CALIFORNIA ENERGY COMMISSION

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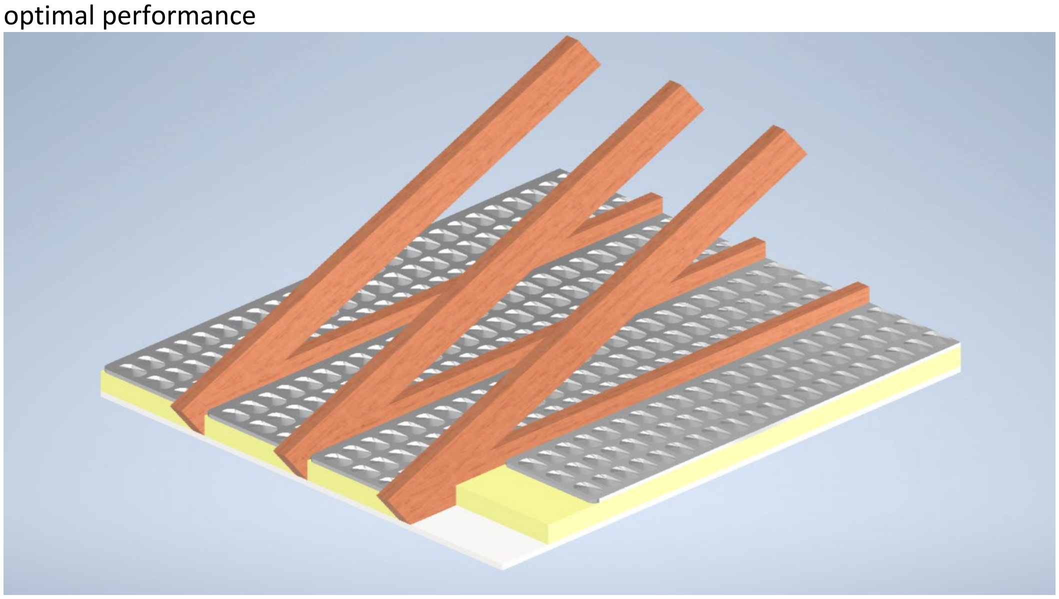
Attic Phase Change Material Design and Installation Guide

How to select and install sheets of encapsulated phase change materials in residential attics for optimal performance



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I. Introduction

What are Phase Change Materials (PCMs)?

When a solid melts and transitions from a solid to a liquid state, heat energy is absorbed. The converse is true when a liquid freezes, that is, the substance gives up heat to its environment. The quantity of thermal energy involved in the change of state is referred to as "latent" heat, as distinguished from "sensible" heat, which is the heat involved in changing the temperature of a material. The amount of latent heat transfer is dependent on both the properties of the material itself, as well as the quantity of material going through a change of state. PCM melting points can be tuned to match the needs of the application. The phase change phenomenon is illustrated in Figure 1.

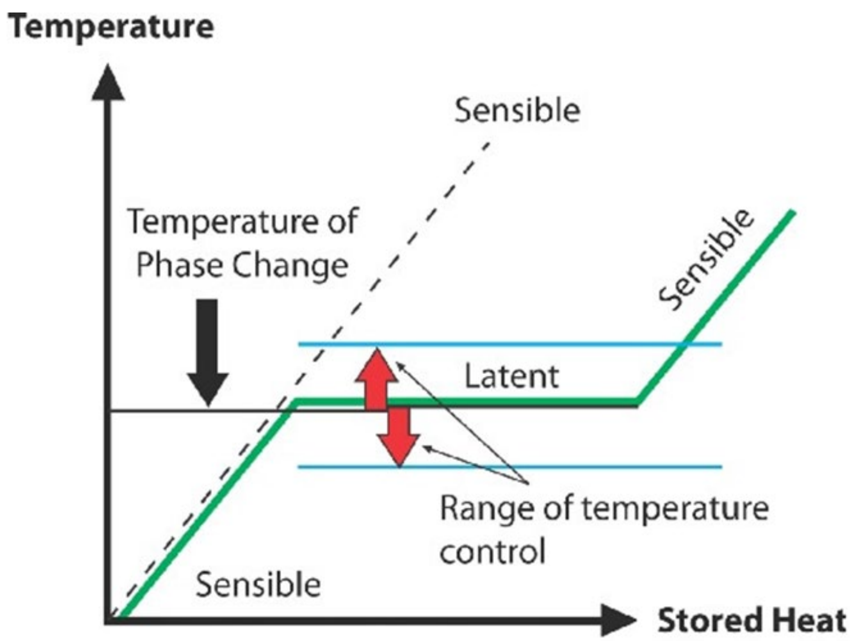

Figure 1. Latent and sensible heat storage in PCMs.
Image credit: RGEES (https://rgees.com/phase-change-technology/)

What are the Benefits of PCMs in Buildings?

Energy storage can be useful for energy efficiency or peak demand reduction when installed in a building envelope because it can reduce or delay heat transfer between the outside and the interior space, potentially avoiding the need for heating or air conditioning at certain times of day. Unlike traditional materials used in buildings to add thermal mass such as concrete and masonry, energy storage through phase change occurs over a relatively constant temperature and requires much less volume. The application described in this guide focuses on flexible mats of PCM installed above or below the insulation in residential attics.

What are the Features of PCM Mats Used in Attics?

The type of PCM assumed for this guide is made of hydrated salts, hydrated magnesium aluminum silicate, and hydrated sodium calcium aluminosilicate. The compound is stored and sealed in a multilayer poly film pocket. The packaging is available in both 24” X 48” and 16” X 48” sheets as seen in Figure 2. By varying the mixture of PCM salts and other components, the product can be manufactured with a variety of melting points ranging from 66-84°F and beyond. The material is usually thin, lightweight, and fire resistant. Typical PCM mats have characteristics and performance values comparable to those shown in Table 1.

Figure 2. PCM mat used for residential attic applications.
Image credit: Bob Hendron

Table 1: Typical properties of PCM mats

Physical Properties	**Values**
Melting Point	66 - 84°F
Latent Heat	~86 Btu/lb
Thermal Conductivity	~0.09 W/ft/°F Liquid
	~0.18 W/ft/°F Solid
Dimensions	24.5” X 48”
	16.5” X 48”

Thickness	0.25”
Weight	0.75 lb/ft^2

Who Can Benefit from This Guide?

This Guide is designed to help homeowners or contractors who have decided to install PCMs in an attic. It will provide product characteristics and installation methods intended to maximize the potential for energy savings and minimize potential installation and long-term durability issues. However, energy and peak demand savings for PCM in attics is still a topic of ongoing research, and some of the potential benefits remain unproven. The focus is on design and installation of PCM in existing homes, but the information provided can also be applied to new construction.

II. Design Considerations

PCM melting points can be tuned to match the needs of the application, making PCMs an appealing technology for use in building envelopes, including in walls and attics. PCMs do not contribute to the R-value of the building envelope in any significant way, but when installed adjacent to the insulation, the PCM can reduce the temperature difference across the ceiling (or wall) assembly while it freezes or melts, thereby reducing heat transfer into or out of the conditioned space. This can both delay and reduce heating and cooling loads on the HVAC system. However, in certain mild climates the attic can actually provide beneficial heating during sunny winter days, and also cooling during summer nights. These benefits may be reduced through the use of PCM as energy is absorbed or released during the change of state. The net benefit for homeowners is dependent on multiple variables, including climate, interior thermostat settings, attic insulation levels, and time-of-use utility costs. These benefits have not yet been accurately quantified through detailed laboratory or field test studies. For the purpose of the following discussion, we will assume that it is beneficial to achieve more frequent and complete melting and freezing of the PCM.

To take the greatest advantage of PCM in a building application, three conditions must be met:

1. The PCM must be exposed to temperature changes on both sides of its melting point over the course of the day.
2. The duration of these temperature swings must be long enough to freeze and melt the PCM at least partially.
3. The heat transfer rate to and from the PCM must be fast enough to substantially melt or freeze it within the duration of the daily temperature swing.

Attic PCM Mat Placement Relative to Insulation

The PCM mats can be placed either above the insulation between the joists (see Figure 3), or below the insulation (see Figure 4). Each placement location has its own pros and cons. PCM above the insulation is exposed to larger temperature swings, increasing the average amount of energy stored in the material. It is also easier to install because temporary removal of the insulation is unnecessary. The PCM mats would be more exposed to temperature extremes that could potentially reduce its durability and useful life, but if the mats degrade or become damaged, it would be easier to remove them. If the PCM is below the insulation, there would be greater temperature stability adjacent to the living space, potentially improving comfort levels. Also, the mats would not be visible in the attic, and would be more protected from the elements. However, the melting and freezing process would be heavily dependent on large temperature swings inside conditioned space, which may not occur in all households[1]. Frequent thermostat set-up and set-back would be beneficial to thermal performance. Placement below insulation is also much more costly to install, and possibly remove if it becomes necessary. If leaks from PCM mats occur, they could cause damage to the ceiling gypsum board before they are noticed by homeowners.

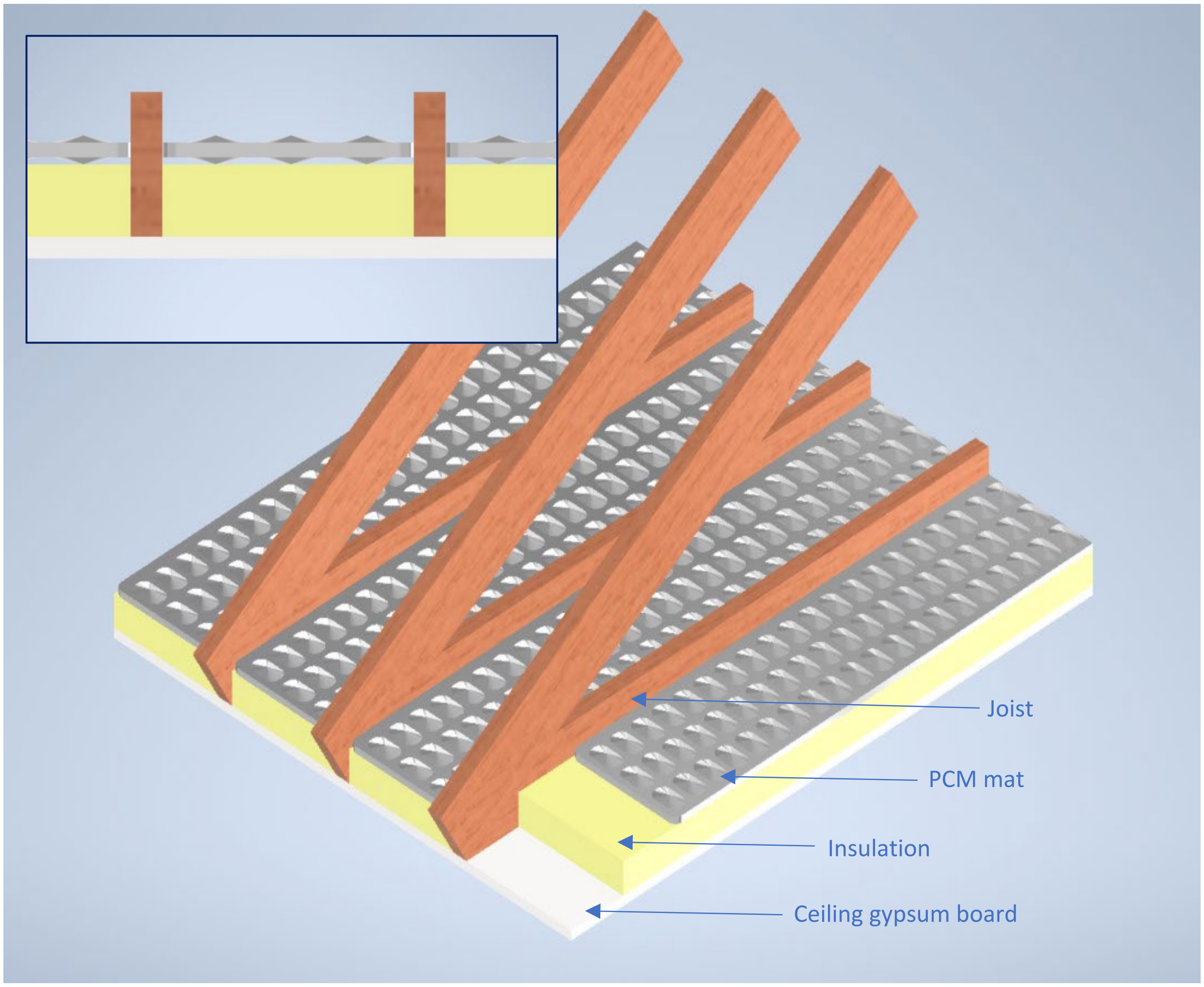

Figure 3. PCM placement above insulation.
Image credit: Edward Calderon

[1] Some occupants maintain uniform fixed thermostat set points, while others allow for 5-10°F indoor temperature swings in both winter and summer.

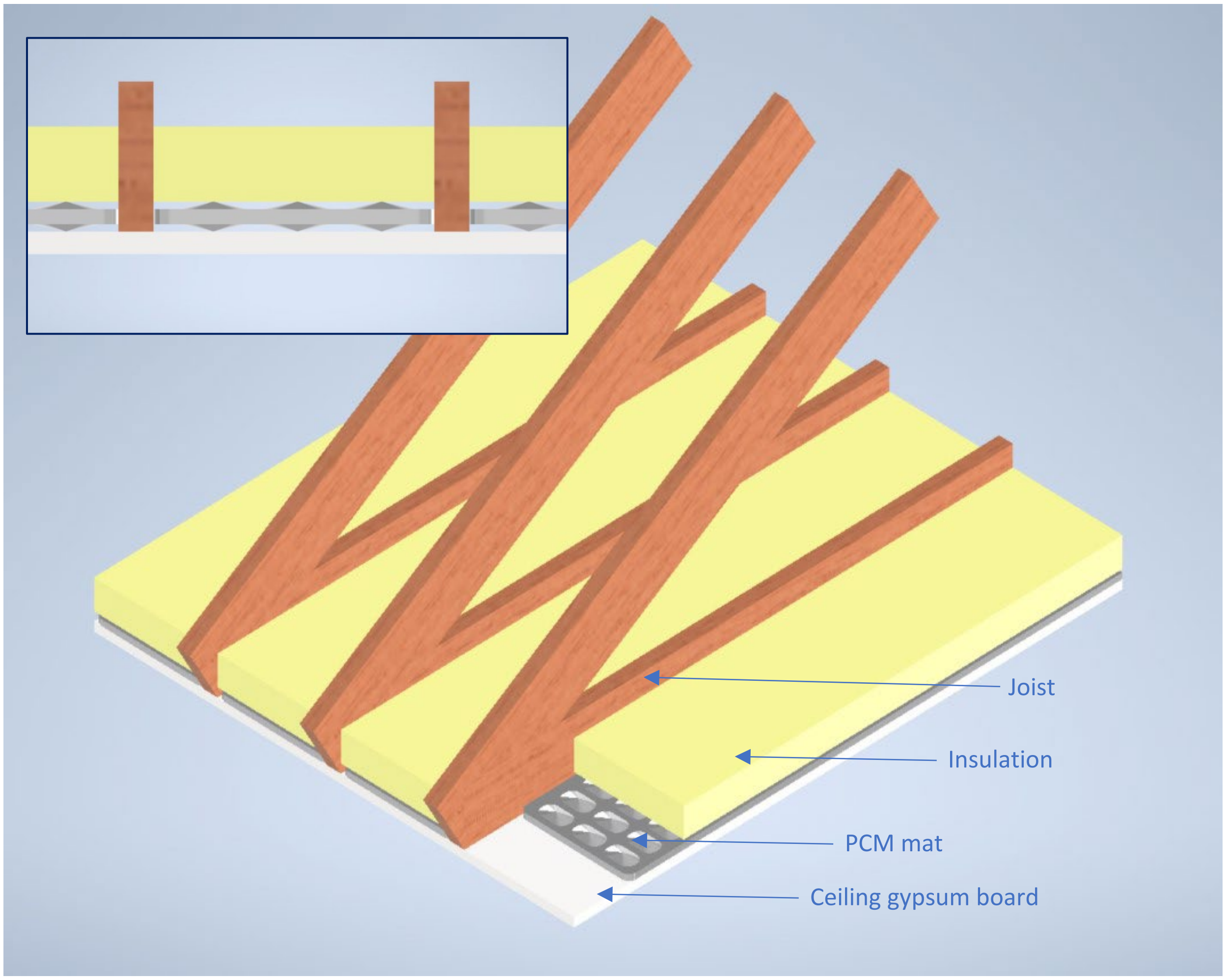

Figure 4. PCM placement below insulation.
Image credit: Edward Calderon

Melting Point

Recent field work in the mild Sonoma County climate, coupled with and a laboratory study, indicated that PCM has greater potential for reducing summer cooling energy than winter heating energy (Hendron, Chally, & Asay, 2022). Therefore, if the PCM is under the insulation, the melting point should be near the cooling set point used by the thermostat, perhaps slightly higher to account for warmer indoor air at the ceiling. We recommend 77°F as a good choice of melting point to optimize performance during the cooling season.

If the PCM is above the insulation, the melting point is less important because attic temperatures can change 50°F or more over course of a typical summer day, well beyond the available range of PCM melting points. However, selecting a melting point of 77°F would still be a good strategy because it is near the mid-point of daily attic temperature swings and will provide a more comfortable ceiling temperature near the thermostat set point.

Other Considerations

Additional options when selecting PCM mats are the size and number of layers. The width of the PCM mats should match the joist spacing in the attic, typically 16 inches or 24 inches. A mix of longer and shorter lengths (generally 2 feet or 4 feet) provides greater flexibility for fitting the PCM into the available attic spaces, which sometimes have ducts, piping, or other obstacles that must be worked around. One layer of PCM is likely to be adequate to store the available energy during the course of a day. Additional layers may be helpful from a performance standpoint, but are probably not worth the additional cost. There may also be issues of additional weight on the ceiling that could begin to cause structural concerns, as well as potential compression of attic insulation (and associated reduction in R-value) if the PCM mats are installed on top.

PCM mats act as a vapor barrier. As such, there should be 2-inch air gaps between mats if trapping moisture is a potential concern, especially in more humid climates.

III. Installation Guidelines

PCM mats can be installed with a minimal number of tools. When installed above insulation, the mats simply rest on the insulation, assuming it protrudes above the ceiling joists. If installed below the insulation or above installation adjacent to the joists, it is best to secure the mats to the joists using staples. The following tools are generally needed:

- Cutting/Box Knife
- Tape Measure
- Duct Tape or Specialized Adhesive Tape
- Ladder
- Safety Gear –Glasses, Hard Hat, Protective Gloves, Fall Protection & Breathing Protection as Required.
- Shop Rags/Wipes
- Staple Gun – Electric, Pneumatic or Hand Staplers – DO NOT USE Hammer Staplers.

If temporary removal of insulation is necessary, especially if fiberglass insulation is present, it is very important to wear gloves, protective glasses or goggles, and a face mask. Safety tips for working with fiberglass insulation can be found here: https://homeupward.com/working-with-fiberglass-insulation/

Boxes of PCM should be carried or handed up to the attic a few at a time to avoid excessive localized weight on the ceiling, and the potential for accidentally tripping or knocking boxes onto the gypsum board. Installers should always tread carefully when navigating an attic. Heat in the attic may also be a concern depending on the time of year, and frequent breaks for hydration and rest are recommended.

It is not necessary to provide complete coverage of the attic space, and it is therefore acceptable to avoid cramped spaces, ductwork/air handlers, lighting, piping, wiring, and other obstacles. It is best to leave 12 inches between the PCM and live wires or potentially hot surfaces such as water heater flues. 70% area coverage is generally adequate. The edges of the mats should be stapled to the joists on both sides every 12 inches to help minimize movement when the insulation is added. If space is restricted, the PCM mats should either be folded onto themselves or overlaps, as shown in Figure 5. The PCM should never be cut to size using scissors or box cutters (see Figure 6).

Figure 5. PCM folded or overlapping where necessary.
Image credit: Bob Hendron

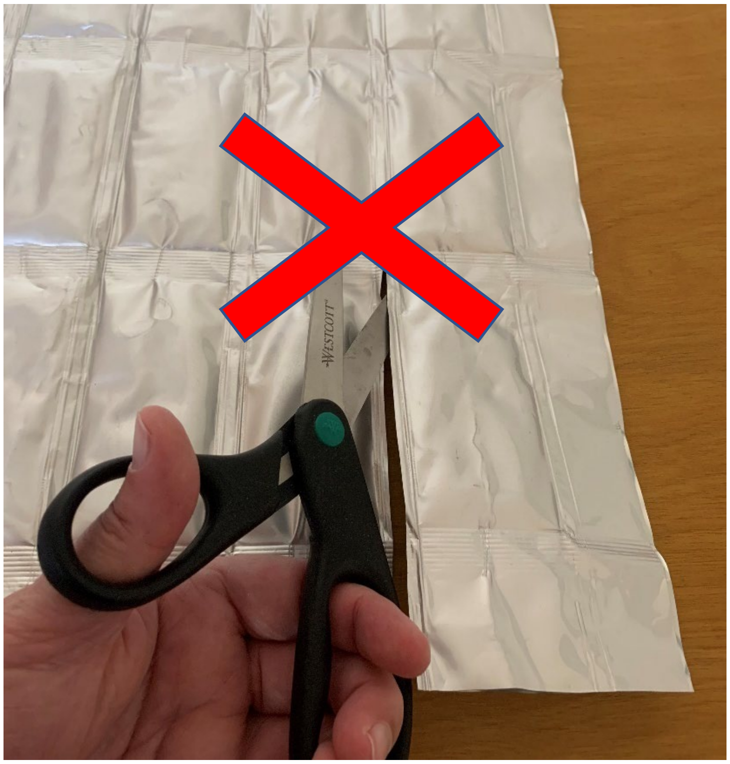

Figure 6. PCM should not be cut to avoid potential leakage.
Image credit: Bob Hendron

Sharp objects such as screws, nails, staples, sheet metal, and sharp corners of wood framing should be carefully avoided during installation to avoid puncturing the PCM pockets. If a leak occurs, the mat should be disposed of, and the area cleaned and covered with a primer to prevent possible condensation caused by the moisture-attracting nature of the PCM.

IV. Final Thoughts

New PCM products are becoming more readily available for residential building applications as the technology continues to advance. Optimal performance and installation methods depend on many variables, including the climate, attic design, insulation levels, and thermostat usage patterns. This guide addressed a particular application in residential attics, and hopefully provides some general insights into best practices and important considerations for other PCM products and applications. It is always best to consult with the PCM product manufacturer to confirm best practices for product selection and installation prior to beginning a project.

V. References

Hendron, R., Chally, S., & Asay, C. (2022). Energy Savings and Durability of Phase Change Materials in Residential Attics. *2022 Summer Study on Energy Efficiency in Buildings.* Asilomar, CA: ACEEE.