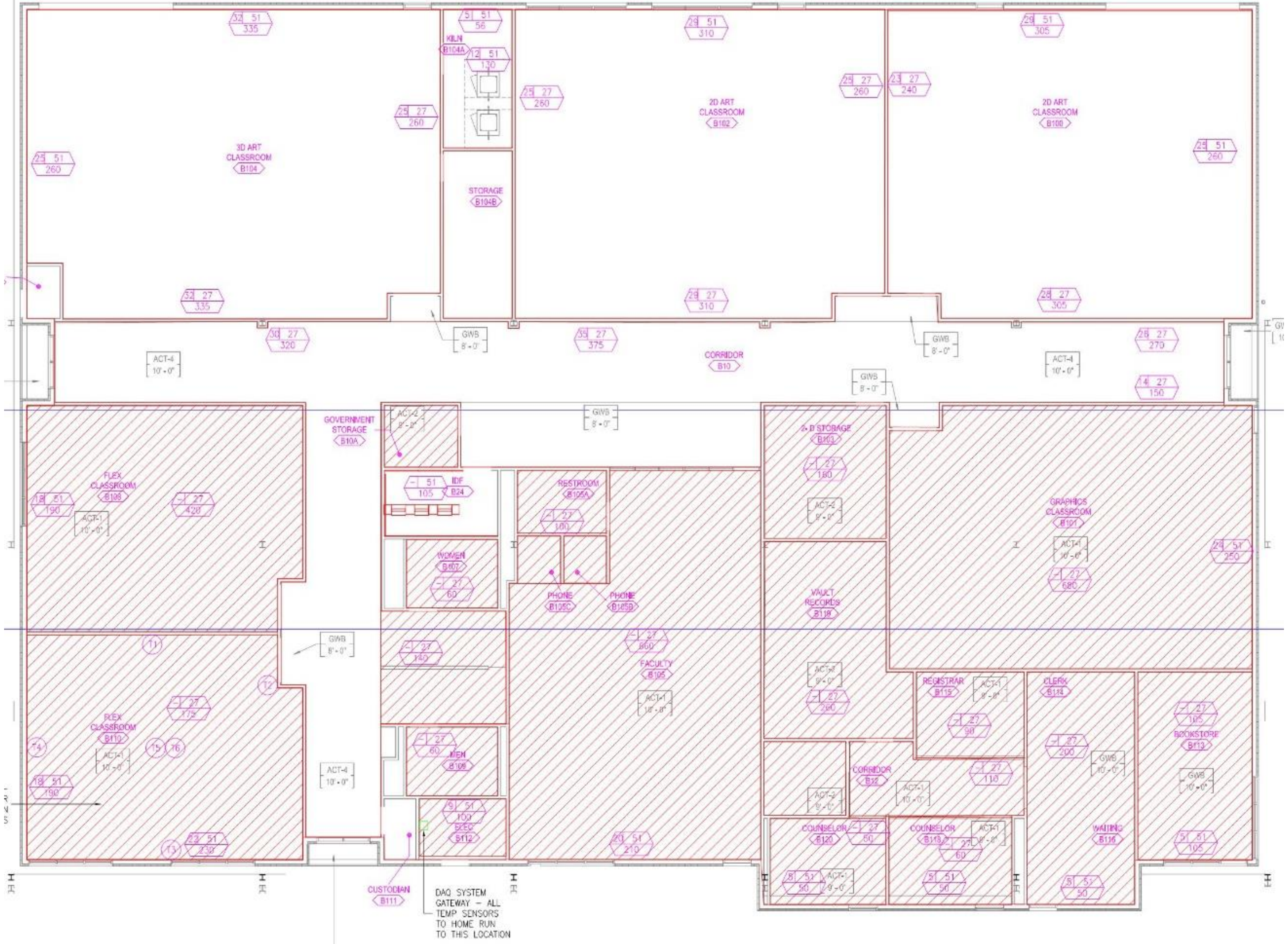
MODEL NUMBER NOMENCLATURE: Q##M##-###

WIDTH (IN)
ENERGY CAPACITY (BTU/SQR FT)
TEMPERATURE RATING (°C)

OF BLANKETS, 8' LONG. '–' INDICATES INSTALLED ABOVE ROOM T-GRID CEILING

PCM 'M-VALUE' (BTU/HR)

PCM AREA (SQR FT) FOR ADJACENT ASSEMBLY



PCM Application
in New Construction

BLDG B, 2ND FLR
13,390 SQR FT
12" STUDS O.C. EXCEPT NORTH WALL

PHASECHANGE
ENERGY SOLUTIONS
120 E. PRITCHARD ST.
ASHEBORO, NC 27203
1-336-629-3000
WWW.PHASECHANGE.COM

PHASE CHANGE MATERIAL SCHEDULE

Tag	PCM-1	PCM-2	PCM-3	PCM-4	PCM-5	PCM-6
Make	ENRG BLANKET	ENRG BLANKET	ENRG BLANKET	ENRG BLANKET	ENRG BLANKET	ENRG BLANKET
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PHASE CHANGE ENERGY SOLUTIONS – ENRG BLANKET, CLASS A, INSTALLED ABOVE T-GRID & HARD LID CEILINGS

HATCHED AREAS INDICATE PCM ABOVE CEILING

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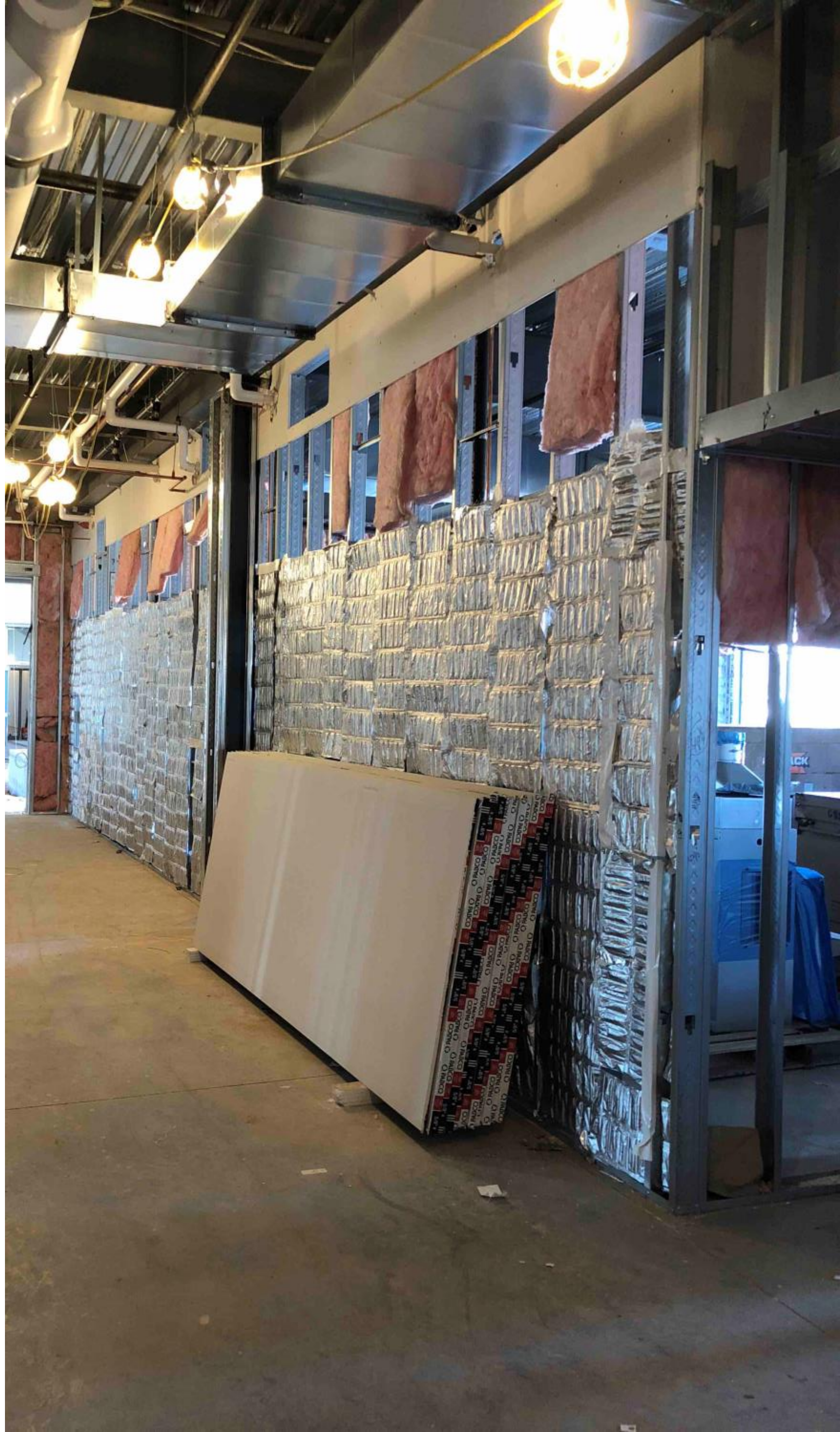
WIDTH (IN)
ENERGY CAPACITY (BTU/SQR FT)
TEMPERATURE RATING (°C)

OF BLANKETS, 8' LONG. '–' INDICATES INSTALLED ABOVE ROOM T-GRID CEILING
PCM 'M-VALUE' (BTU/HR)
PCM AREA (SQR FT) FOR ADJACENT ASSEMBLY


PCM Application
in New Construction
CHASSE
BUILDING TEAM
biopcm
Smart Thermal Mass

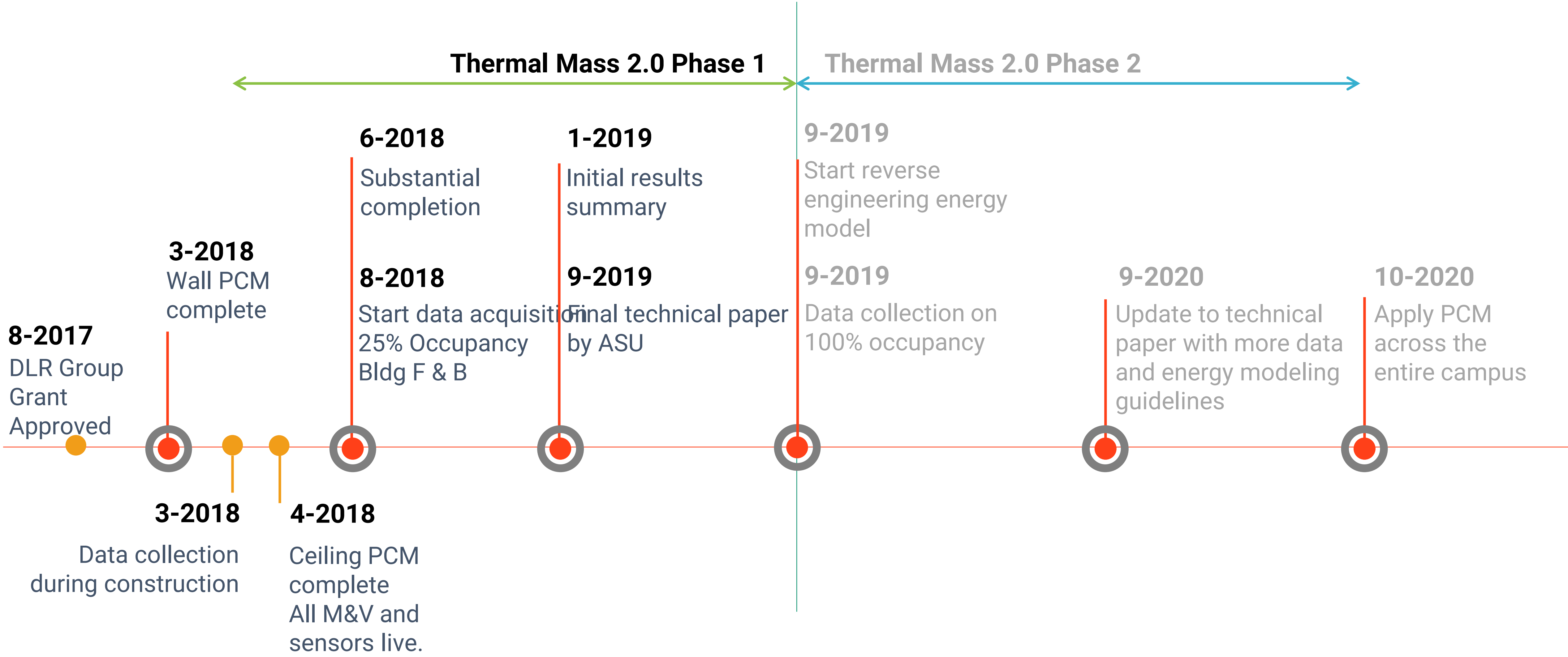
PCM Application
in New Construction




PCM Application
in New Construction

Thermal Mass 2.0

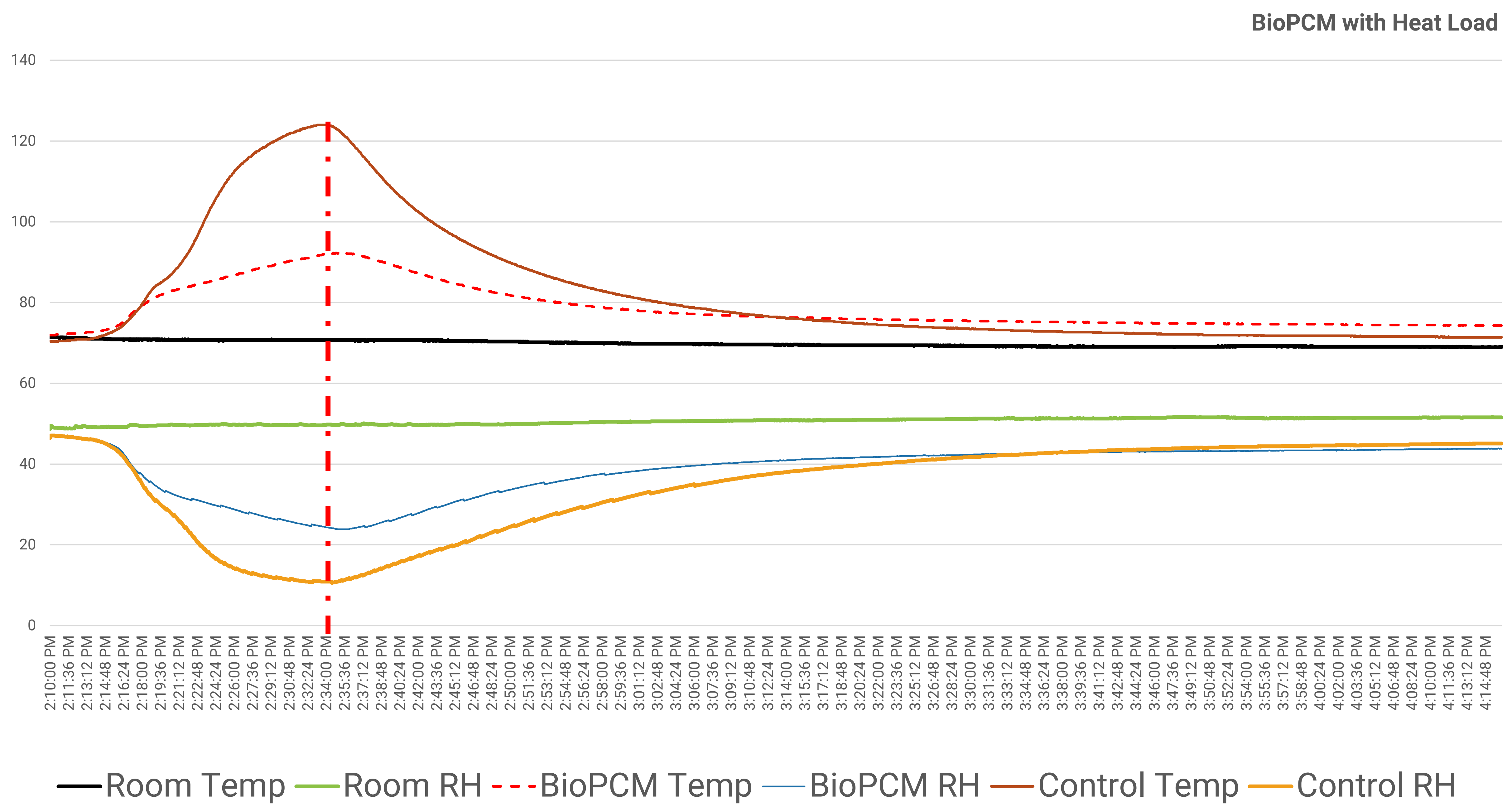
Research Timeline



4

CURRICULUM INTEGRATION


2015
TEST
SENSOR 2
Insulfoam
A CARLISLE Company
CONTROL
-TECH
SENSOR 3



BioPCM with Heat Load
140
120
100
80
60
40
20
0
2:10:00 PM
4:14:48 PM
Room Temp
Room RH
BioPCM Temp
BioPCM RH
Control Temp
Control RH

Curriculum

- Integration into community
- Project based learning environment (learn by doing)
- Physics first high school

Curriculum
Progress

- Agua Fria High School District Science Coordinator
  - Fold research into Freshman Physics course
    - Unit on Energy and States of Matter
    - Intro “Box” Experiment
- Introduce concepts in the vein of phenomena learning project
- Research possible on multiple platforms

Curriculum

Next Steps

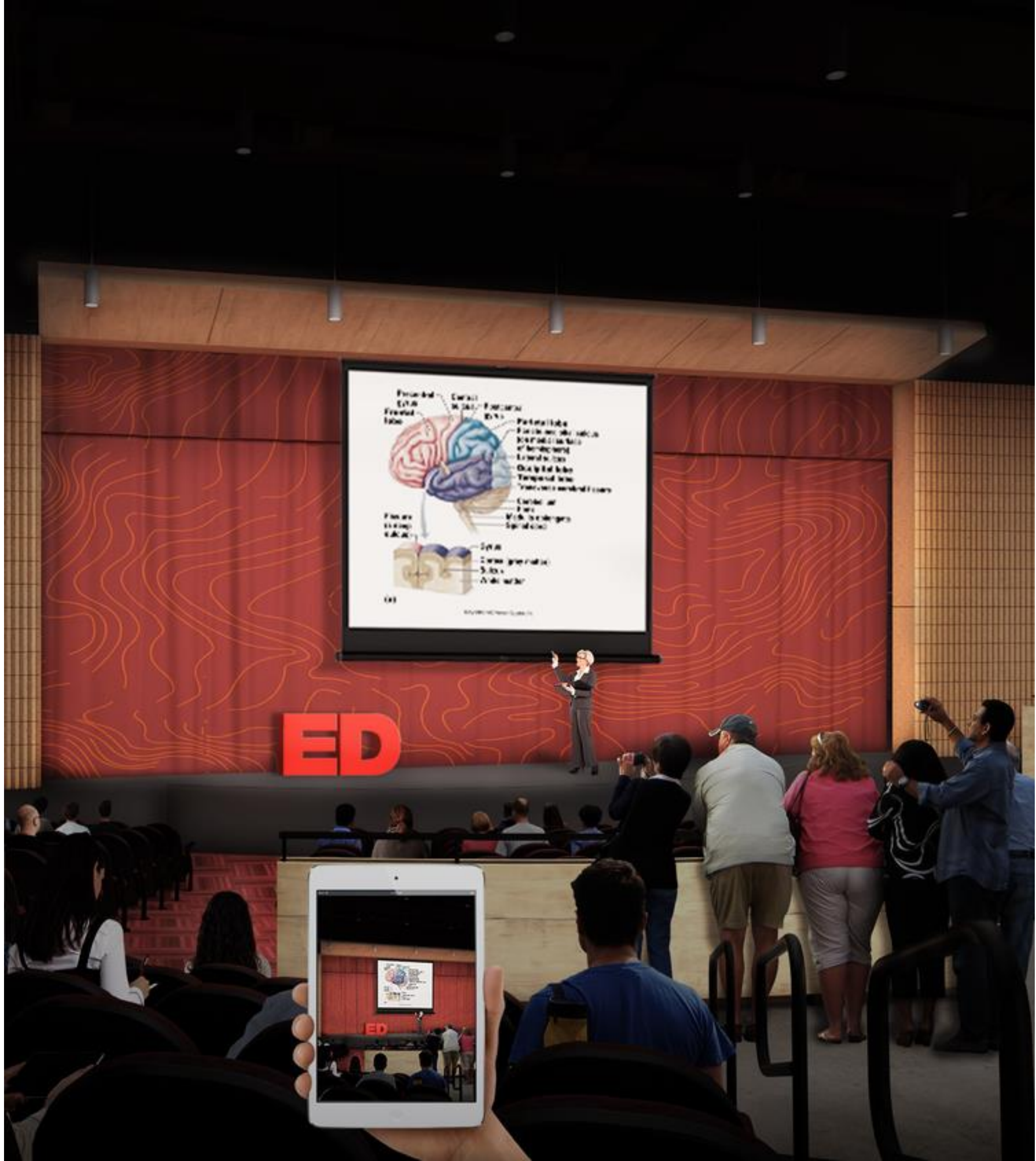
- Connect with new high school teachers
- Grow curriculum objective to span all four grade levels culminating in a senior research capstone project

Freshman
Introduction

Sophomore
Research

Junior
Experiment

Senior
Research Report

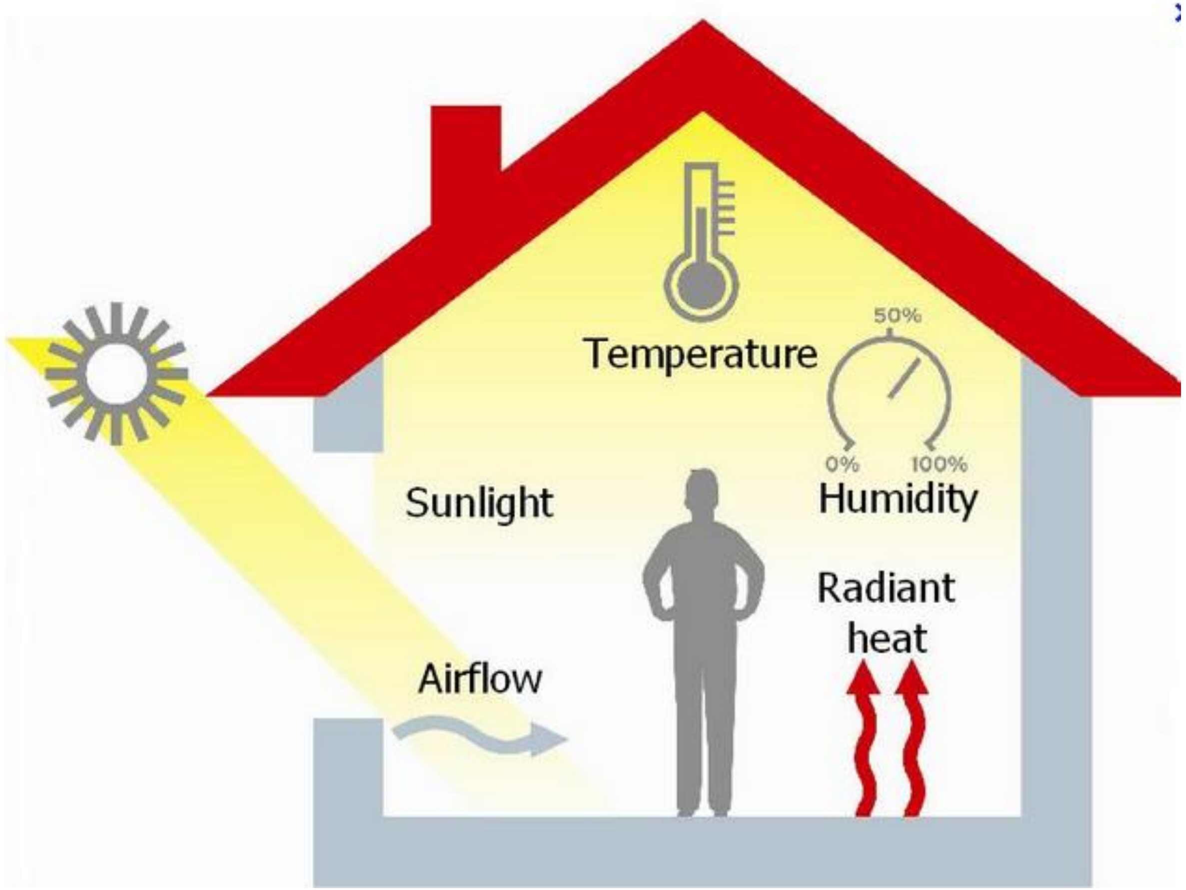


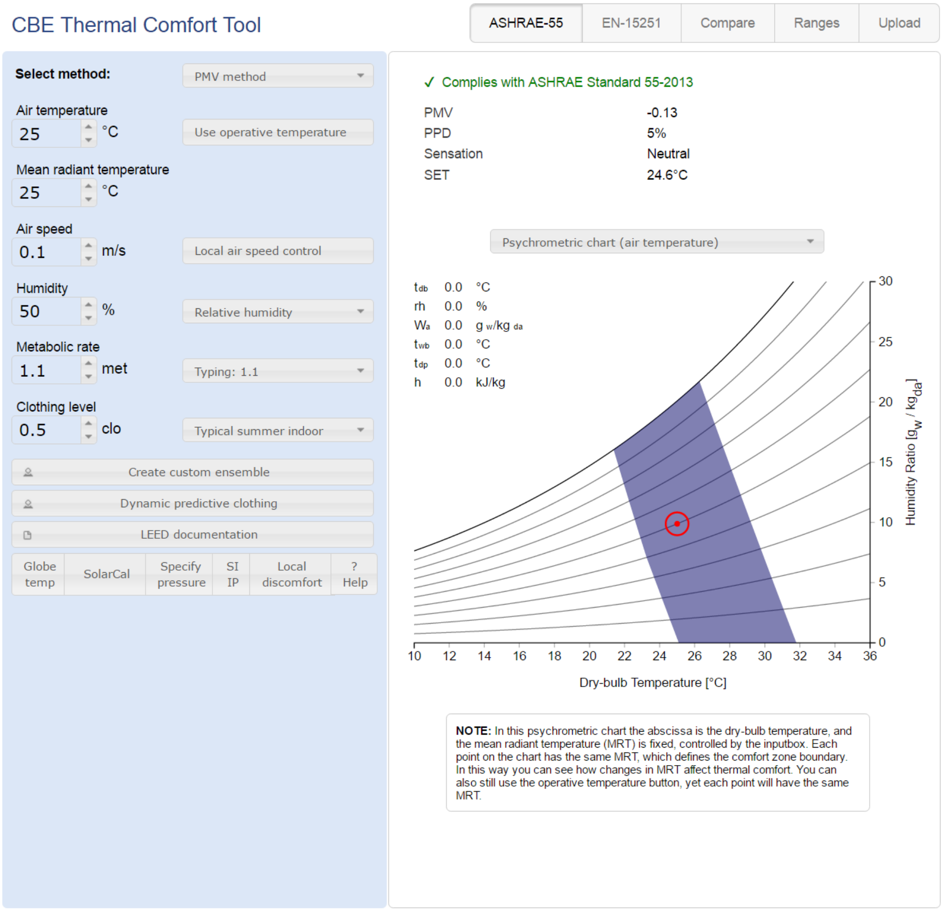
5

THERMAL COMFORT RESEARCH

Thermal Comfort Research

Factors





Source: Alam Peudeung

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Criteria

OPERATIVE TEMPERATURE = $\frac{\text{AIR TEMPERATURE + MEAN RADIANT TEMPERATURE}}{2}$

+

PREDICTED MEAN VOTE VIA THERMAL COMFORT SURVEY

=

COMPLY WITH AHRAE 55-2010

Thermal Comfort Research

Sensors

Thermal Comfort Research

Cycle

Cooling Mode

- Charge – release heat
  - Night flushing through dedicated outdoor air system
- Discharge – absorb heat
  - People, equipment, lights and solar radiation during the day

Heating Mode

- Charge – absorb heat
  - Charges during the day
- Discharge – release heat
  - When building cools off during night, releases heat instead of using HVAC system
- Benefit but not the driving factor

Real Time Data
During Construction

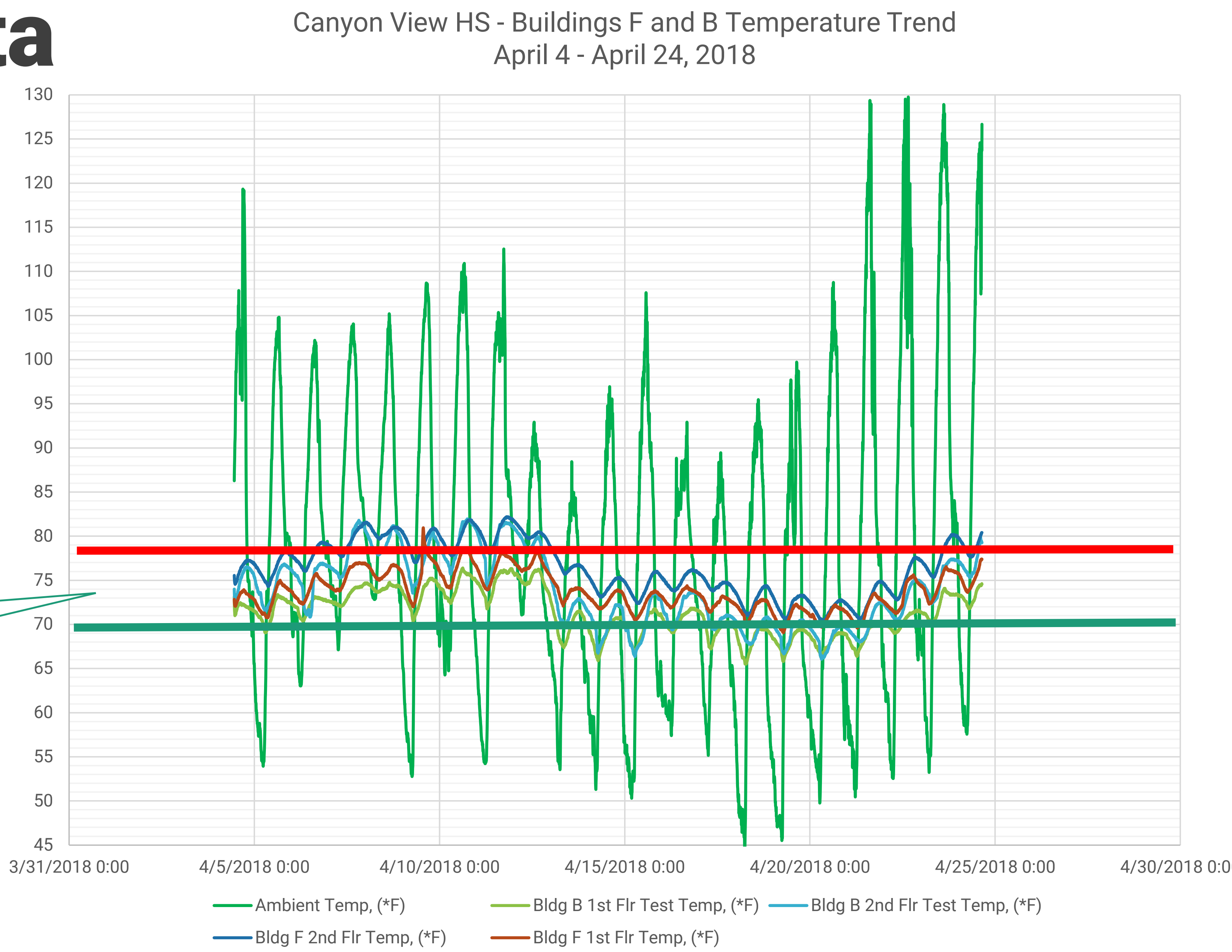
Real Time Data

During Construction

Delta between Test & Control

- First Floor
  - 2.48 deg F
- Second Floor
  - 2.56 deg F

BioPCM Latent Range



Q & A

- Is “Thermal Mass” part of your conversation for building design?
- Do you night purge?
- Is “Thermal Comfort” important to you?