Passive Thermal Energy Storage in Acoustical Ceilings using Phase Change Materials

Thursday, October 2nd | 2025 REBUILD Conference

Armstrong®
World Industries

Passive Thermal Energy Storage in Acoustical Ceilings using Phase Change Materials

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Buildings of the Past & Buildings of Today

Before the advent of insulation ancient building techniques relied on Thermal Mass, which took us all the way up into the early 1900's. Insulation, wood, metal and glazing have all largely replaced the use of thermal mass in many of our modern buildings.

Ancient Building Methods – Thermal Mass

(Adobe Building – The Inn at Loretto, NM)

Modern Building Methods - Glass, Metal, Insulation

(Adobe Building, California)

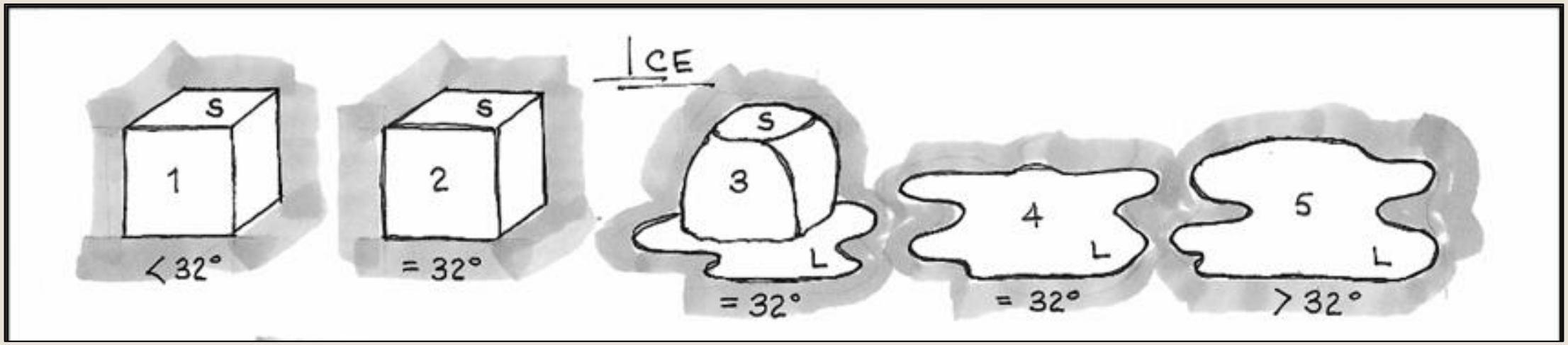
Grid Interactive – Energy Storage

Types of Energy Storage

Electric Storage

Thermal Storage

Phase Change Materials



When Ice (solid) is placed in an environment **ABOVE** 32F (0C) it **MELTS** and **absorbs** heat.

When Water (liquid) is placed in an environment **BELOW** 32F (0C) it **FREEZES** and **releases** heat.

FRONT of ceiling panel

BACK of ceiling panel

The Most Common Source of Dissatisfaction in Buildings

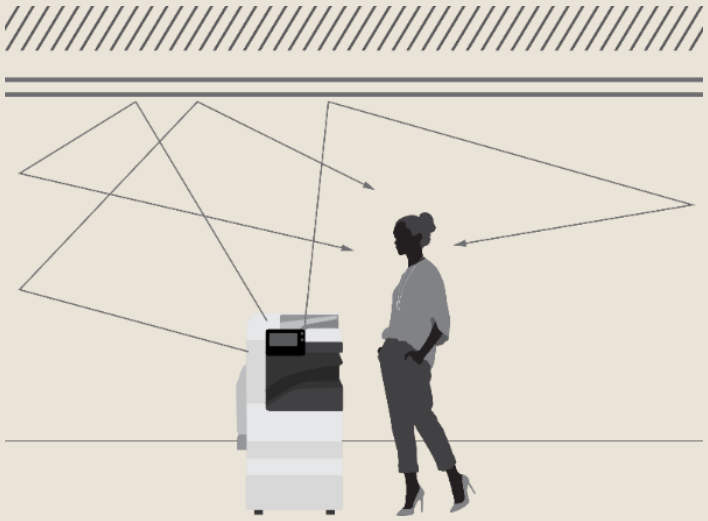
#1 Acoustics

#2 Temperature

Source: Occupant Dissatisfaction Survey (CBE); Schiavon, UC Berkeley, January 17, 2023

Acoustical Terms

Materials with a high Noise Reduction Co-efficient **(NRC)** dampen sound and those with a high Ceiling Attenuation Class **(CAC)** reduce sound transfer through ceilings.



NRC

CAC

Tax Credits

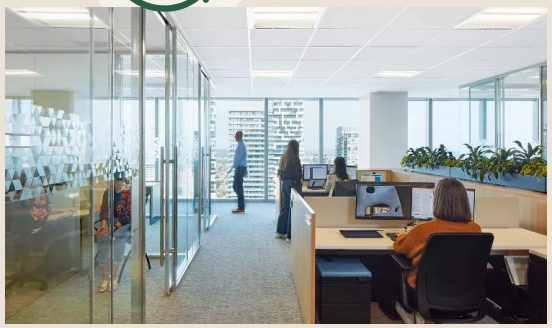
48E Federal Tax Credits

48E Investment Tax Credits

Who Qualifies?

Eligible Taxpayers including public and private sector segments

Government Entities (Public)



Office, Retail etc. (Private)

501(c)(3) Charitable Organizations

Education (K-12, Higher Ed)

What is it? Think Solar.

PCM Ceilings may qualify for up to 50% in tax credits, similar to solar.

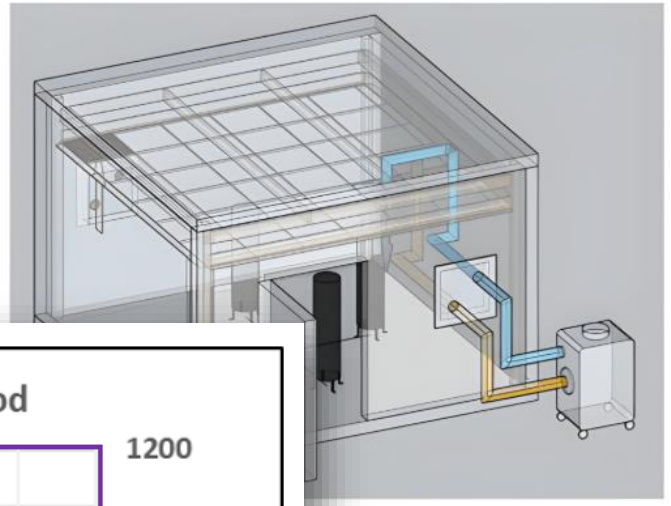
PCM Ceilings may qualify for Investment Tax Credits (ITC)

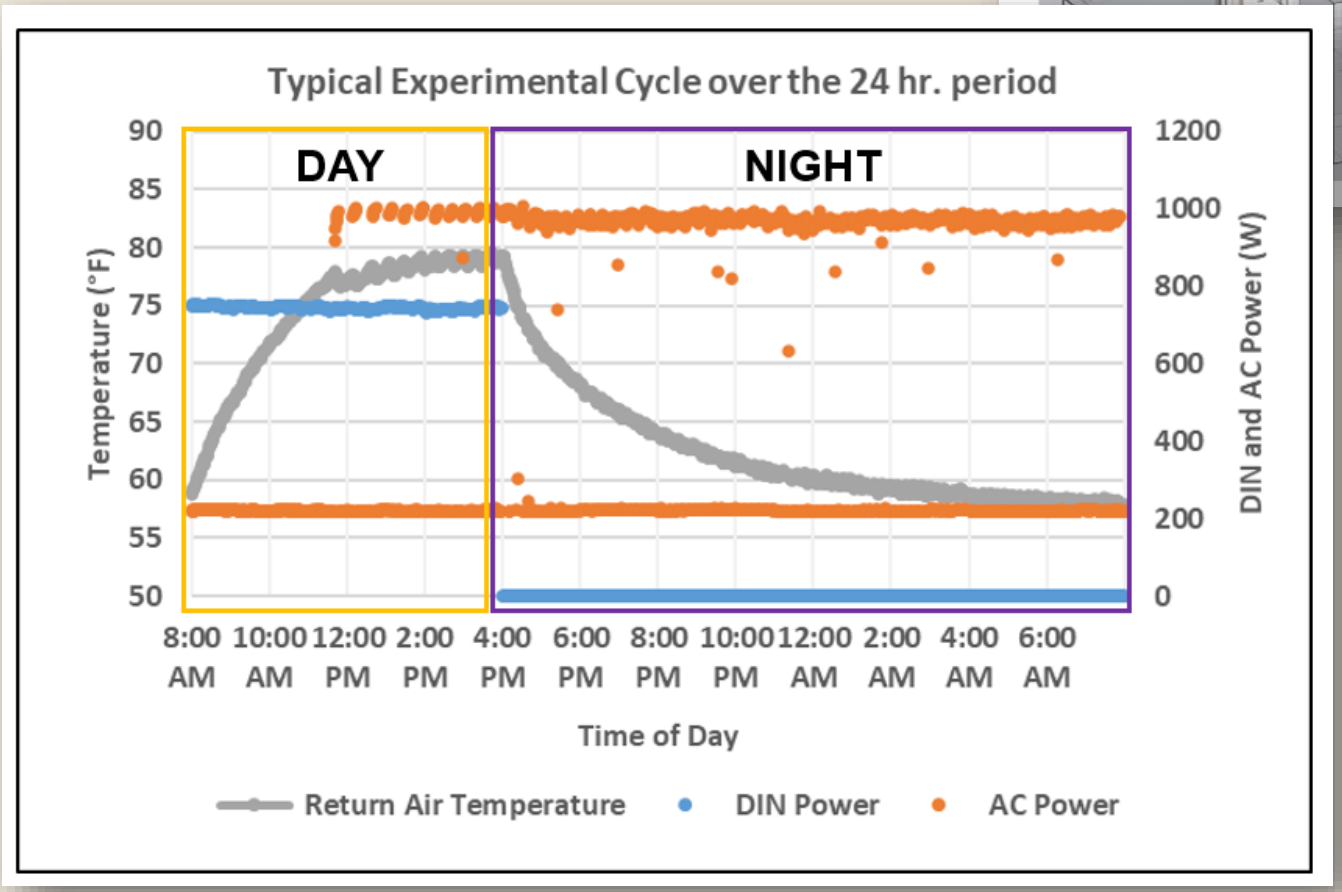

up to 50% in tax

Testing and Evaluation

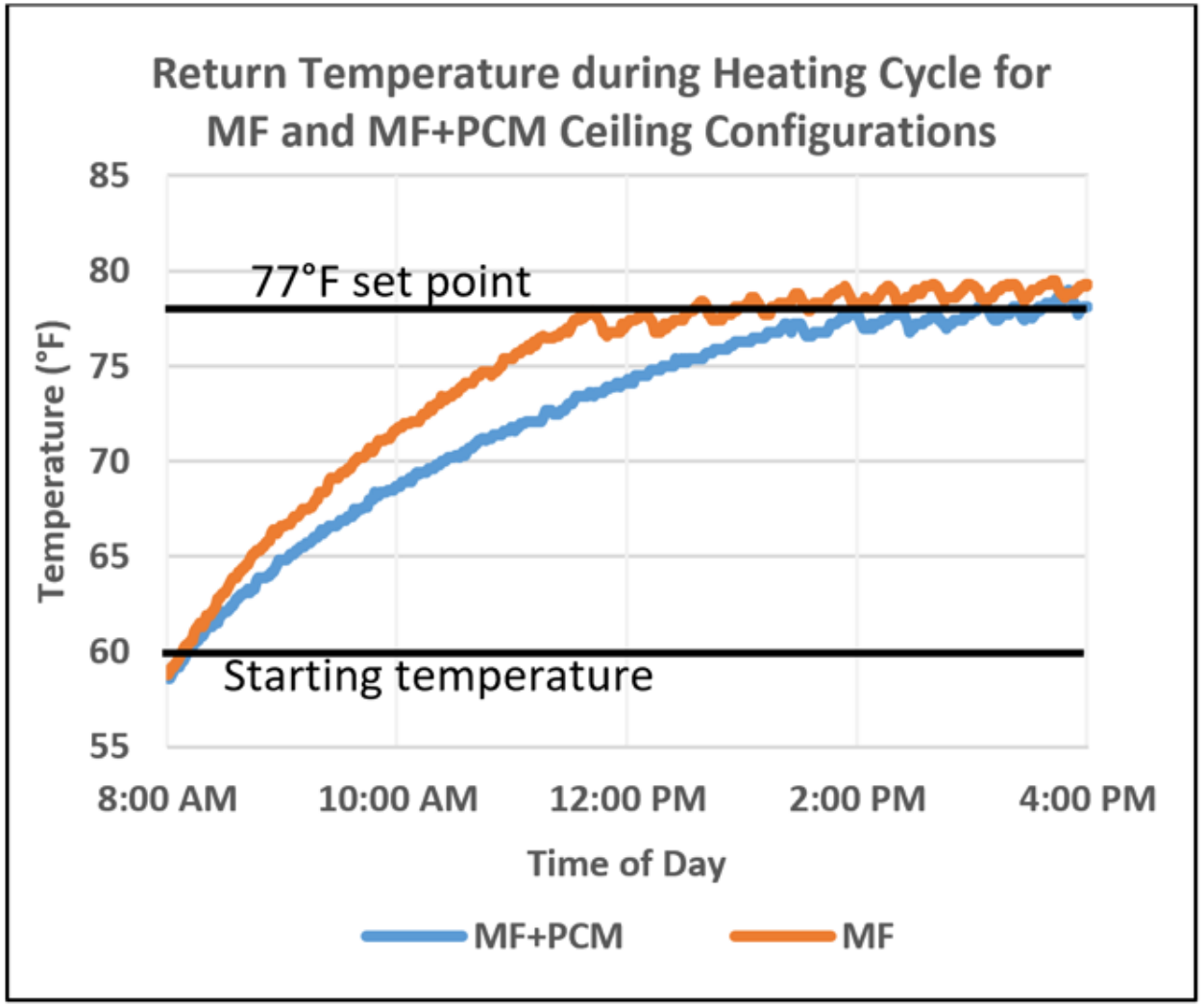
Measuring the capacity & potential for PCM

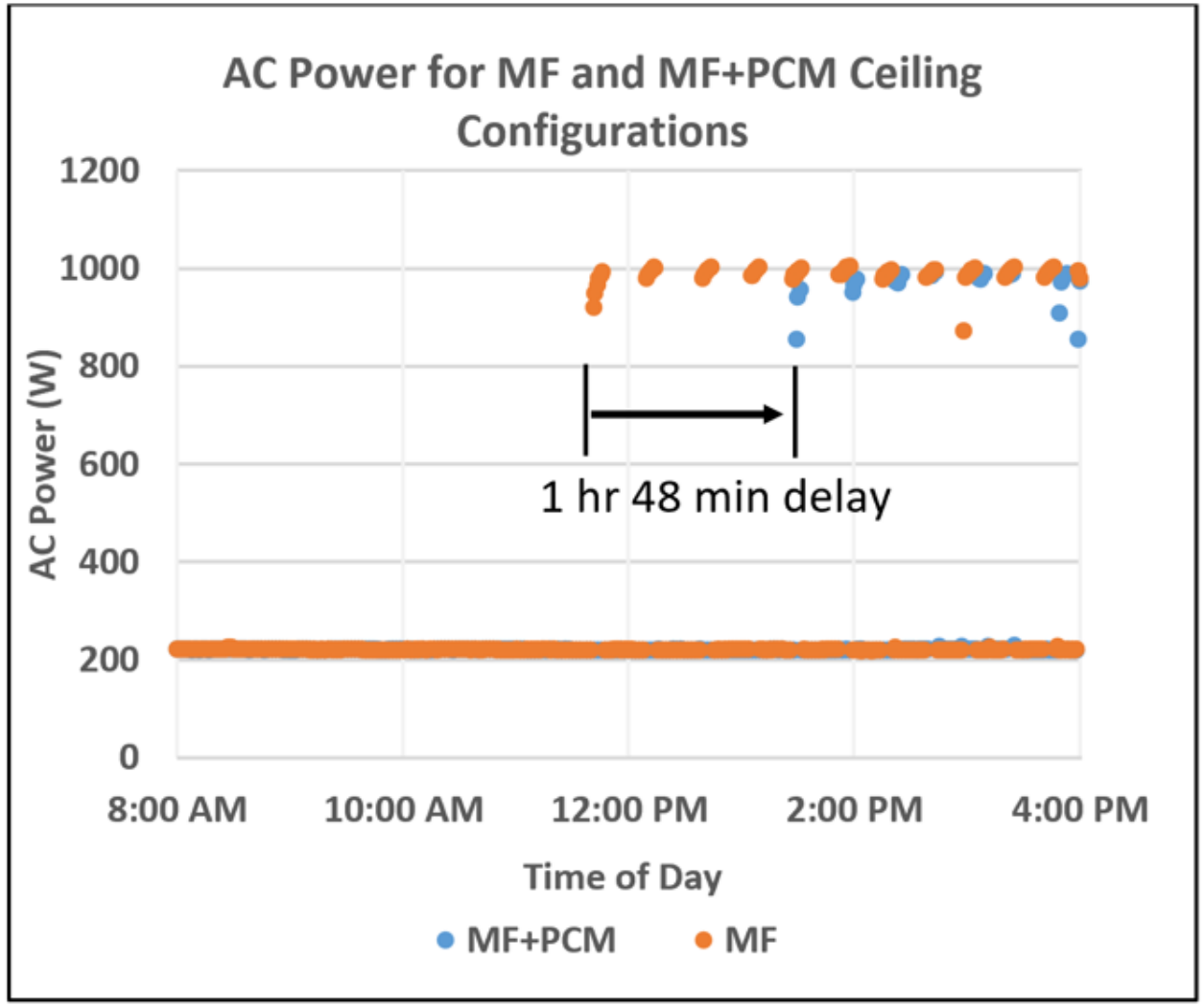
Thermal Chamber Testing





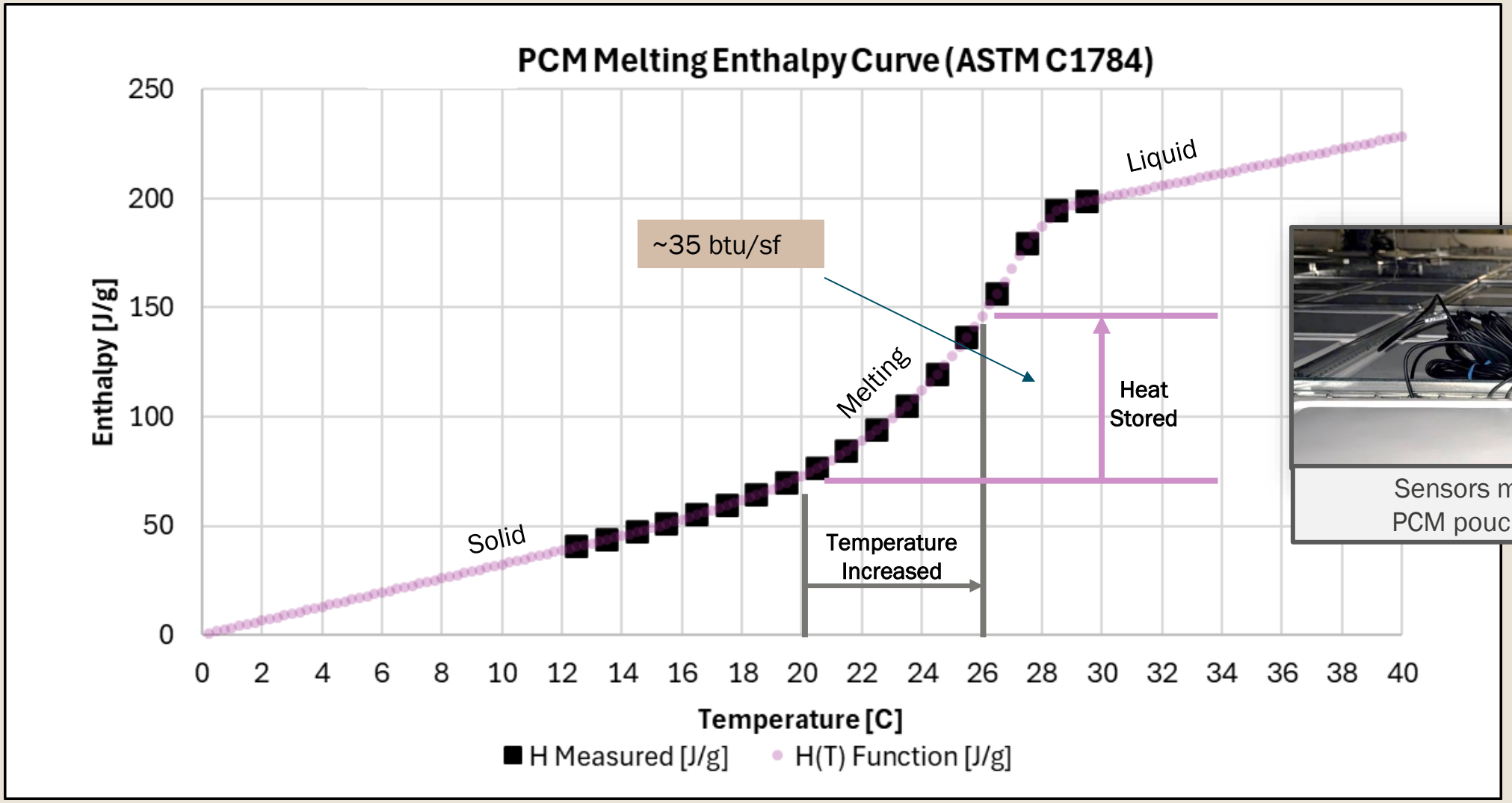
Thermal Chamber Testing

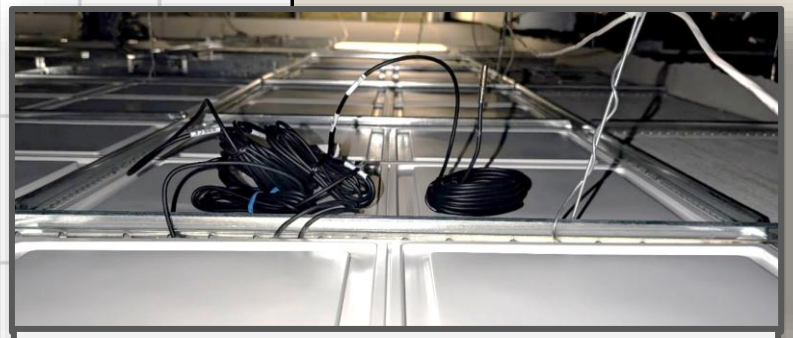




Heat Stored in PCM Tile

We estimate **how much heat the PCM is storing and releasing** by monitoring its temperature cycles.

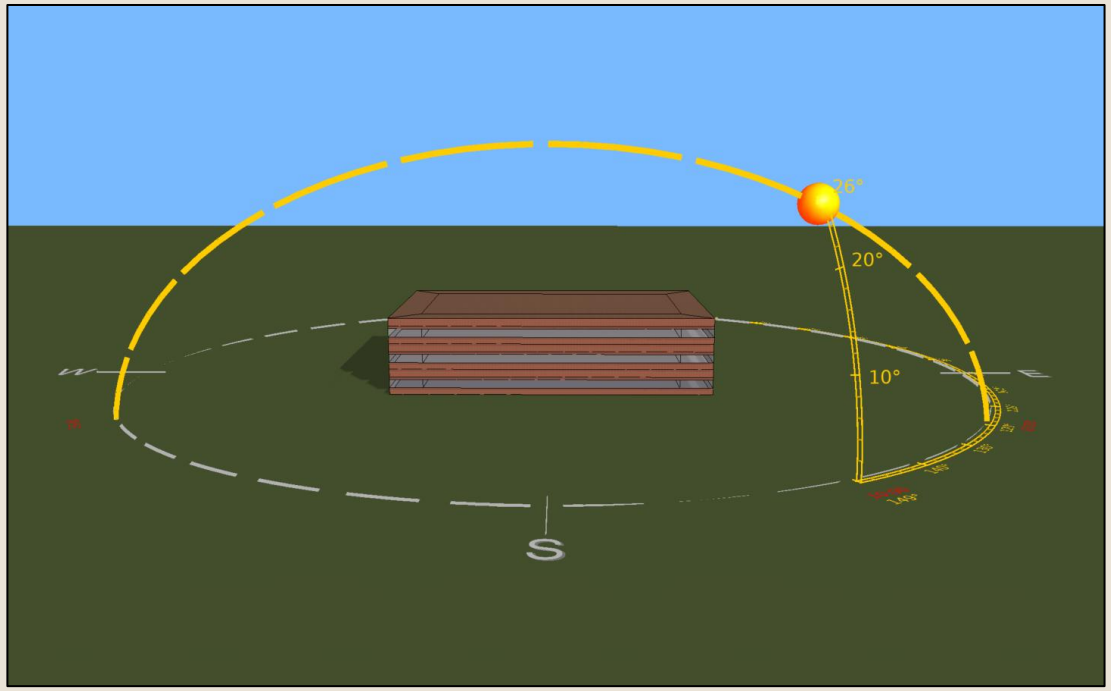




Sensors mounted above/under PCM pouch measuring heat flux

Bringing PCM Ceilings to Energy-Modeling Software

- Multi-State integration of PCM Ceilings and phase change material into the IES Virtual Environment (IESVE) software
- IESVE Parametric Simulation feature analyzes
  - Energy Consumption
  - Cost
  - Thermal Comfort



Modeling Study

Denver, CO Small Office

Sample Office Building

~14,000 square feet, single story

Denver, CO (Climate Zone 5B)

Envelope ASHRAE 90.1-2019 compliant

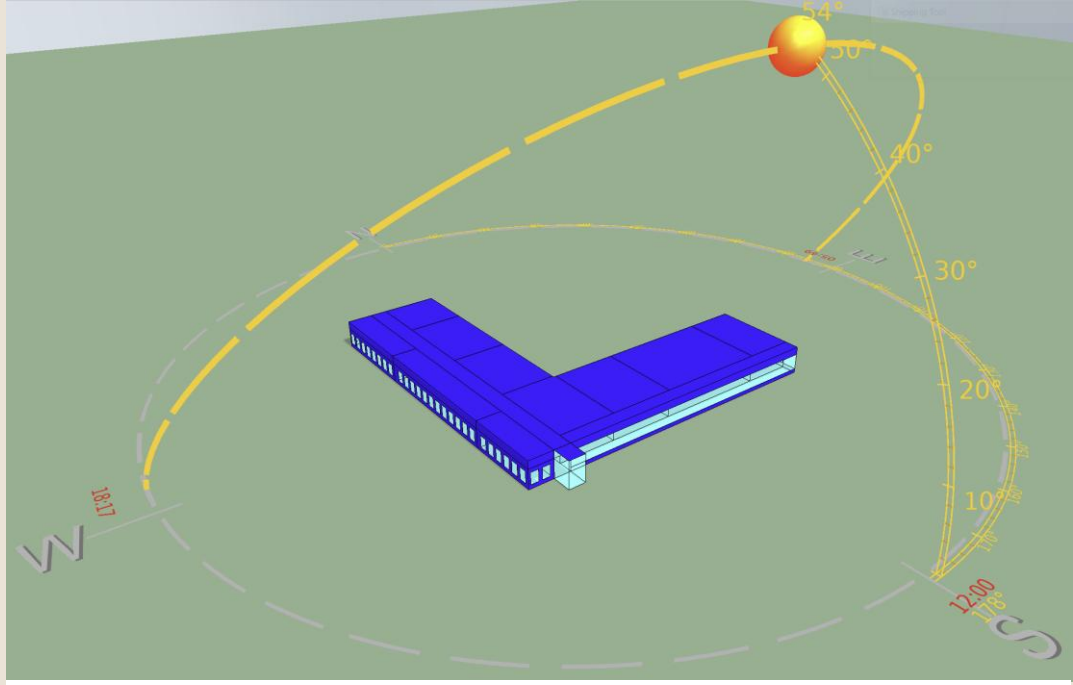
33% Window-to-wall ratio

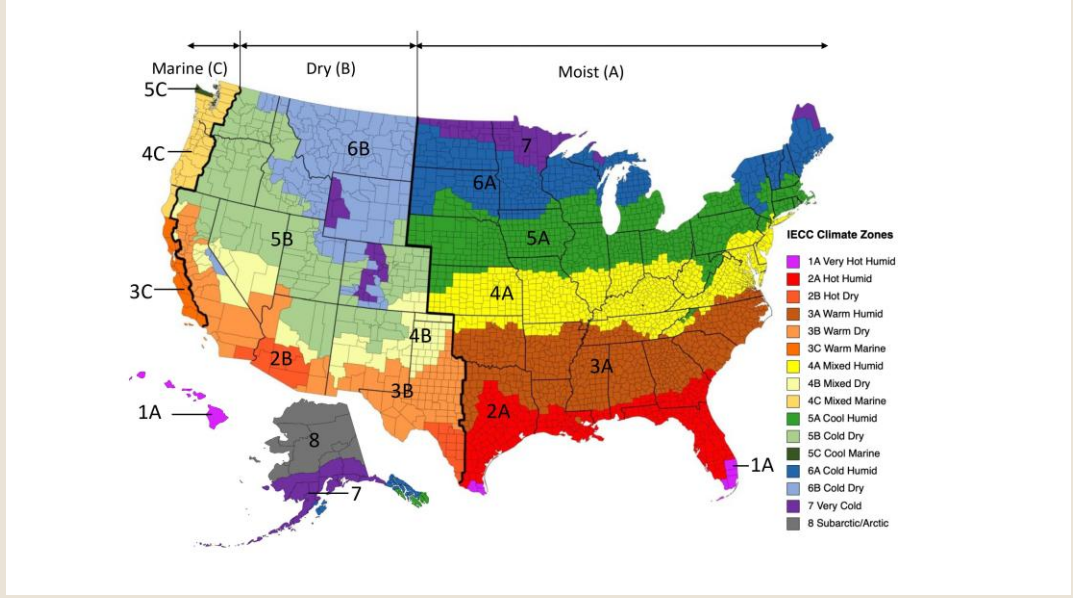
0.6 W/SF Lighting Power Density

1.25 W/SF Receptacle/Computers

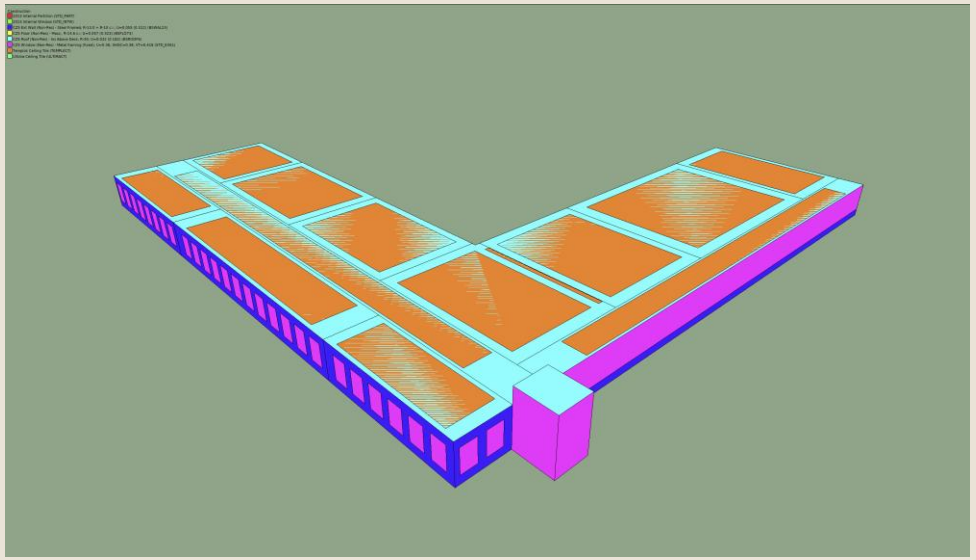
VAV system, air-cooled DX, air-source heat pump, back-up electric heat

- (meets requirements of Energize Denver to eliminate methane gas)





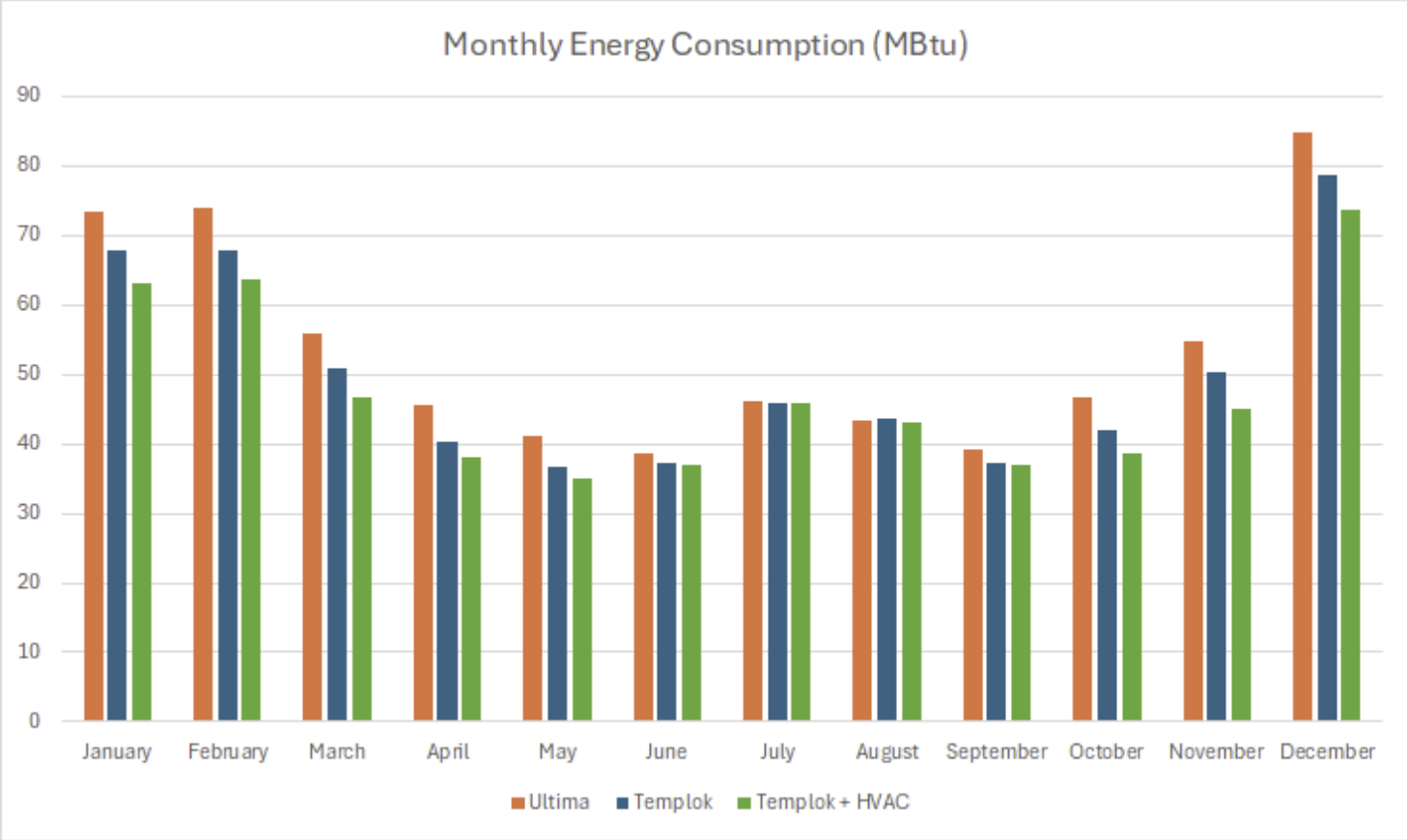
Iterations

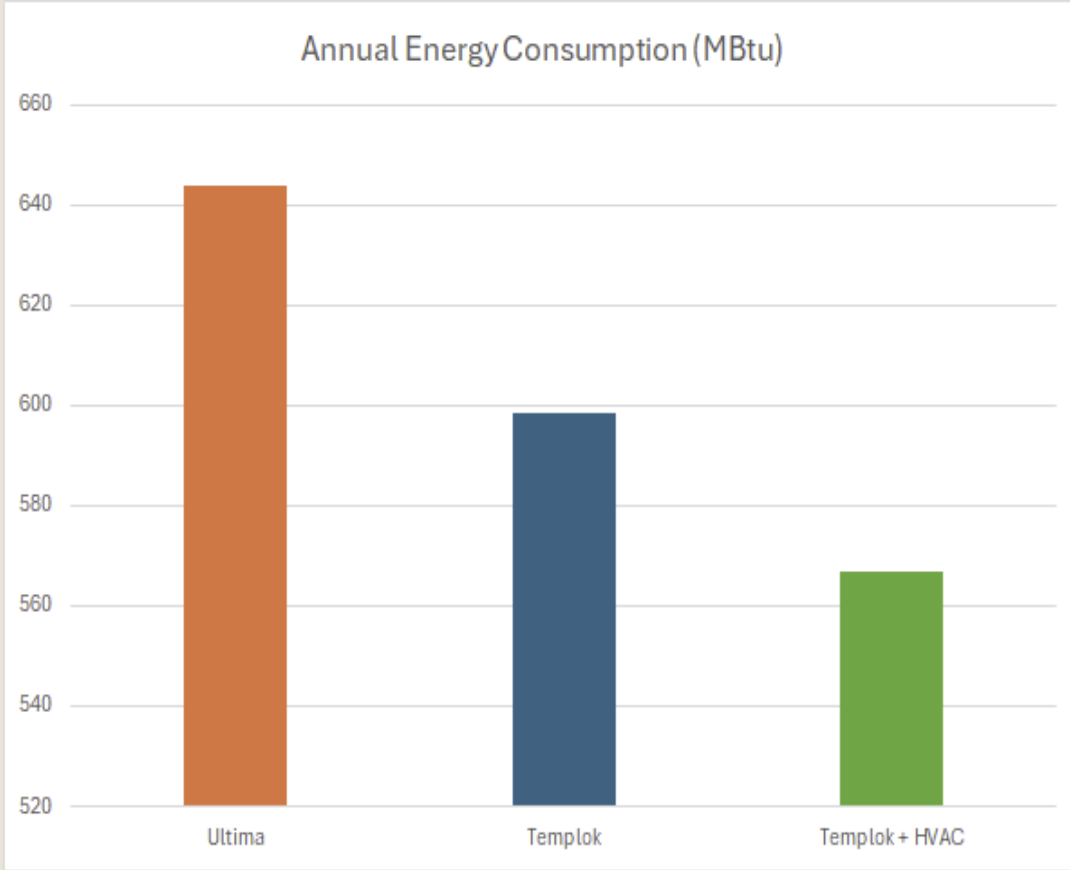


All inputs remain the same, except:

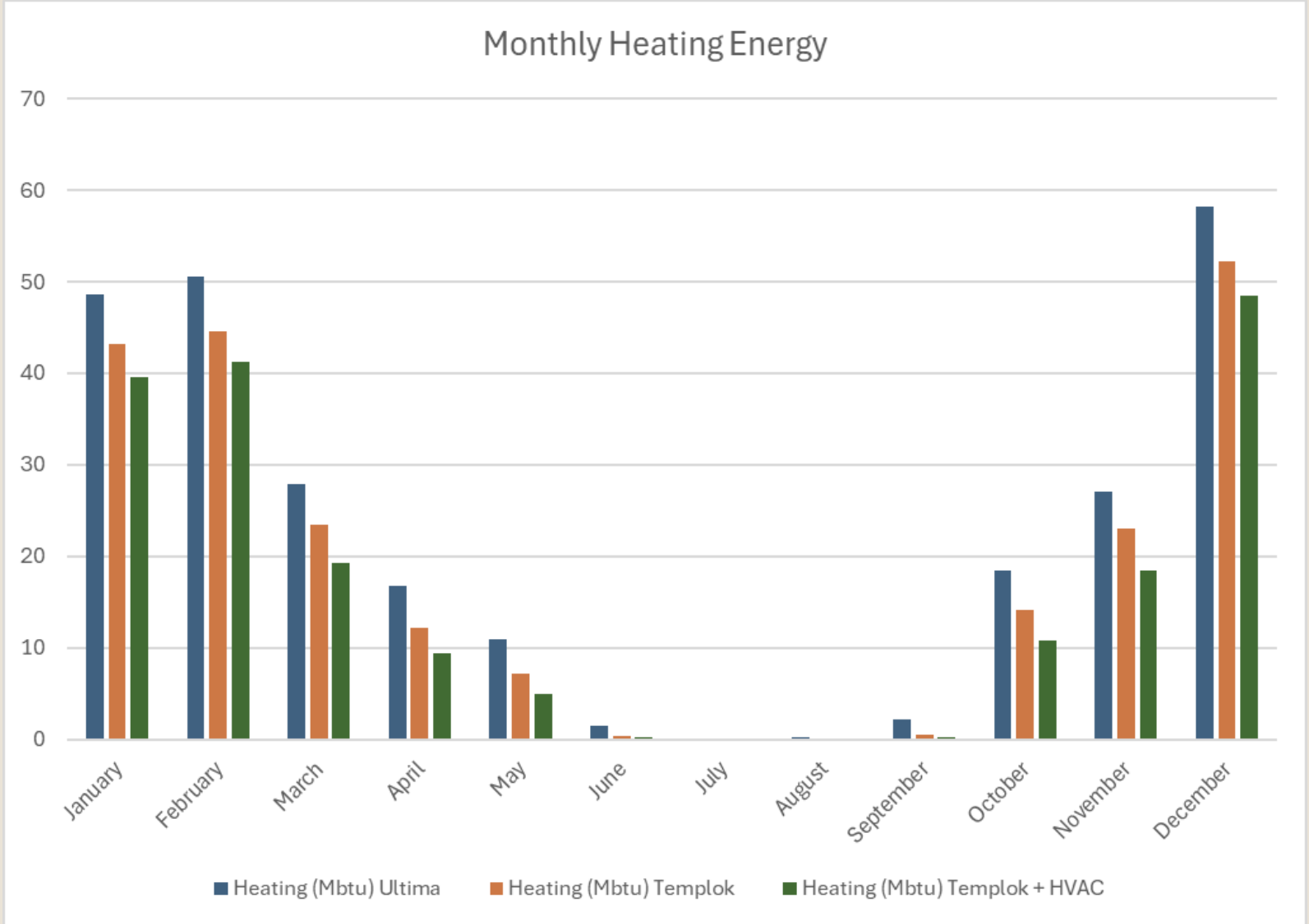
Base Case (90.1-2019)	Iteration 1	Iteration 2
"Typical" Ceiling Tile	PCM Ceiling Tile (70%)	PCM (70%) + HVAC controls
EUI = 45	EUI = 42	EUI = 40
Energy Savings = N/A	Energy Savings = 6.7%	Energy Savings = 11.9%

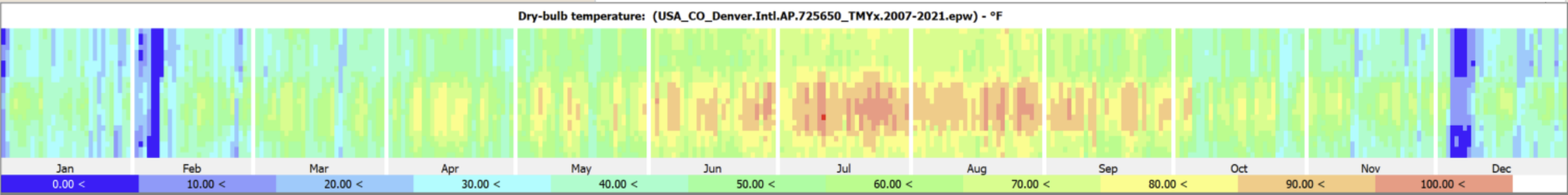
Whole Building Energy Results



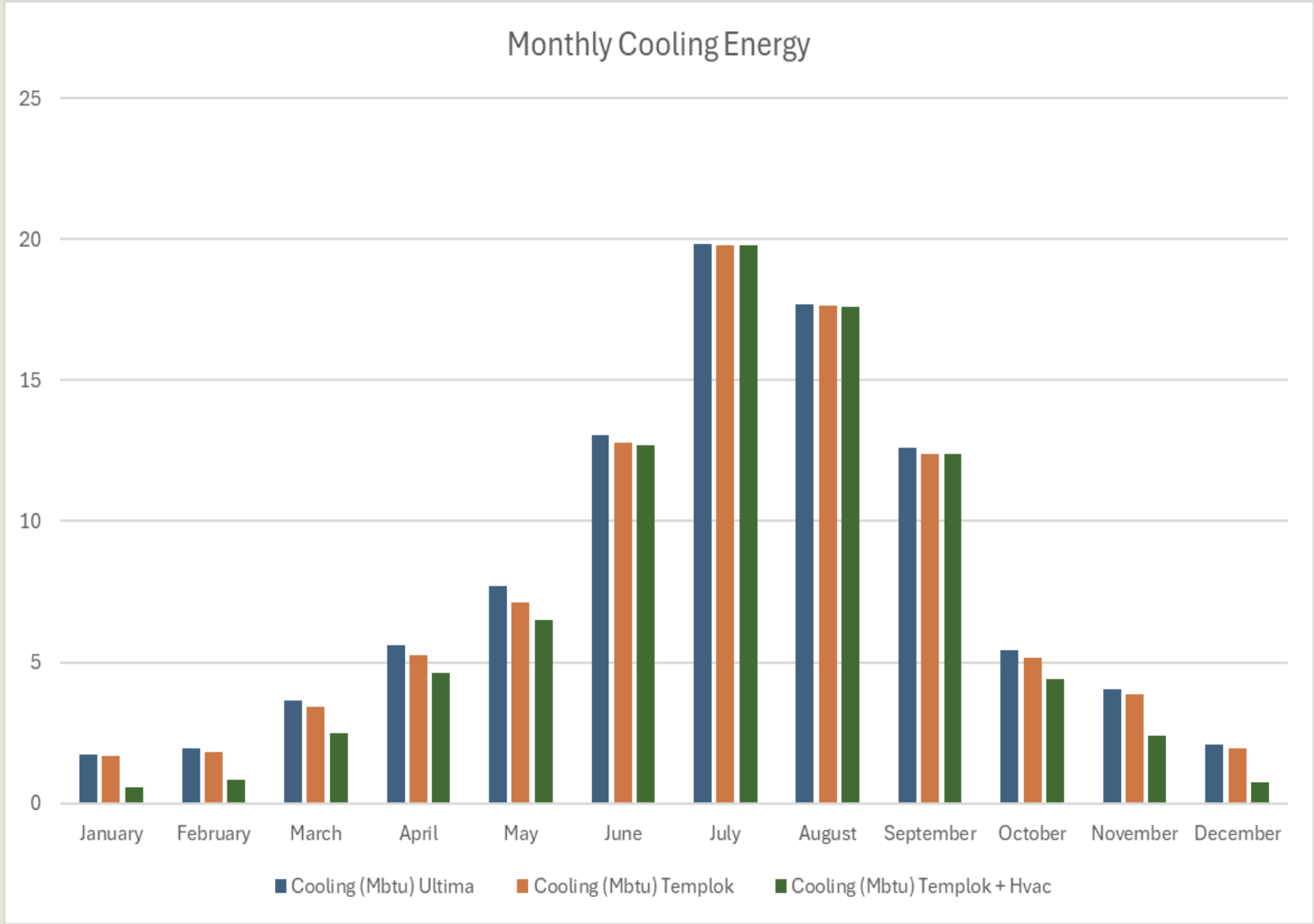


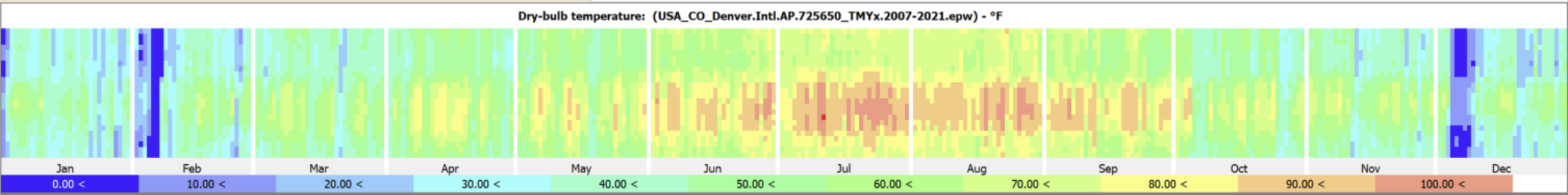
Heating Energy Reduction





Cooling Energy Reduction

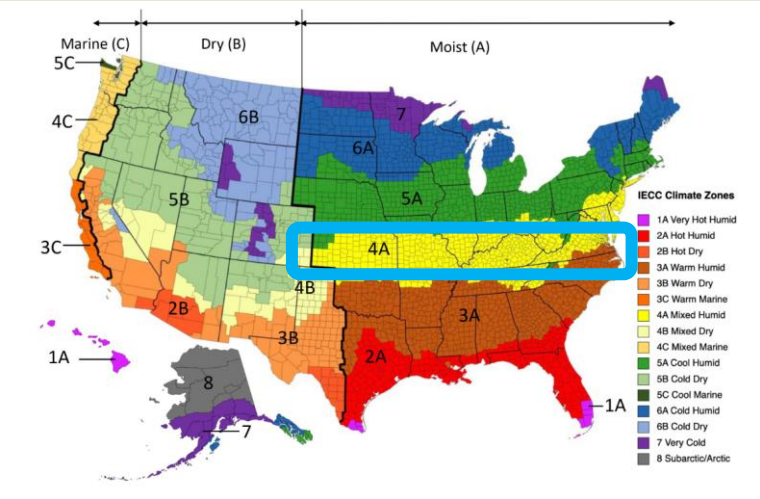




Modeling Study

Climate Zone 4A/5A

Climate Zone 4A - Healthcare

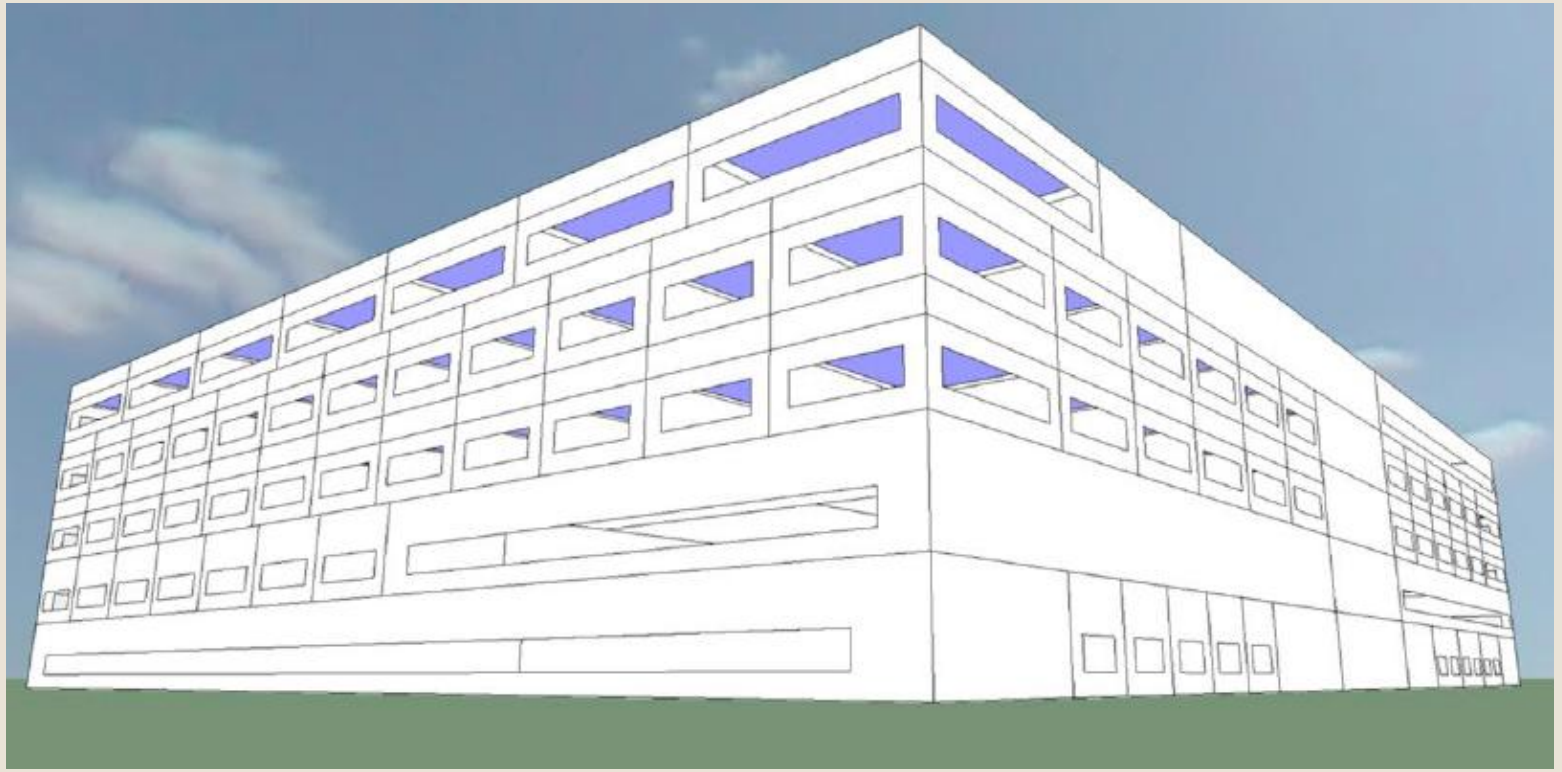


Climate Zone
IECC Climate Zone 4A (Mixed-Humid)

Building Type
Hospital
(241,500 ft², 5 stories + basement)

Retrofit
Ultima Templok ceiling tiles in upper-floor patient rooms and offices with high heat gains (26,550 ft²)

Standards Referenced
ASHRAE 90.1-2007 Appendix G
(Baseline specifications)



Model Characteristics

Building Model Details

Floors
5 + basement

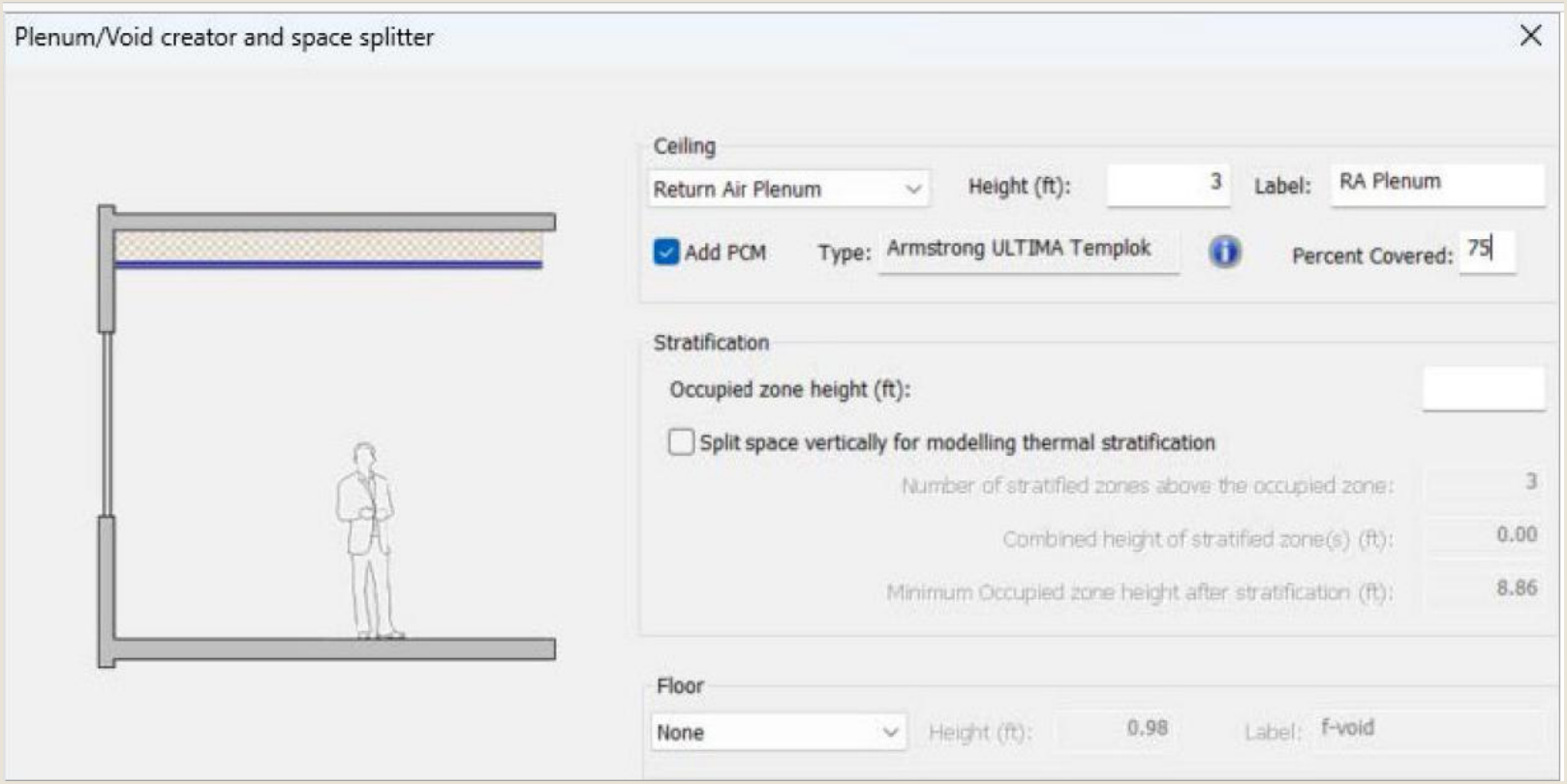
Occupancy Schedule
24/7

Occupied Setpoints
75°F Cooling; 69°F Heating

Unoccupied Setbacks
80°F Cooling; 60°F Heating

Building Envelope
ASHRAE 90.1-2007 Appendix G compliant insulation and glazing

Retrofit
Ultima Templok ceiling tiles in upper floor patient rooms and offices with high heat gains



Cooling

Figure A

Sensible Cooling Load by Hour

5th Floor Corner Office on April 22

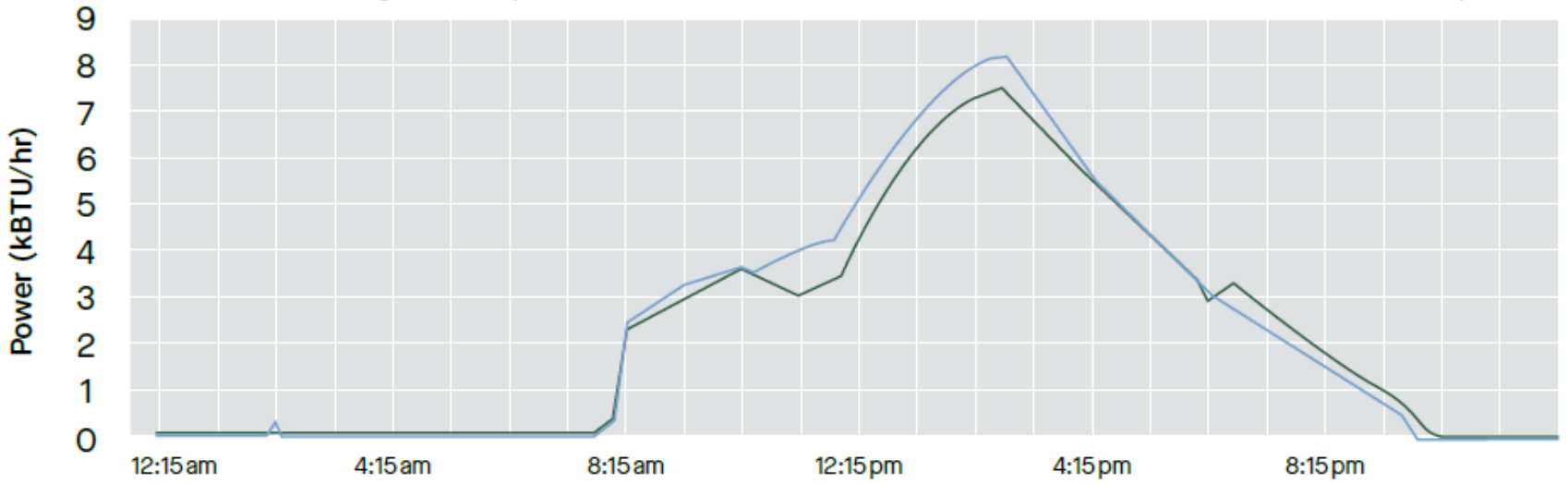
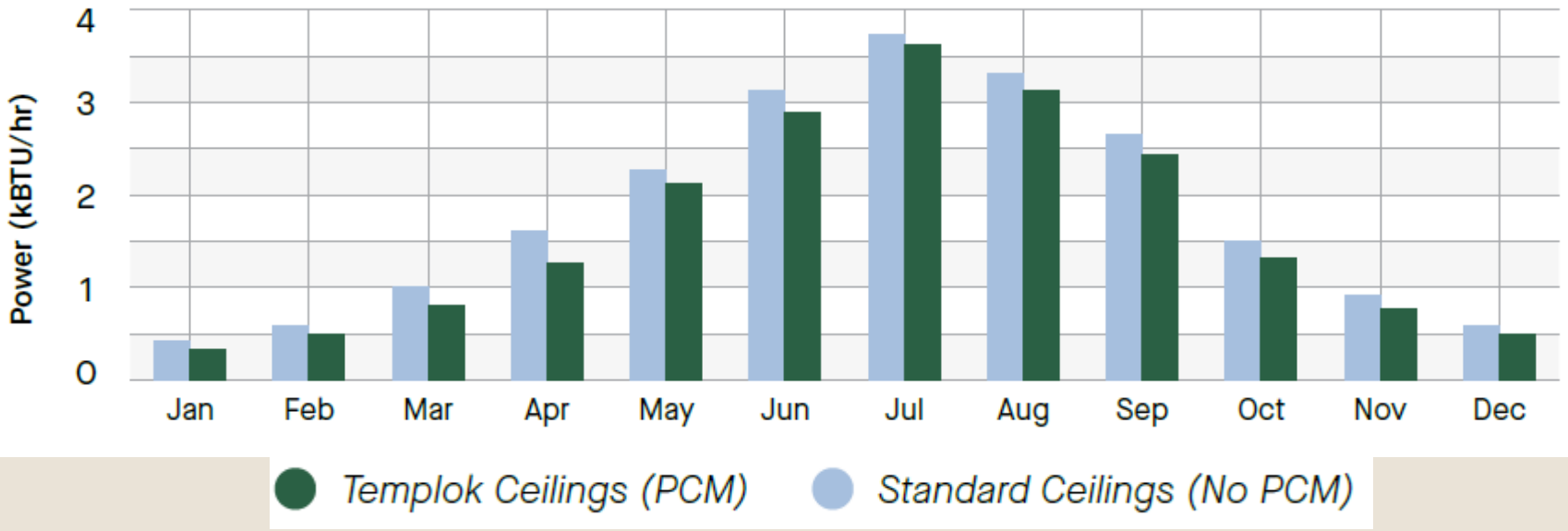


Figure B

Average Sensible Cooling Load By Month

3rd/4th/5th Floor Patient Rooms & Offices



Heating

Figure C

Sensible Heating Load by Hour

5th Floor Corner Office on April 22

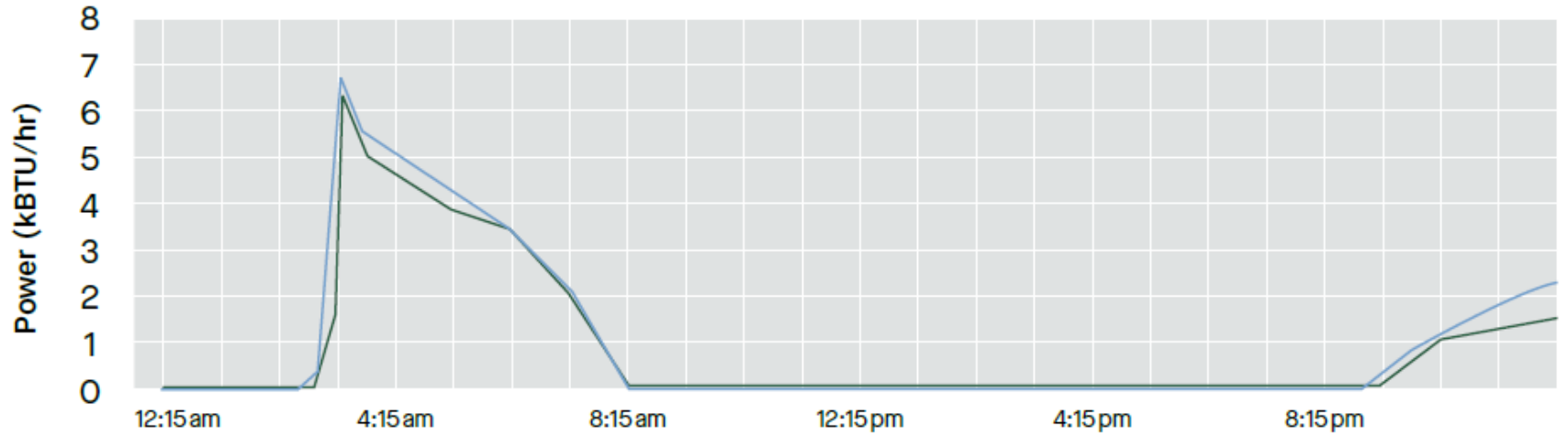
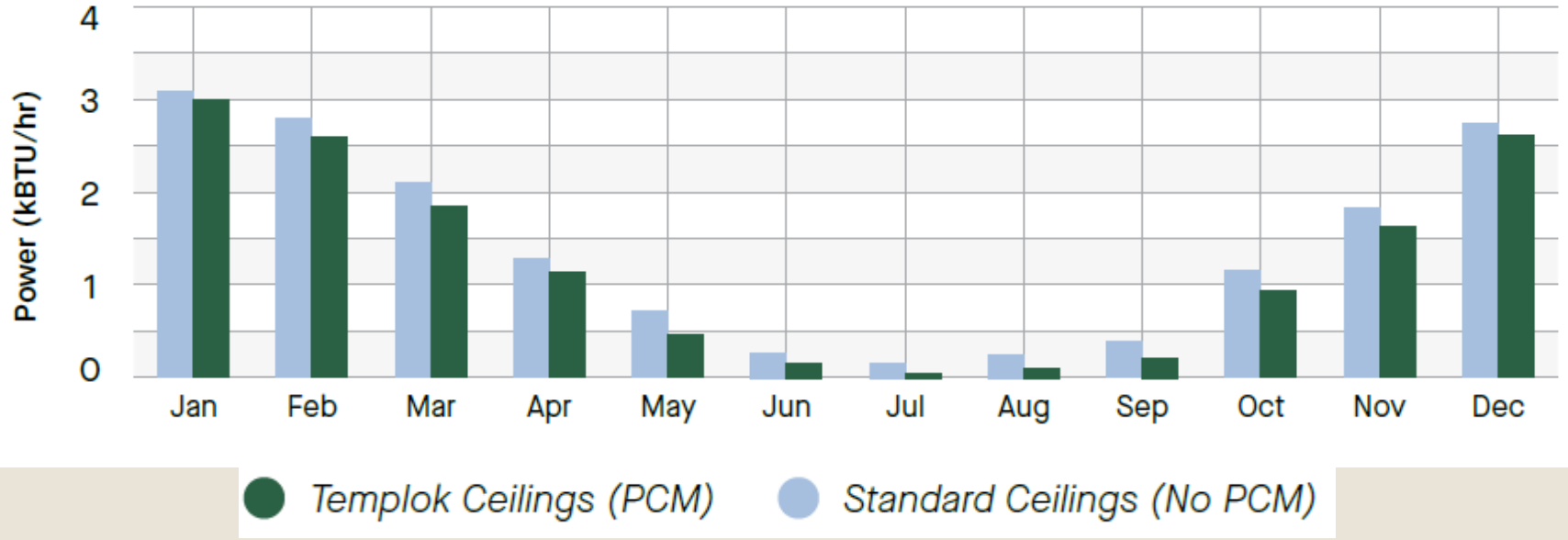


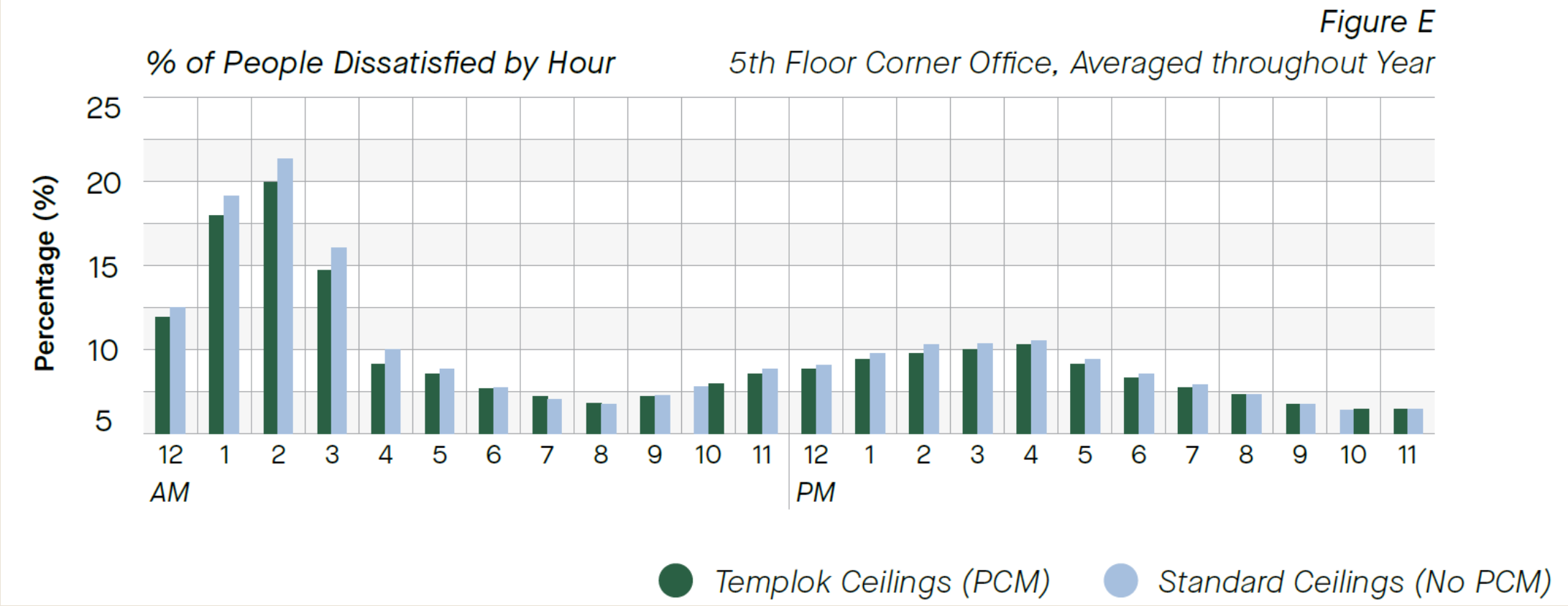
Figure D

Average Sensible Heating Load By Month

3rd/4th/5th Floor Patient Rooms & Offices



Thermal Comfort in Healthcare



Summary of Results

Annual Simulation Result

Electricity - 4¢/ft²-yr

Natural Gas - 3¢/ft²-yr

Demand Charges - 1¢/ft²-yr

9% Reduction in Heating Loads

4% Reduction in Cooling Loads

5% Reduced Percentage of People Dissatsified

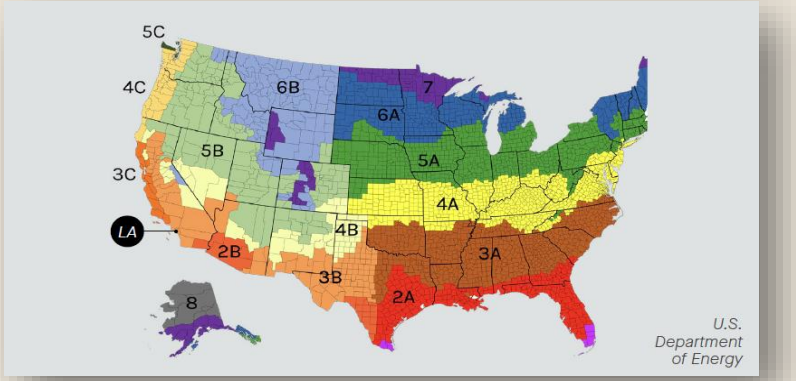
Energy Savings of
8¢ per sq.ft. of Templok

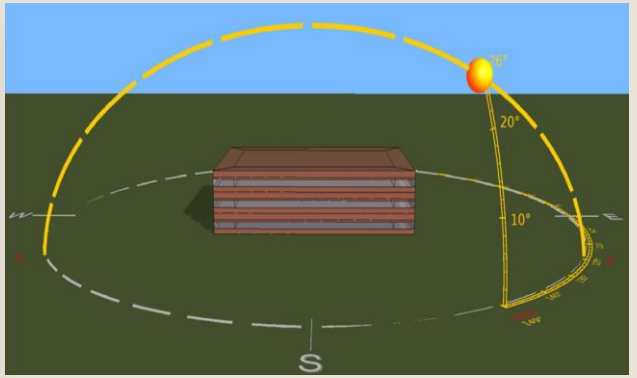
Fewer people thermally dissatisfied throughout the year in corner office with Templok Ceilings

Modeling Study

Climate Zone 3B

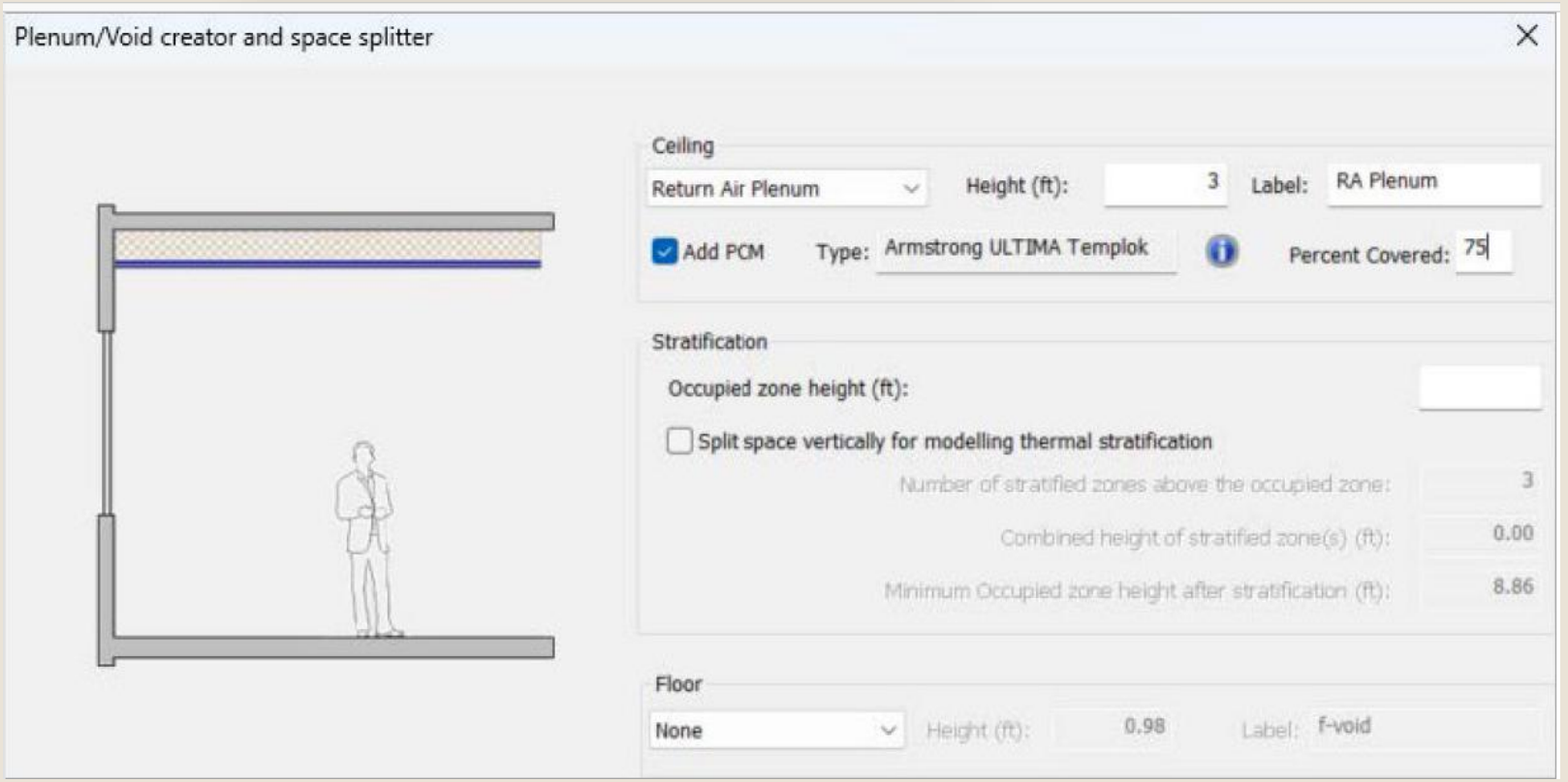
LA Model Study



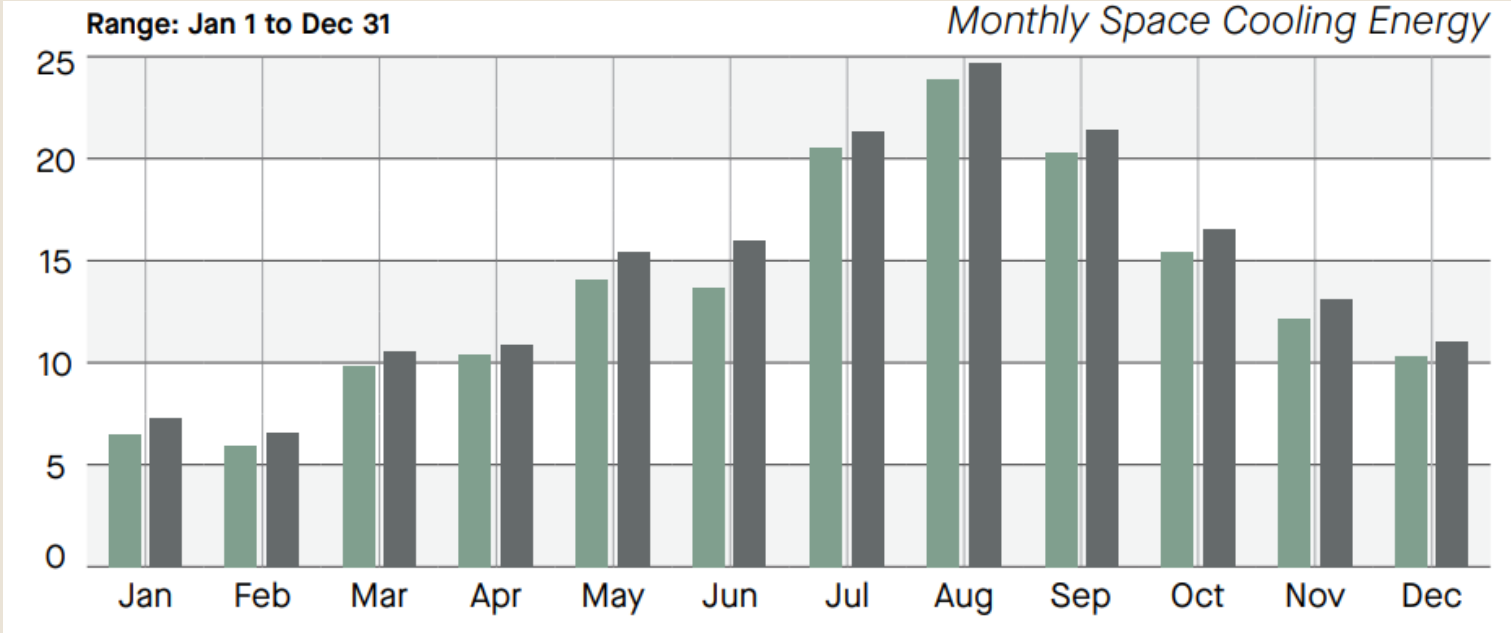


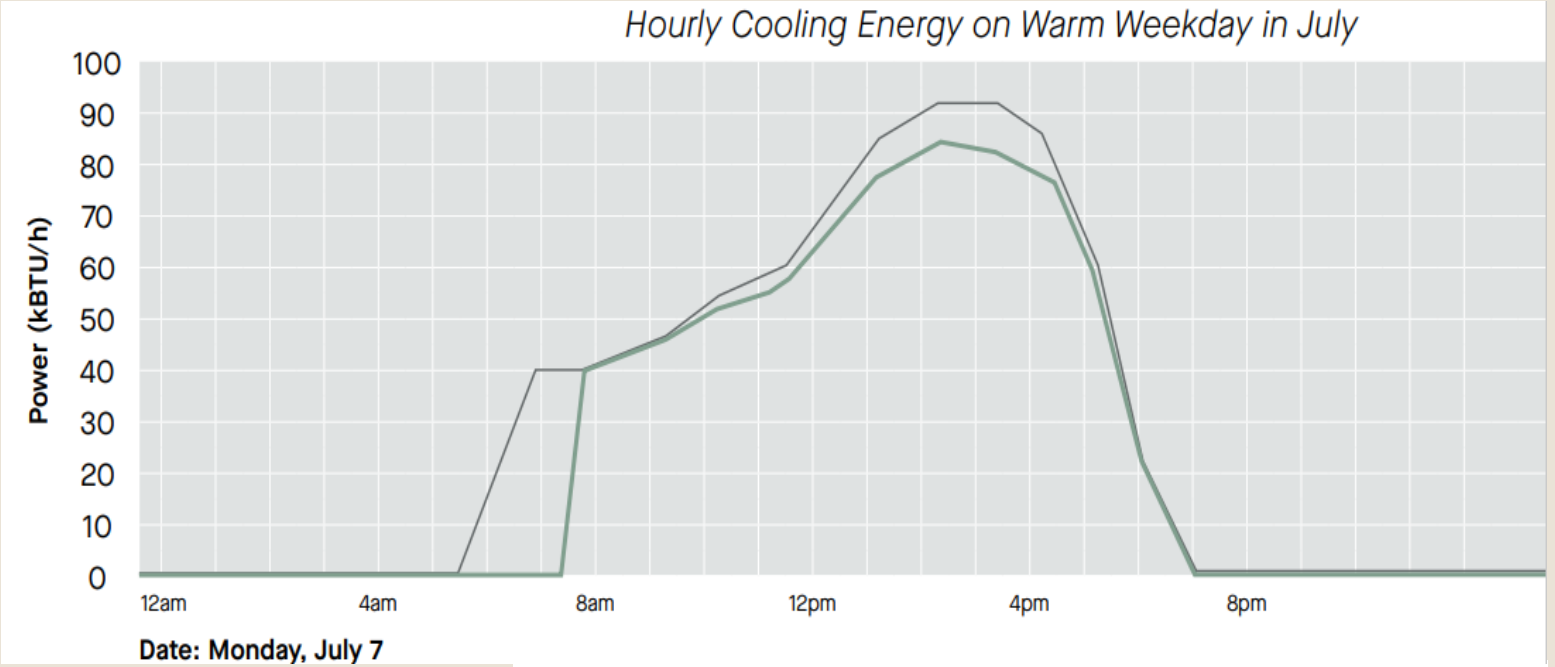
Building Model Details

- **Baseline model:** Department of Energy's medium office building
- **Total Area:** 53,660 ft²
- **Floors:** 3
- **Occupied Hours:**
  8 am – 6 pm, *Monday – Friday*
  10 am – 5 pm, *Saturday/Sunday*
- **Occupied Setpoints:** 75°F *Cooling;* 69°F *Heating*
- **Setbacks:** 80°F *Cooling;* 60°F *Heating*
- **Baseline HVAC System:** Air Handling Units with direct expansion cooling and recirculation, variable air volume boxes with reheat coils, natural gas hot water loop per ASHRAE 90.1 Appendix G requirements
- **Building Envelope:** ASHRAE 90.1 Appendix G compliant insulation and glazing
- **Baseline Scenario:** Standard mineral fiber acoustic ceiling
- **Templok Scenario:** Ultima® Templok® tiles installed into 75% of the ceiling area

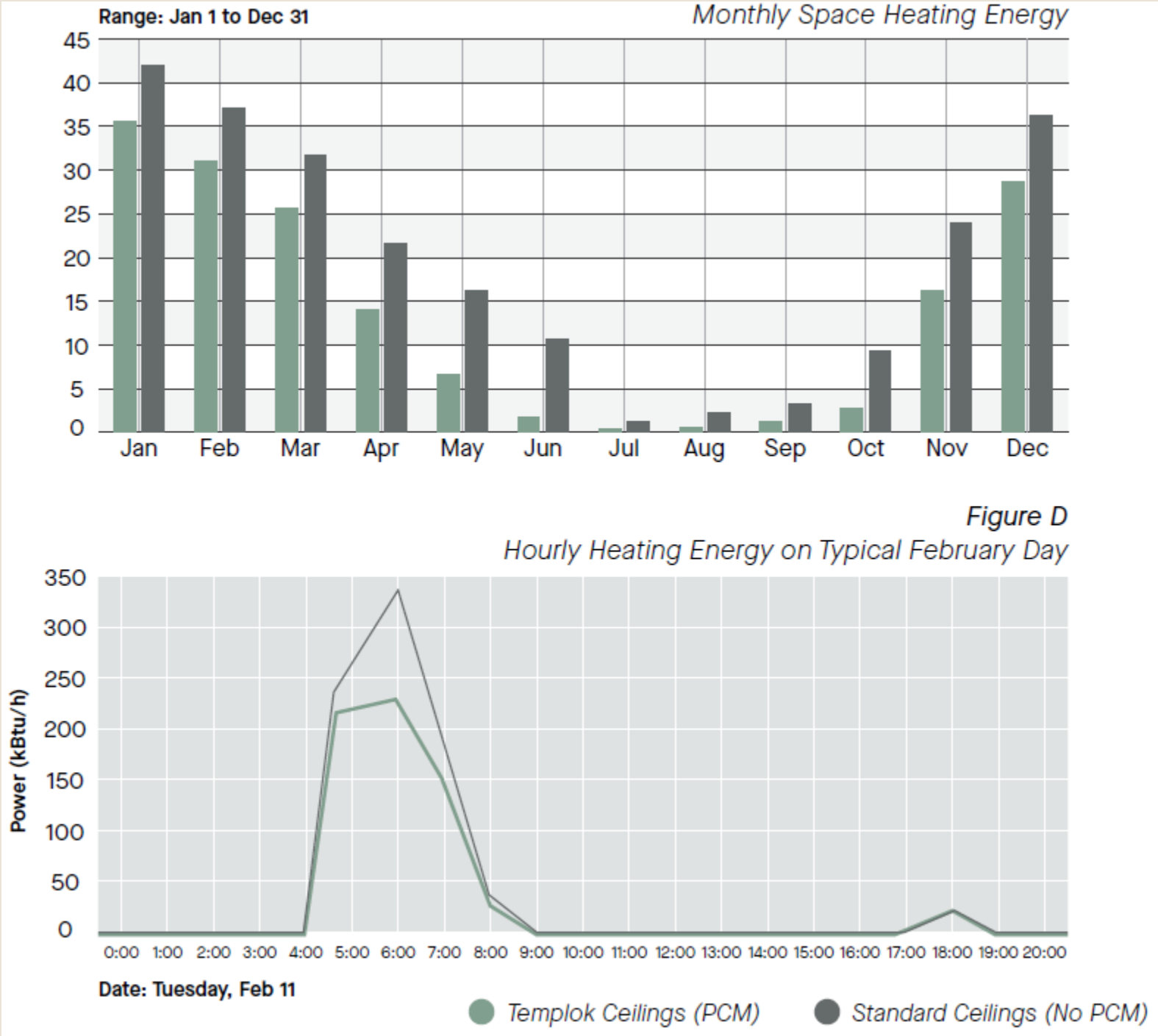


Cooling


Range: Jan 1 to Dec 31
Monthly Space Cooling Energy
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Hourly Cooling Energy on Warm Weekday in July
Power (kBTU/h)
100
90
80
70
60
50
40
30
20
10
0
12am
4am
8am
12pm
4pm
8pm
Date: Monday, July 7
Templok Ceilings (PCM)
Standard Ceilings (No PCM)

Heating


Range: Jan 1 to Dec 31
Monthly Space Heating Energy
45
40
35
30
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Figure D
Hourly Heating Energy on Typical February Day
Power (kBtu/h)
350
300
250
200
150
100
50
0
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00
Date: Tuesday, Feb 11
Templok Ceilings (PCM)
Standard Ceilings (No PCM)

Diurnal Temps and HVAC Demand

Figure E

Diurnal Temperature Swing on Winter Day

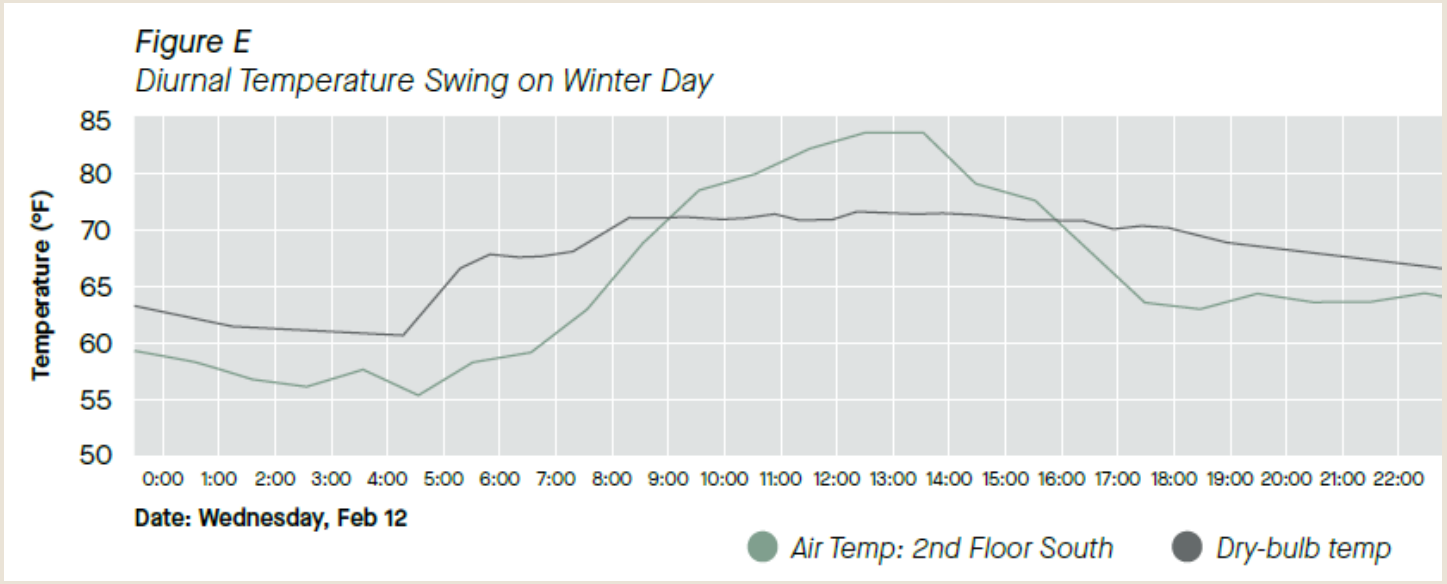
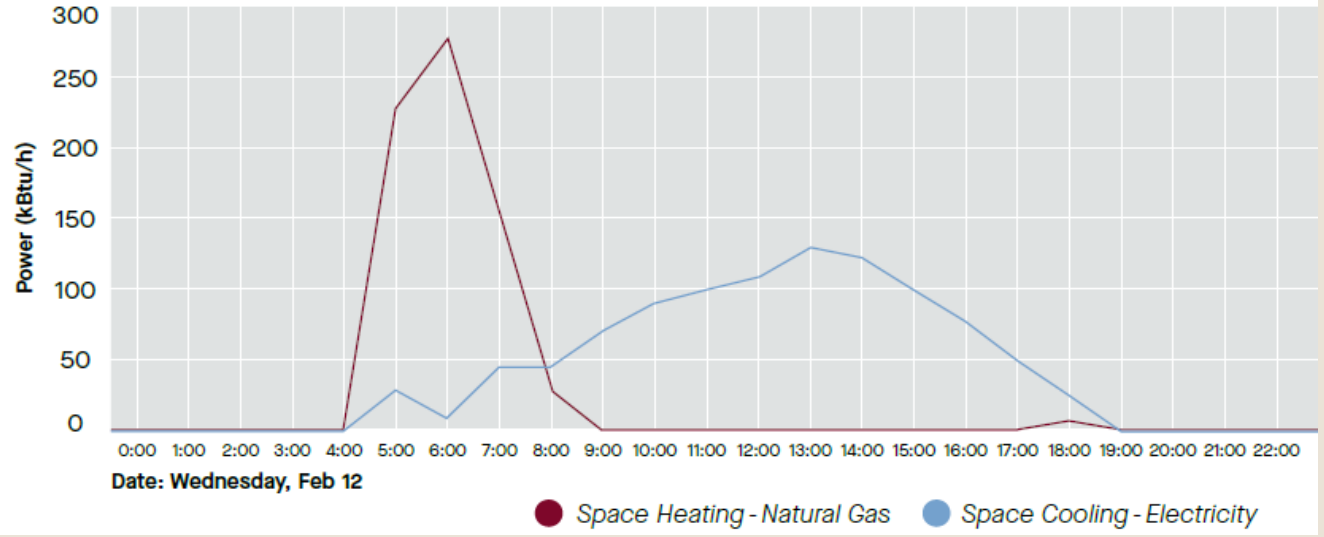


Figure F

Heating and Cooling Demand Profile on Winter Day



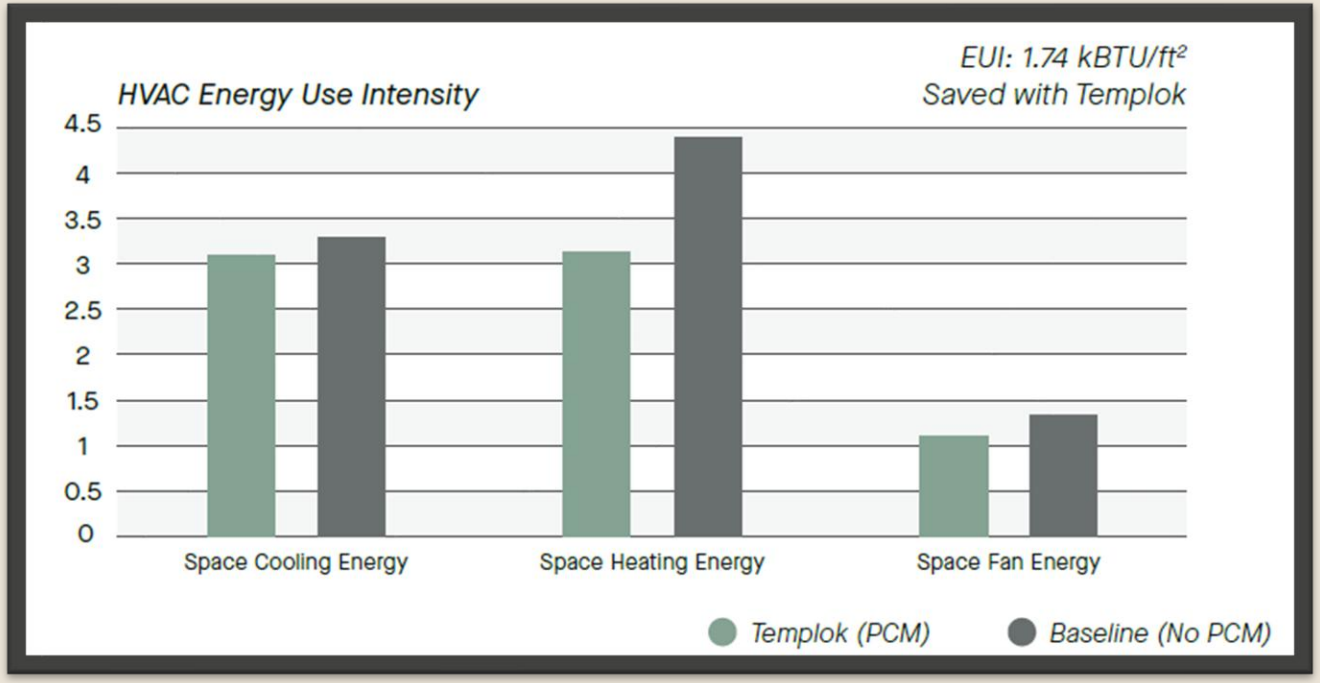
Summary of Results

Annual Cooling Energy Savings = 7.2 %

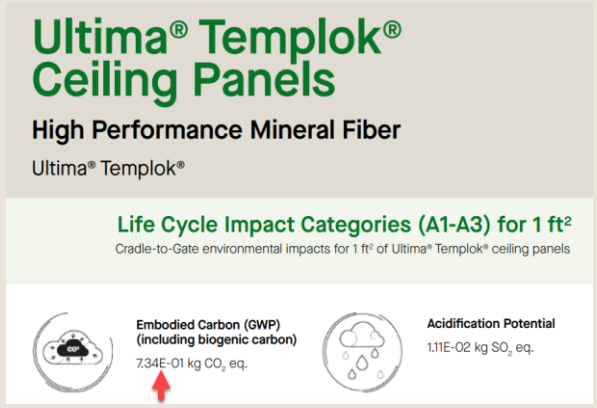
Annual Heating Energy Savings = 30.2 %

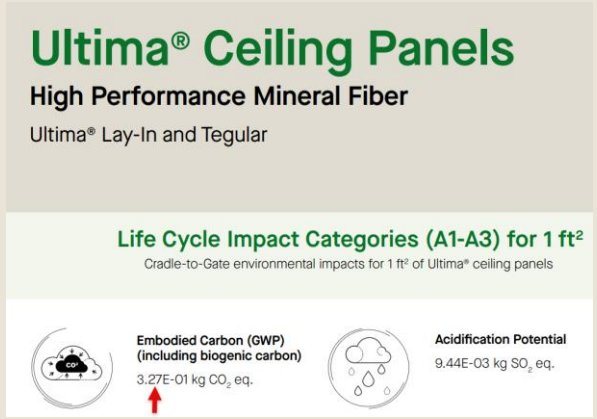
Annual Fan Energy Savings

= 13.7 %



Embodied Carbon



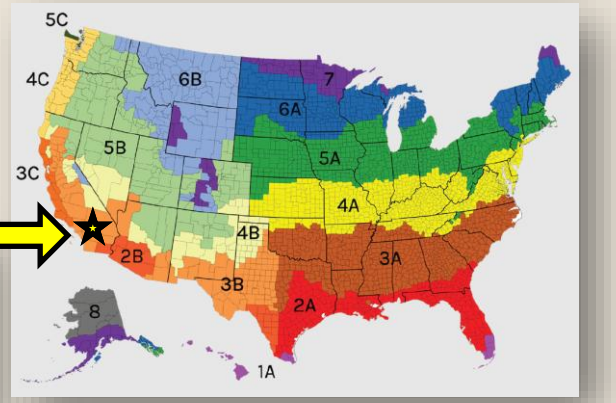


	Templok Average	Templok Optimized
Incremental Embodied Carbon [lbCO2/ft2]	0.9	0.9
Carbon Avoided Annually [lbCO2/ft2]	0.114	0.93
Carbon Payback Yrs	~8.0	~1.0

Field Case Study

Palm Springs, CA

Executive Summary – Introduction



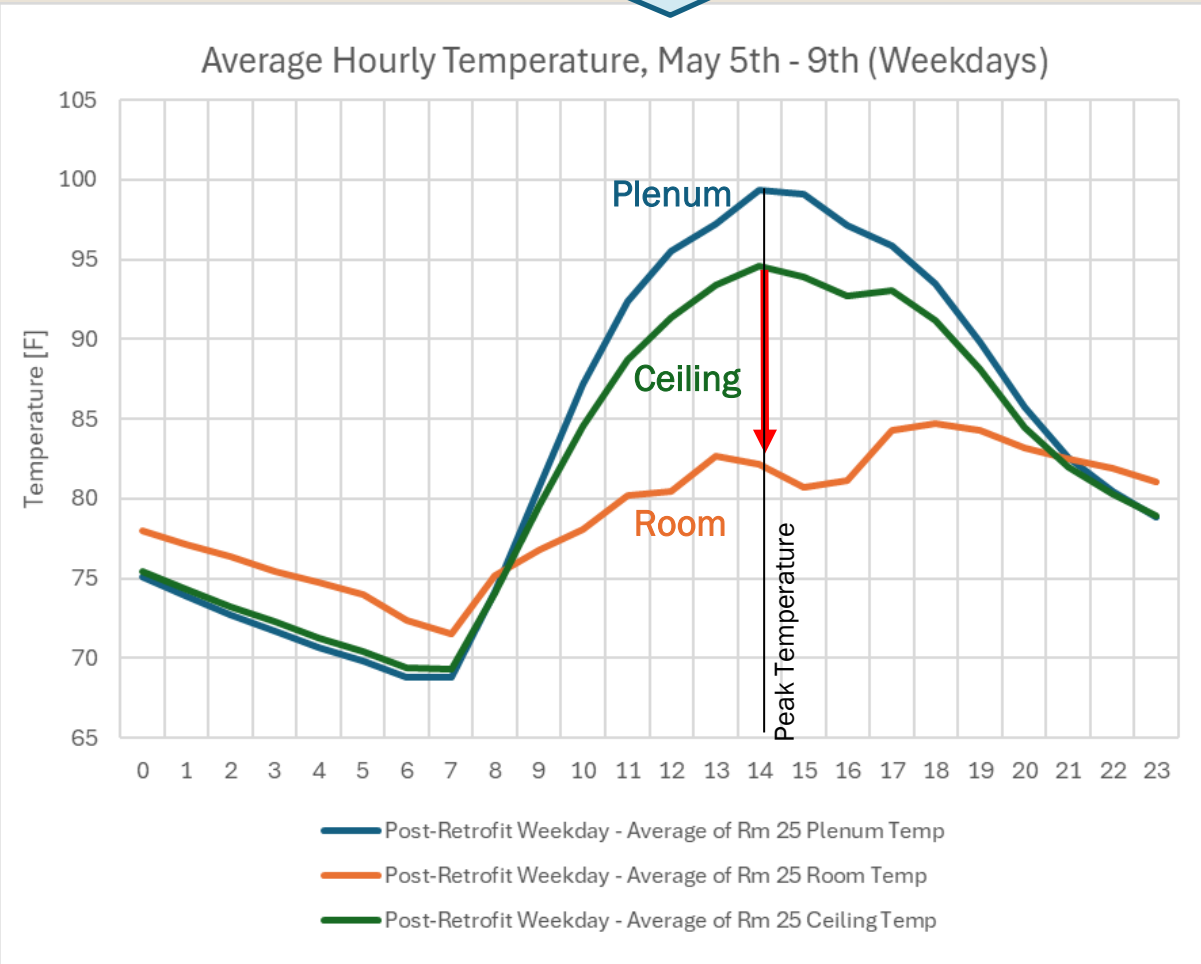
Portable Classrooms| Palm Springs, CA

- ✓ Dry, diurnal climate
- ✓ Poor envelope insulation
- ✓ PCM/Plenum thermally linked to outdoor air temperature
- ✓ Inefficient cooling system
- ✓ High daytime gains
- ✓ Low-mass building
- X No Economizing – but indoor air temperature naturally fell overnight due to poor envelope/low mass

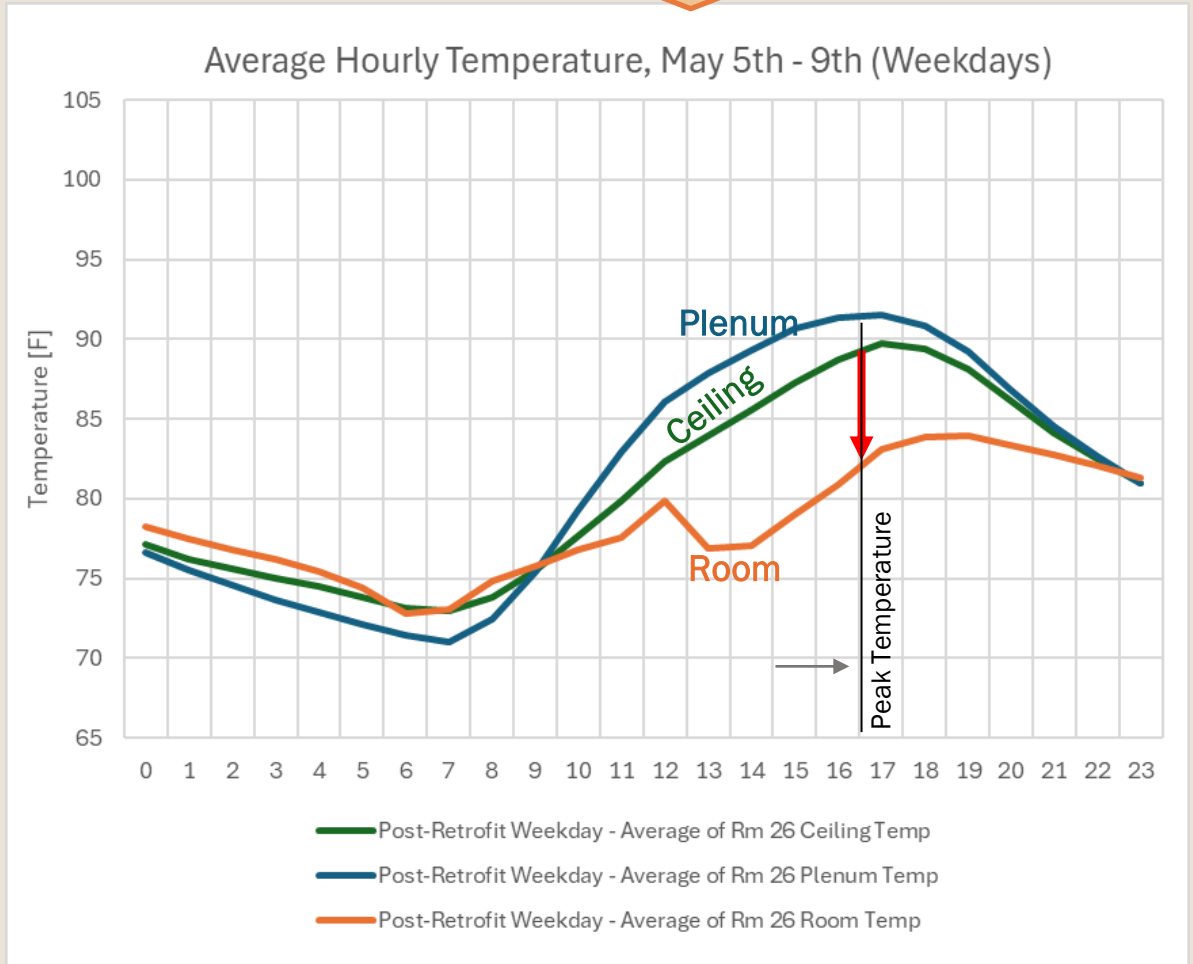
Plenum, Ceiling, and Room Temperatures

The plenum and ceiling stayed 5-10°F cooler in the hottest part of the day, passing considerably less heat to the room.

Rm 25, No PCM



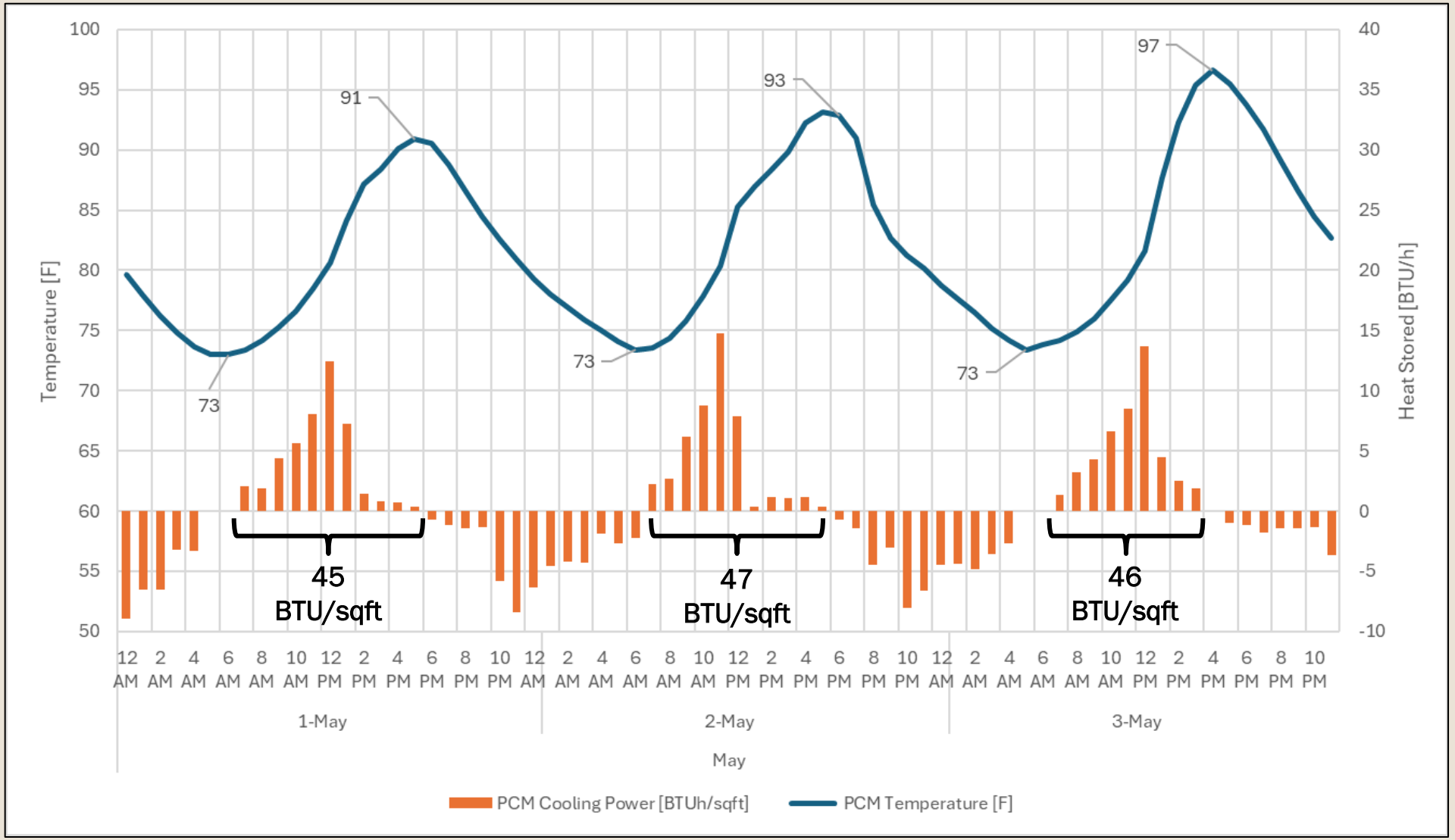
Rm 26, PCM



Peak temperatures occur 2-hours later.

Heat Stored in Templok

Plot: In the first 3 days in May, the PCM increased in temperature by ~20°F from 6am to 6pm, absorbing ~45 BTU per square foot of Templok as the PCM melted.



Theoretical Energy-Savings:
Stats on 30 weekdays 5/1-6/11:

Average Daily Heat Stored:
43 BTU/sqft

Templok per classroom:
656 ft²

Daytime Cooling Load Saved:
28.2 kBTU/classroom/day

Est. Delivered Cooling COP:
3.0

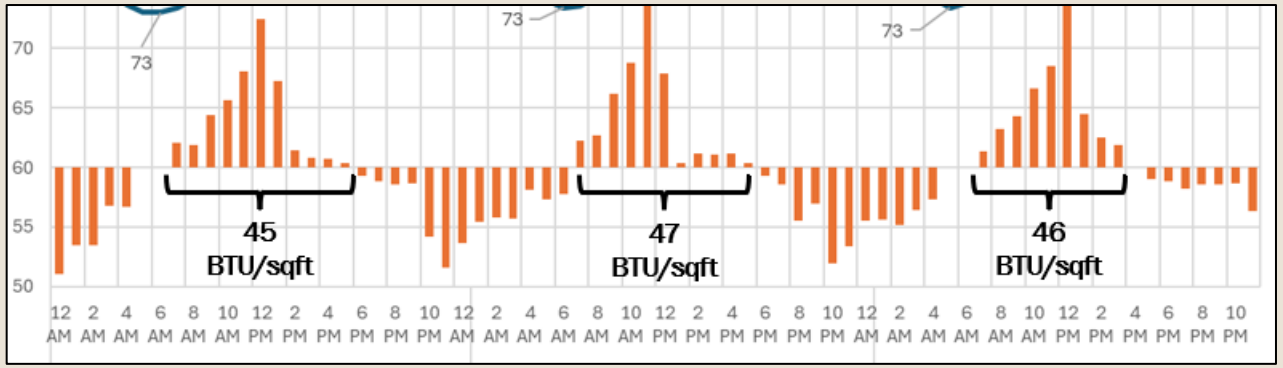
Est. Cooling Energy Saved:
2.8 kWh/room/day

The Bard units use about 20 kWh per day.
Potential **~15% energy savings** to deliver same cooling.

Utilities

TOU Blended Rates

Month	12am	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am	12pm	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm
Jan	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.20	$0.20	$0.20	$0.20	$0.20	$0.14	$0.14	$0.14
Feb	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.19	$0.19	$0.19	$0.19	$0.19	$0.13	$0.13	$0.13
Mar	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.19	$0.19	$0.19	$0.19	$0.19	$0.13	$0.13	$0.13
Apr	**$0.13**	**$0.13**	**$0.13**	**$0.13**	**$0.13**	**$0.13**	**$0.13**	**$0.13**	**$0.11**	**$0.11**	**$0.11**	**$0.11**	**$0.11**	**$0.11**	**$0.11**	**$0.11**	**$0.19**	**$0.19**	**$0.19**	**$0.19**	**$0.19**	**$0.13**	**$0.13**	**$0.13**
May	**$0.16**	**$0.16**	**$0.16**	**$0.16**	**$0.16**	**$0.16**	**$0.16**	**$0.16**	**$0.11**	**$0.11**	**$0.11**	**$0.11**	**$0.11**	**$0.11**	**$0.11**	**$0.11**	**$0.20**	**$0.20**	**$0.20**	**$0.20**	**$0.20**	**$0.16**	**$0.16**	**$0.16**
Jun	**$0.21**	**$0.21**	**$0.21**	**$0.21**	**$0.21**	**$0.21**	**$0.21**	**$0.21**	**$0.21**	**$0.21**	**$0.21**	**$0.21**	**$0.21**	**$0.21**	**$0.21**	**$0.21**	**$0.76**	**$0.76**	**$0.76**	**$0.76**	**$0.76**	**$0.21**	**$0.21**	**$0.21**
Jul	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.76	$0.76	$0.76	$0.76	$0.76	$0.21	$0.21	$0.21
Aug	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.76	$0.76	$0.76	$0.76	$0.76	$0.21	$0.21	$0.21
Sept	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.76	$0.76	$0.76	$0.76	$0.76	$0.21	$0.21	$0.21
Oct	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.20	$0.20	$0.20	$0.20	$0.20	$0.14	$0.14	$0.14
Nov	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.20	$0.20	$0.20	$0.20	$0.20	$0.14	$0.14	$0.14
Dec	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.20	$0.20	$0.20	$0.20	$0.20	$0.14	$0.14	$0.14
Study-Period Weighted Average																								
Electric	$0.15	$0.15	$0.15	$0.15	$0.15	$0.15	$0.15	$0.15	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.27	$0.27	$0.27	$0.27	$0.27	$0.15	$0.15	$0.15

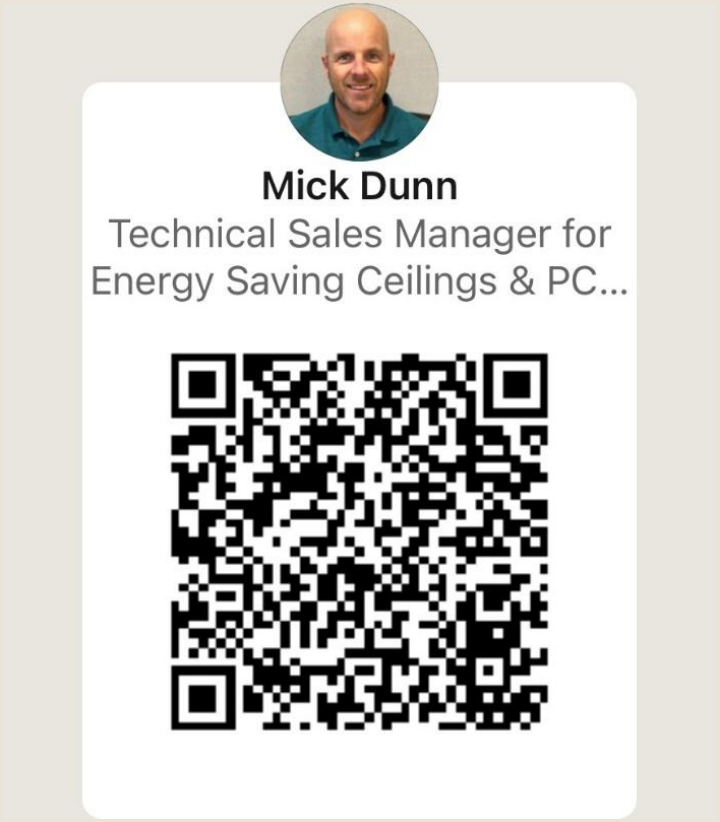


We can estimate potential energy-savings from Templok using its heat storage rate (BTU/h) across time.

Summary of Potential Benefits

- 48E Tax Credits
- Carbon Payback
- LEED Credit potential with 3% to 6% total energy reductions
- Thermal Comfort
- HVAC Sizing Optimization and support of electrification
- Peak Demand Management

Thank You – Contact Information



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