Armstrong®
World Industries

Technical Guide

Templok®

Phase Change Material (PCM) Ceiling Tile

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Ultima® Templok® Energy Saving Ceiling Panels

Calla® Templok® Energy Saving Ceiling Panels

Thermal Mass

Introducing Templok®

High-mass materials like concrete and brick can absorb a substantial amount of heat. In buildings, these materials are considered thermally massive because they increase a building's thermal 'inertia'.

Thermally massive buildings tend to change temperature more gradually, keeping closer to the average of the day-night temperature range. This stabilizing effect can delay and reduce the need for mechanical heating and cooling during peak hours, leading to benefits in energy savings, thermal comfort, and sustainability.

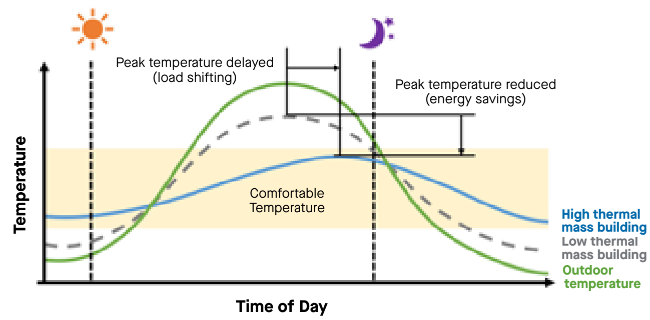


Illustration of temperature variation in thermally massive and light buildings in a climate with warm days and cool nights

Phase Change Materials

Phase Change Materials (PCM) have high energy storage capacity in a small volume and weight compared to conventional high-mass materials. Additionally, their energy storage is concentrated around their phase-change temperature. These features make PCM attractive for building retrofits, from ease of transportation and integration in the building to concentration of performance around operative building temperatures. PCM with a phase-change temperature around 72°F can be highly effective at regulating indoor temperatures in a comfortable zone compared to conventional high-mass materials.

As a building warms, PCM inside the building absorbs heat and melts. The melting process stores heat 'latently', or without changing temperature. The stability of the PCM's temperature helps to stabilize the air temperature. Later in the evening as temperatures fall, the PCM releases heat and 'recharges' for the next day. In effect, the movement of heat from day to night can reduce and shift mechanical cooling load while reducing the temperature variation in the building.

Material	Heat Capacity (kJ/m³°F)
Brick	1,400
Concrete	2,000
Granite	1,600
Gypsum	800
Acoustical Ceiling	240
PCM	20,000

Example heat capacities of materials per unit of volume near the phase-change temperature of a PCM.

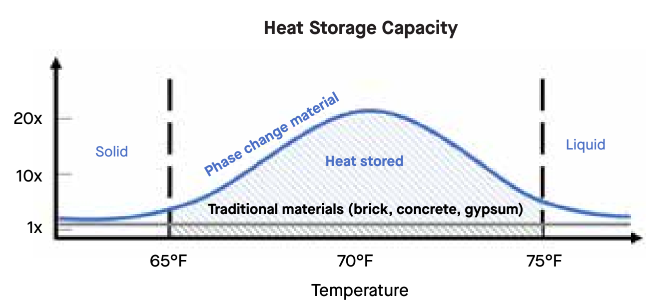


Illustration of concentrated heat storage capacity of a PCM compared to conventional materials.

How PCM Ceilings Work

Phase Change Materials

The ceiling plane is an expansive surface above heat generating sources like people and electronics. Its large surface area allows the ceiling to efficiently exchange heat with air inside the building. Throughout the day and night, the ceiling absorbs and releases heat in response to changes in air temperature. When the air temperature is warmer than the ceiling, heat flows into the ceiling. When the air temperature falls, heat flows out of the ceiling. A thermally massive ceiling helps to moderate temperature by absorbing and releasing heat in response to fluctuations in real time.

Passive Cooling

On warm days with cool nights, PCM ceilings can shave peak air conditioning load by providing a passive cooling effect as the building warms up throughout the day. Overnight, as the building's temperature falls, the PCM releases heat and freezes to 'recharge' for the next day.

When favorable weather conditions allow, automated systems like economizers can induce cool night air to ventilate the building. This 'free cooling' strategy can effectively remove heat from the PCM with minimal energy expenditure. Pre-cooling the thermal mass of the building can shift cooling load from the warmest afternoon hours to more efficient and sustainable morning or nighttime hours. Greater efficiency or alignment with cleaner energy sources can be achieved. Shifting cooling load can also be cost-efficient as it can move energy use to off-peak utility rates and reduce peak demand charges.

Illustration of cooling demand

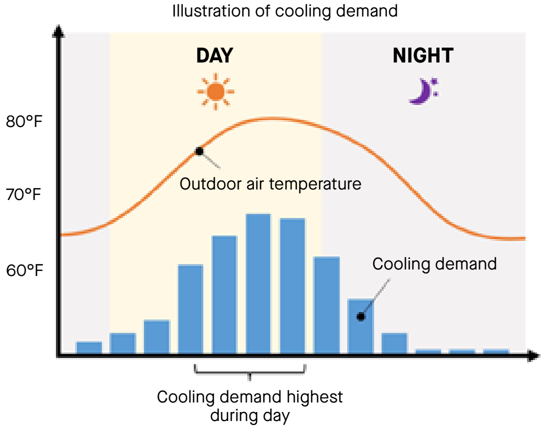
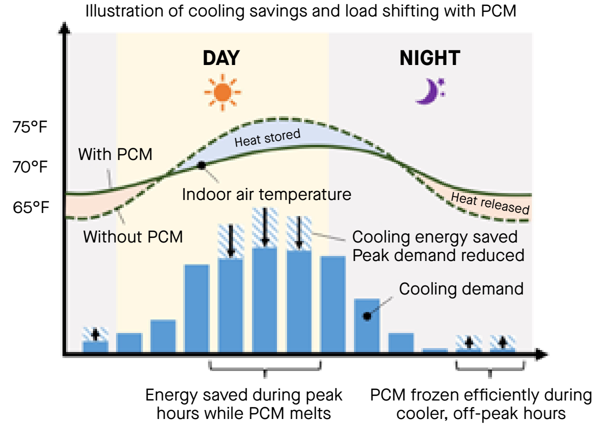


Illustration of cooling savings and load shifting with PCM



Passive Heating

On cool days and in buildings that naturally generate significant heat during the day, PCM ceilings can store excess heat from the day and release it back to the building at night as temperatures fall. PCM can keep a building warmer at night and reduce the intensity of heating required for morning warmup. The most beneficial applications are in spaces that start the day cool but accumulate a significant amount of heat during the peak hours of the day to an extent that heating is not needed in the afternoon hours. For instance, a high-rise building with glass facades may require cooling due to significant solar gains by day, and heating to maintain comfort overnight. In this case, PCM can store excess heat from the afternoon for 'free' and releases the heat back to the building overnight. Thermal mass is typically less effective within buildings in very cold climates with low internal gains, or in buildings that use deep nighttime setbacks.

Temperature Stabilization

In spaces with intermittent loads throughout the day, thermal mass in the ceiling can help to stabilize the temperature. In spaces like conference rooms or building perimeters with intermittent occupant and solar gains, temperature management can be a challenge. The buffering effect of thermal mass can also save energy by reducing the inefficiencies of overheating and overcooling spaces.

Illustration of heating demand

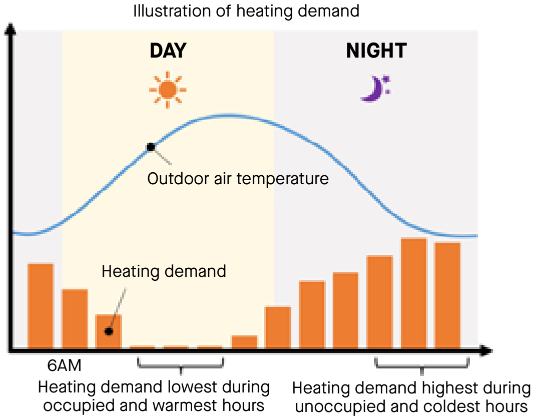
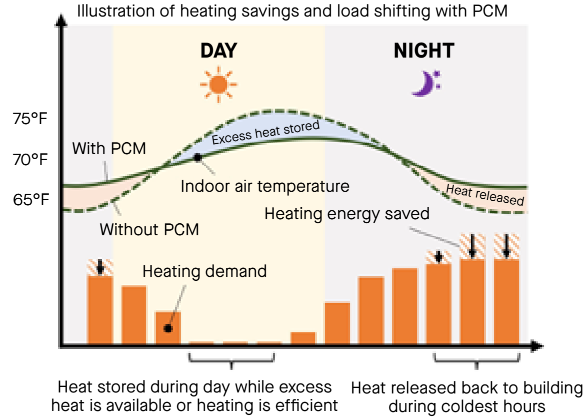


Illustration of heating savings and load shifting with PCM



Templok® Ceiling Tiles

This page provides guidance for representing Templok® ceilings in building energy models. A pre-configured, easy-to-use model is available in IESVE 2025 (User Guide). Properties of the mineral fiber panel are listed on its data page.

Description

Templok ceiling tiles are a factory-bonded assembly consisting of an upper PCM component and a lower mineral fiber panel. Tiles are supplied in nominal 2'×2' and 2'×4' sizes. In the 2'×4' format, two 2'×2' PCM components are adhered to the back of a 2'×4' mineral fiber panel. Each PCM component contains a proprietary PCM-composite sealed within a durable metallized polymer film. The effective PCM-area is approximately 21.5″×21.5″ per 2′×2′ module.

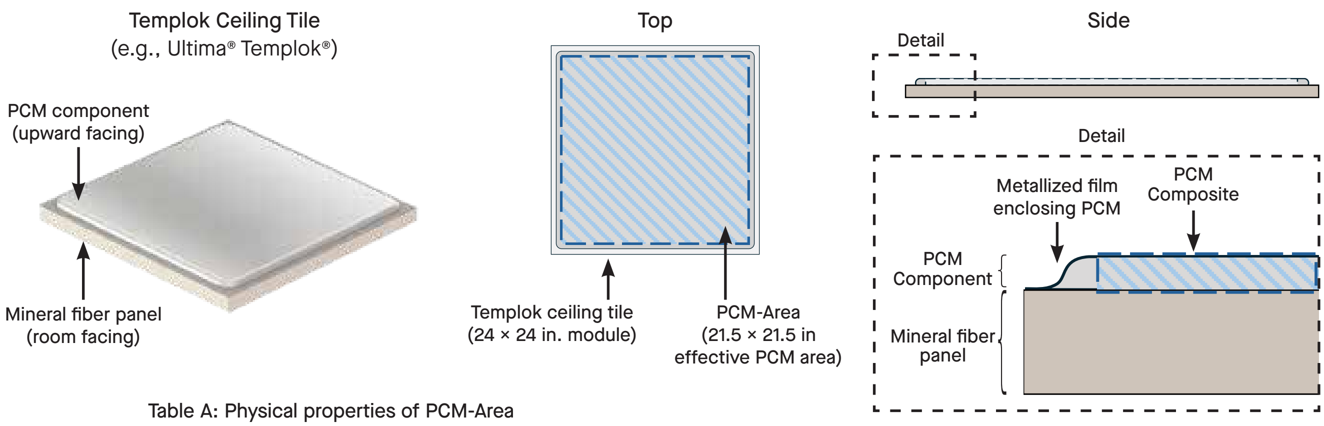


Table A: Physical properties of PCM-Area

Property	Value
Areal dimensions (in)	21.5 × 21.5
Thickness (in)	0.25
Areal density (lb/ft²)	1.15

Table B: Thermal Properties of PCM-Area

Property	Solid-Phase Value (<64°F)	Transition Value	Liquid-Phase Value (>84°F)
Areal Heat Capacity	1.8 BTU/(ft²·°F)	Varies; See Table C	1.2 BTU/(ft²·°F)
Thermal Conductivity	0.12 BTU/(h·ft·°F)	Varies	0.10 BTU/(h·ft·°F)

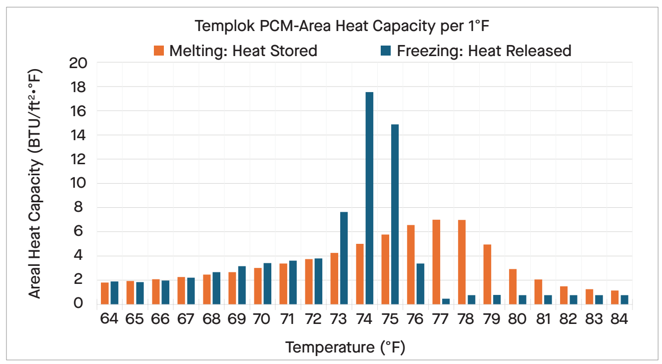


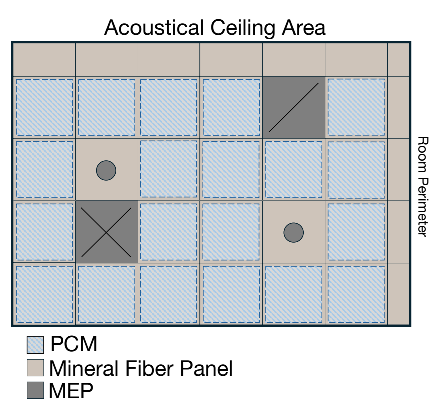
Table C: Thermal Properties of PCM-Area

Temperature °F	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84
Melting Heat BTU/(ft²·°F)	1.8	1.9	2.1	2.3	2.5	2.7	3.0	3.4	3.7	4.3	5.0	5.8	6.6	7.0	7.0	4.9	2.9	2.1	1.5	1.3	1.2
Freezing Heat BTU/(ft²·°F)	1.9	1.8	2.0	2.2	2.7	3.2	3.4	3.6	3.8	7.6	17.5	14.9	3.4	0.5	0.8	0.8	0.8	0.8	9.8	0.8	0.8

Modeling Suggestions

Phase change behavior: In typical conditioned buildings, the PCM rarely reaches full melt (indoor highs are usually < ~80 °F). After partial melting, the PCM re-freezes along a heat-capacity path that closely tracks the melting curve. For most operating conditions, the melting curve can reasonably represent both melting and freezing.

PCM area representation: Most acoustical ceilings combine full, uncut tiles with areas of cut tiles and MEP/fixture penetrations. Templok is installed only in full, non-penetrated grid openings, which typically constitute ~50-80% of the total ceiling area. For modeling, assign PCM-Area properties to that covered fraction and use standard mineral fiber tile properties for the remainder. In IESVE 2025, this assignment is automated.

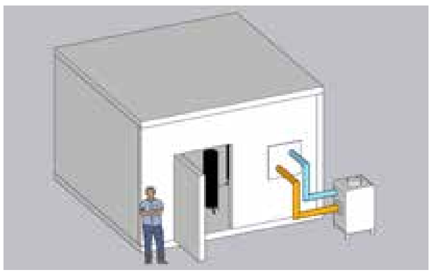
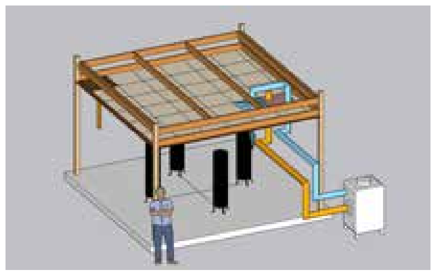
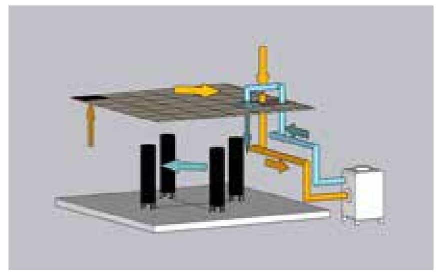


Graphics are for illustration only and are not to scale. Heat-capacity data were measured using a heat-flow meter apparatus per ASTM C1784-20. This document is subject to change.

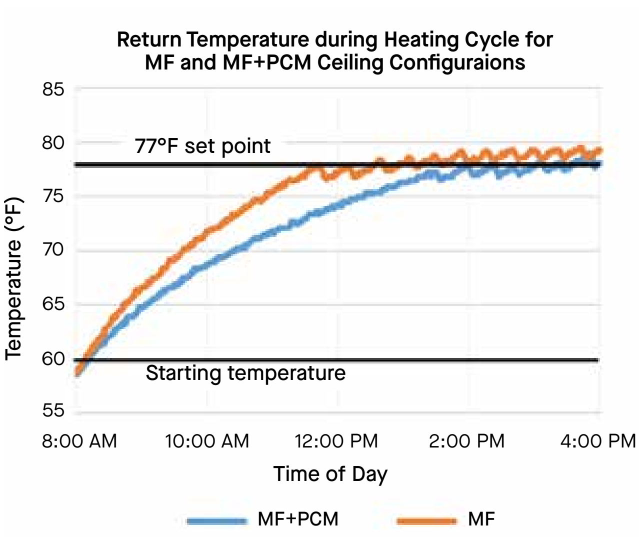
Laboratory Assessment of Ultima® Templok® Ceiling Tile Performance

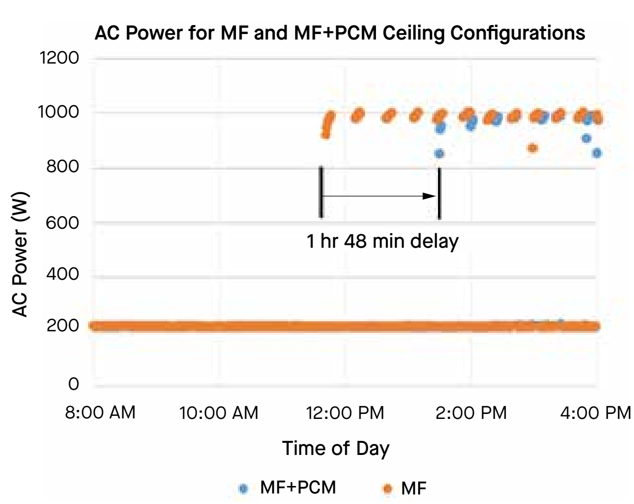
Overview: This experimental study demonstrates the load shifting and temperature moderating effects of a PCM ceiling in a well-controlled and instrumented test room. The study measures about 53 BTU/sqft of heat moved from day to night in Ultima Templok ceiling tiles, leading to a significant reduction in daytime cooling energy and about a 20% reduction the rate of change of the air temperature.

Experimental Setup: An insulated test room was constructed and equipped with extensive temperature, power, and heat flow monitoring equipment. This setup included 22 thermocouples and eight heat flux sensors distributed across all interior surfaces of the chamber and both sides of the ceiling. The chamber was supplied with a constant airflow of 100 Cubic Feet per Minute (CFM) equal to 5 Air Changes per Hour (ACH) from an air conditioning unit outside of the chamber in a closed air loop. In the experiment, set points were varied to emulate free cooling by night ventilation. Heat sources were turned on during the day and off at night to simulate occupant gains.

Passive Cooling and AC Delay: The experiment compared two scenarios: one with Ultima Templok ceilings (MF+PCM) and another with standard Ultima mineral fiber ceilings (MF). The test sequence involved pre-cooling the chamber to 60°F in the early morning, followed by a set point increase to 77°F at 8AM. The AC in the MF+PCM scenario began cooling about two hours later than in the MF scenario. This delay correlated with a slower increase in air temperature, as the air temperature was moderated by the PCM ceiling.



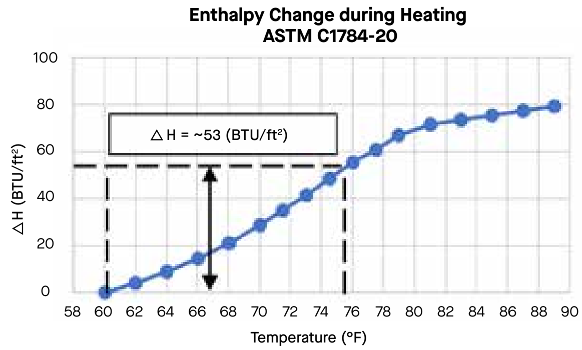


Load Shifting: Quantifying Energy Flows and Savings: Notably, the AC in the MF+PCM scenario removed 4080 BTU less heat during the day than in the MF scenario. The heat absorbed by the ceiling in the MF+PCM case was significantly higher, by 3815 BTU, affirming the PCM was responsible for the reduced daytime cooling load.

Furthermore, the estimated heat stored by the PCM, based on temperature changes throughout the day and the enthalpy properties of the PCM was about 53 BTU/SF or 3935 BTU total, a third point of agreement.

Laboratory Assessment of Ultima® Templok® Ceiling Tile Performance

Energy Savings Discussion: The measured daytime energy saved in the MF+PCM scenario was 20%, predominantly due to reduced compressor energy from 8am to 4pm as the PCM melted. With strategies like 'free cooling' through open windows or efficient economizer operation, significant savings could be realized with minimal energy expenditure at night. In climates with a narrower diurnal temperature range, an attainable cooling savings was estimated to be up to 15%.



Case Study: Heating Savings in New Hampshire High School

Introduction

This case study estimates the impact of Phase Change Material (PCM) through Templok ceiling tiles in a New Hampshire high school, with a focus on heating energy during Winter and Spring.

Study Overview

Multiple modeling techniques were used to evaluate power and temperature data collected in a wing of classrooms before and after treatment with Templok ceiling tiles. The primary objective was to estimate the effect of Templok ceiling tiles in reducing heating energy during Winter and Spring nights. In a cool climate in spaces with significant daytime heat gains, like classrooms, the working principle of energy-savings is illustrated in Figure 1. The thermal mass of the ceiling stores heat during the day when the building naturally warms and mechanical heating is efficient, and releases heat back to the space overnight, moderating the air temperature and offsetting the need for nighttime mechanical heating. This principle was investigated in the case study.

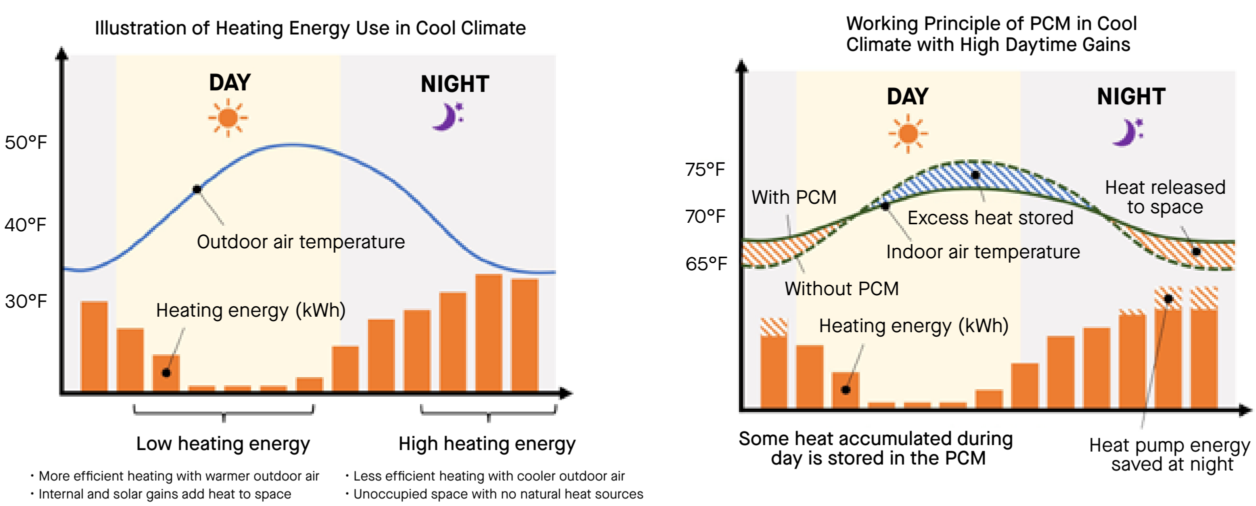


Figure 1. Illustration of energy saving mechanism of thermal mass in a cool climate in a building with high daytime gains.

Heating Savings in New Hampshire High School

Study Design

A wing of classrooms of similar size and use were selected to identify a suitable set of classrooms for control and PCM treatment cases. Each classroom was primarily heated by an individual split heat pump system inside the classroom. While real-world experiments are difficult to control, the uniformity of repeating classrooms heated by individual systems offered an advantageous setup to isolate the effect of the PCM ceiling. The study was conducted in four stages:

1. Baseline Energy Collection: This phase involved the monitoring and selecting a group of classrooms with comparable heating energy usage over several months.
2. PCM and Sensor Deployment: In this phase, Templok tiles were installed in half of the selected classrooms. Simultaneously, temperature sensors were placed in each classroom, in the air below the ceiling, on the back of the ceiling surface, in the plenum air above the ceiling, and in the unit ventilator along the exterior wall.
3. Multivariate Analysis: In this analysis, a multivariate model was developed to predict heat pump power from several measured variables, including the PCM treatment.
4. Difference of Differences Analysis: This analysis compared the difference in energy usage in PCM-treated classrooms before and after the treatment date to the energy usage difference in 'control' classrooms that did not receive PCM before and after the treatment date.

Baseline Energy Data

Current transducers and a data logging system recorded power to the heat pumps in 14 classrooms beginning on September 8th. Figure 1a depicts the layout of each ~800 square foot classroom. A heat pump is located within each classroom near the ceiling. Each room also has a unit ventilator that provides tempered outdoor air in the mornings for ventilation. Temperature loggers were added inside the unit ventilators at the time of PCM deployment to include as a variable in the multivariate model. Figure 1b highlights the classrooms that were monitored for baseline energy use on the first and second stories, and the set of four classrooms that were selected for treatment and control in the next phase.

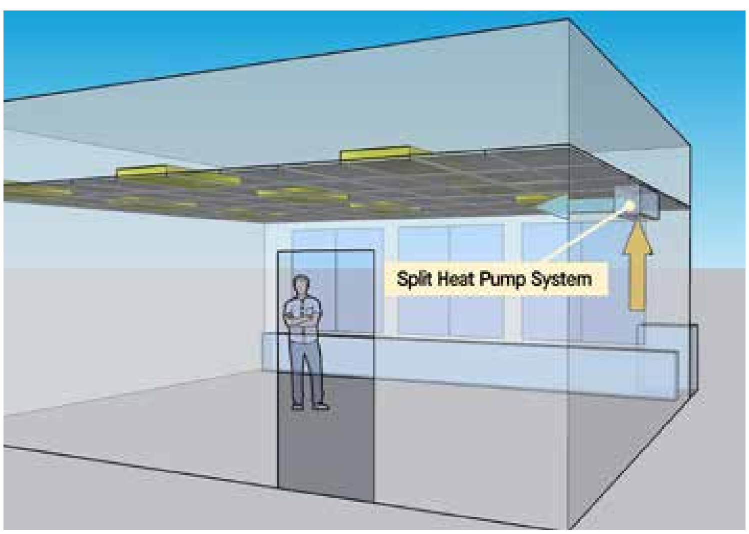


Figure 1a: Classroom layout

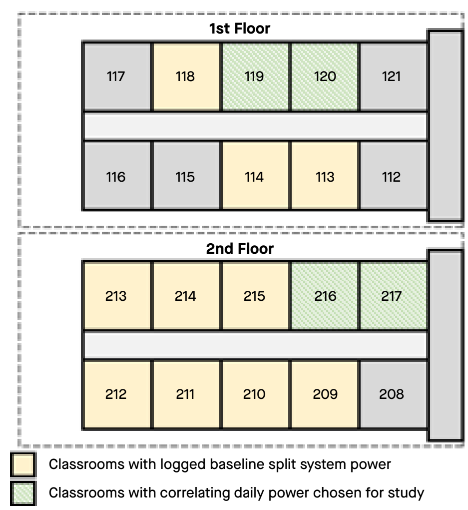


Figure 1b: Classroom wing showing monitored rooms

Heating Savings in New Hampshire High School

Power to each heat pump was recorded in 15-minute intervals to estimate heating energy by each system over time. Correlations between the power data in most of the classrooms began to strengthen in February. In Figure 2a, the power data was binned into daily sums and displayed for the month of February. Neighboring classrooms 119, 120, 216, and 217 on first and second stories showed strong correlations in February, as shown in Figure 2b, and were selected for the study.

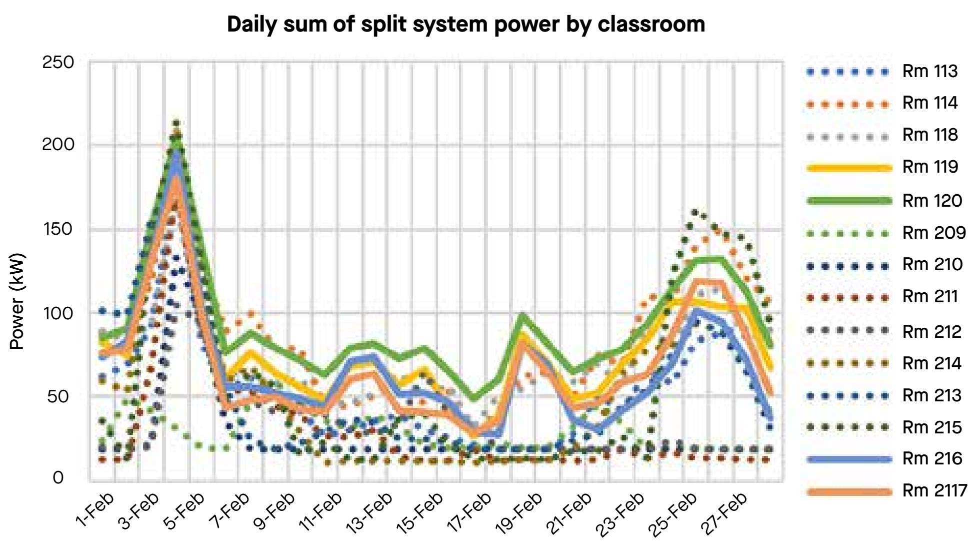


Figure 2a: Daily heat pump power sums in monitored classrooms in February.

Room Number (columns); **Room Number** (rows)

	113	114	118	**119**	**120**	210	211	212	214	213	215	**216**	**217**
113	1.00	0.94	0.93	0.86	0.87	0.68	0.70	0.42	0.91	0.83	0.85	0.78	0.83
114		1.00	0.95	0.87	0.91	0.63	0.62	0.36	0.92	0.81	0.88	0.78	0.86
118			1.00	0.86	0.88	0.62	0.57	0.30	0.87	0.83	0.81	0.80	0.88
119				1.00	**0.98**	0.66	0.71	0.40	0.91	0.87	0.83	**0.94**	**0.96**
120					1.00	0.70	0.71	0.44	0.91	0.89	0.88	**0.94**	**0.97**
210						1.00	0.90	0.84	0.66	0.65	0.56	0.71	0.62
211							1.00	0.81	0.73	0.65	0.57	0.75	0.62
212								1.00	0.40	0.37	0.37	0.47	0.29
214									1.00	0.90	0.84	0.82	0.87
213										1.00	0.76	0.88	0.89
215											1.00	0.75	0.83
216												1.00	**0.95**
217													1.00

Figure 2b: Correlation coefficients between daily heat pump power sums of each classroom pair.

Heating Savings in New Hampshire High School

PCM and Sensor Deployment

On March 1, Templok tiles were installed above the ceiling tiles in rooms 120 and 217. In all four rooms, 119, 120, 216, and 217, thermocouples were installed in the ceiling to measure the room and plenum air temperature and the back of the ceiling tile temperature, as illustrated in Figure 3a.

An air temperature thermocouple is shown in Figure 3b. In the classrooms that did not receive PCM tiles, a thermocouple was positioned on the back of the acoustical tile. Data loggers recorded temperature measurements from each thermocouple.

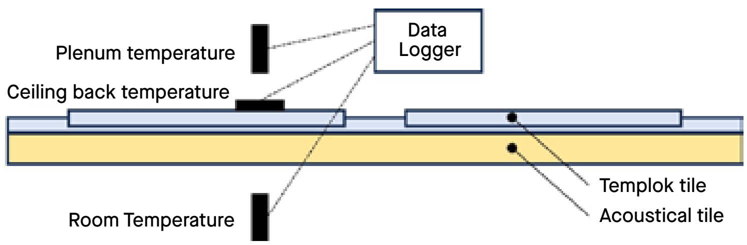


Figure 3a: Ceiling sensor schematic

Figure 3b: Room air temperature sensor.

Power and temperature data from each classroom was recorded from March 1 through May 5. Figure 4 shows the temperature and heat pump power trends during a weekday in Room 217. Heating intensity is highest at night during the coldest hours, and lower in the afternoon when classroom is occupied, and ambient temperatures are warmer. The low and consistent power measurements during the day likely indicates baseline fan energy with little heating. The change in temperature of the ceiling over time indicates the daily heat storage and release pattern. The PCM is storing heat during the day as it warms and melts, and releasing heat back to the building at night as it cools and freezes.

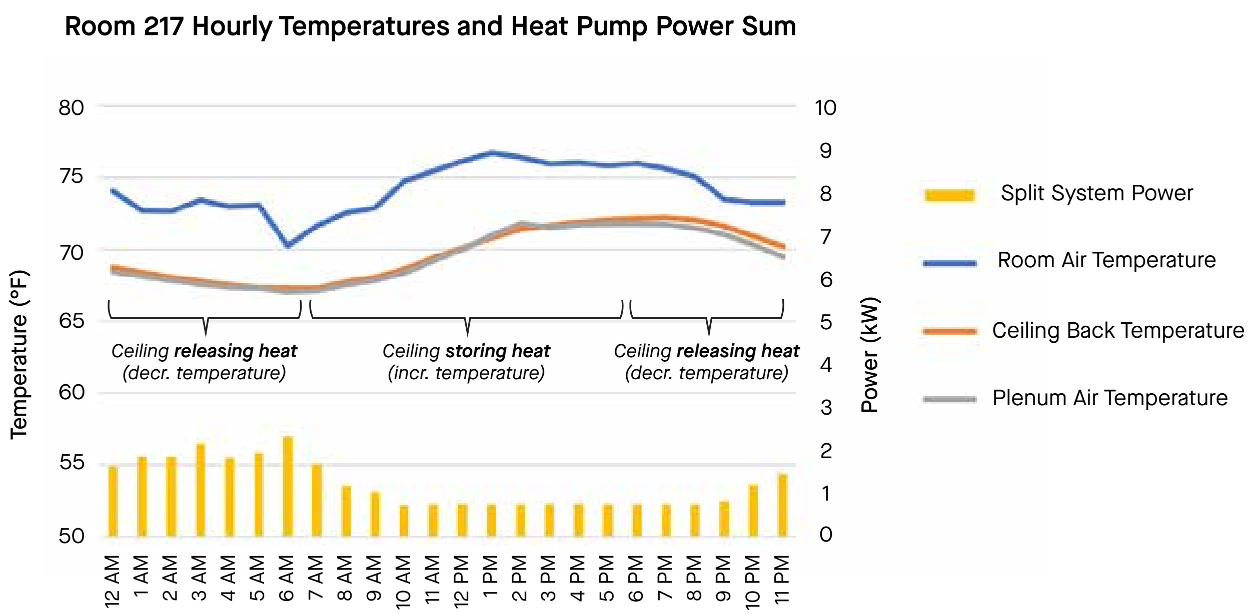


Figure 4: Diurnal room, ceiling and plenum temperatures and hourly split heat pump system power intensity.

Multivariate Analysis

The dataset was stratified by season (Winter, Spring) and hour (Day, Night) for analysis. A generalized additive model was then constructed, including measured variables suspected to affect heat pump power. The model included the true/false status of unit ventilator heating, outdoor and room air temperatures, floor level, timestamp, and true/false status of PCM in the ceiling.

Table 1 shows an analysis of both floors in the Winter. In night hours, a 5% reduction in heating power was estimated by isolating for the PCM variable. The result was statistically significant ($P<0.05$), and the model had strong predictive power ($R2 = 0.81$). In day hours, no significant change in the heating power was estimated.

Table 1: Estimated reduction in heating power due to the PCM variable (Both floors, Winter)

Condition	Estimate	P-value	Adjusted R^2	% Reduction
Winter (3/13-4/4) - Day Hours (8 a.m. - 8 p.m.)	0.000 (P > C)	> 0.05	0.77	--
Winter (3/13-4/4) - Night Hours (9 p.m. - 7 a.m.)	-0.032 (P < C)	< 0.05	0.81	5%

Anomalies in the kW data in Room 119 after 4/4 led to refocusing the Spring analysis on the second floor only. Table 2 shows an analysis of the second floor during Winter and Spring days and nights. The model predicted a 7% and 9% reduction in heating power in Winter and Spring, respectively. Both results were statistically significant with good predictive power. Daytime heating energy was not estimated to be significantly affected by the PCM, although the model was less predictive in Spring Days due to uncontrolled variables not included in the model.

Table 2: Estimated reduction in heating power due to the PCM variable (Second floor, Winter and Spring)

Condition	Estimate	P-value	Adjusted R^2	% Reduction
Winter (3/13-4/4) - Day Hours (8 a.m. - 8 p.m.)	-0.001 (P < C)	> 0.05	0.72	--
Winter (3/13-4/4) - Night Hours (9 p.m. - 7 a.m.)	-0.032 (P < C)	< 0.05	0.71	7%
Spring (4/5-5/5) - Day Hours (8 a.m. - 8 p.m.)	-0.001 (P<C)	> 0.05	0.59	--
Spring (4/5-5/5) - Night Hours (9 p.m. - 7 a.m.)	-0.018 (P<C)	< 0.05	0.78	9%

Difference in Differences Analysis

A difference in difference (DiD) analysis can be used to estimate the effect of a treatment by comparing the outcomes of the control and treatment groups over time (before and after the treatment). In this analysis, DiD estimates the effect installing PCM had on difference in mean power in PCM classrooms before and after installation minus the difference in control classrooms over the same time. The DiD method relies on a parallel trend assumption which held stronger for the second floor than the first floor. Thus, only the second floor was analyzed in the DiD method. The month immediately preceding and following the PCM intervention (February and March) were analyzed. Controlling for outdoor temperature and average change in power measurements in the control rom between February and March, power measurements during night hours decreased on average by 0.045 kW (6%) after installation of PCM.

Table 3: DiD estimated reduction in average power measurements due to PCM variable (Second floor, February and March)

Condition	Estimate	P-value	% Reduction
Day Hours (8 a.m. - 8 p.m.)	-0.022	> 0.05	--
Night Hours (9 p.m. - 7 a.m.)	-0.045	< 0.05	6%

Results

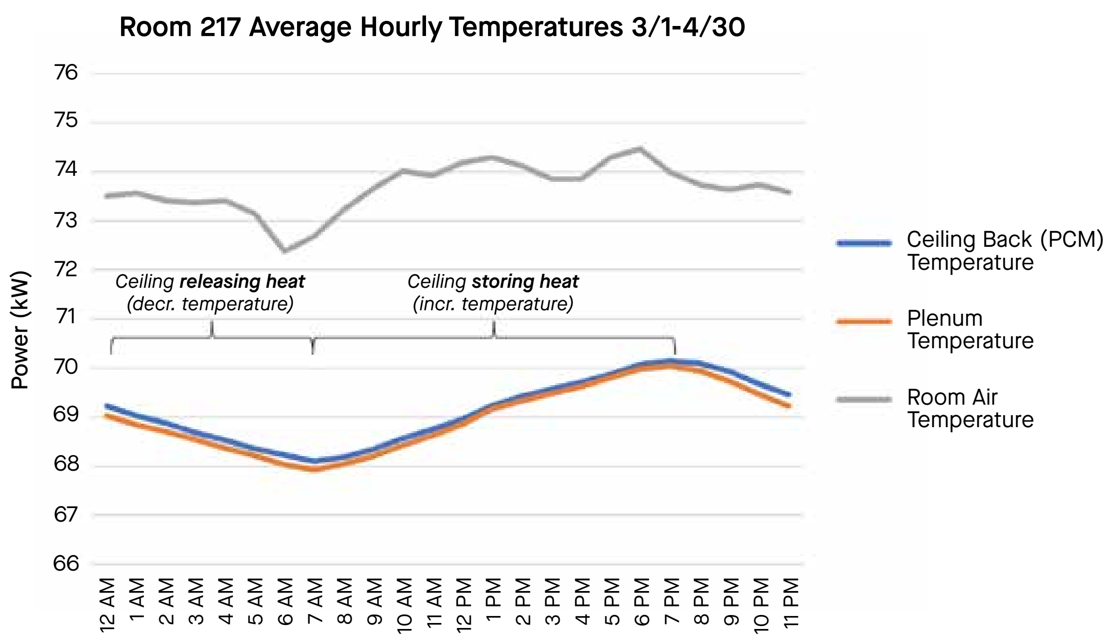
Across several modeling techniques, classrooms with PCM installed saw a 5-9% drop in energy compared to control classrooms during winter nights. This effect was relatively consistent across modeling approaches.

Heating Savings in New Hampshire High School

Reconciliation of Case Study Result with Laboratory Prediction

The diurnal change in temperature of the ceiling tile and its temperature-enthalpy properties can be used to independently estimate the amount of heat moved by PCM from day to night. In March and April, the average diurnal temperature variation of the PCM ceiling was about 2°F, corresponding closely with the plenum air temperature near the ceiling. Referencing the enthalpy properties of the PCM, cooling from 70°F to 68°F corresponds with a release of about 8 BTU/sqft of heat from the PCM to the building. About 144 Templok tiles were installed per classroom, representing coverage of the PCM-containing portion of Templok of about 324 sqft. Therefore, the predicted daily heat moved by the PCM from day to night is about 2600 BTU/classroom.

In the previous section, the reduction in average nighttime kW was estimated to be 5-9% by various methods. In March and April in Rm 217, the average total energy (kWh) in nighttime hours (9pm-7am) was 4.5 kWh. Assuming a COP of 3 for the heat pump, the 5-9% nighttime energy savings represents about 2300-4200 BTU of heat saved, in general agreement with the estimated 2600 BTU of heat released by the PCM tiles overnight.



Discussion

Even with a modest ceiling diurnal temperature range of approximately 2°F, the study observed a significant reduction in nighttime heating energy usage of 5-9% without a daytime heating penalty. This outcome is encouraging, as it suggests that buildings with greater internal and solar heat gains during the day could potentially achieve even more substantial energy savings at night.

Conclusion

The case study at a New Hampshire high school contributes to the relatively less-established application of PCM in cool climates for saving heating energy. The study estimated a 5-9% reduction in nighttime heating energy during winter and spring nights after retrofitting with Templok ceiling tiles. The result agrees with the estimated amount of heat released by the PCM at night measured by thermocouples and referencing the material's enthalpy properties.

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