ASHRAE 2020
Virtual Conference

SMNR 40 - Who Said Thermal Storage Has to be Only in Tanks?
Thermal Storage in the Building Envelope

Energy Demand Management in Buildings using PCM-Integrated Wall

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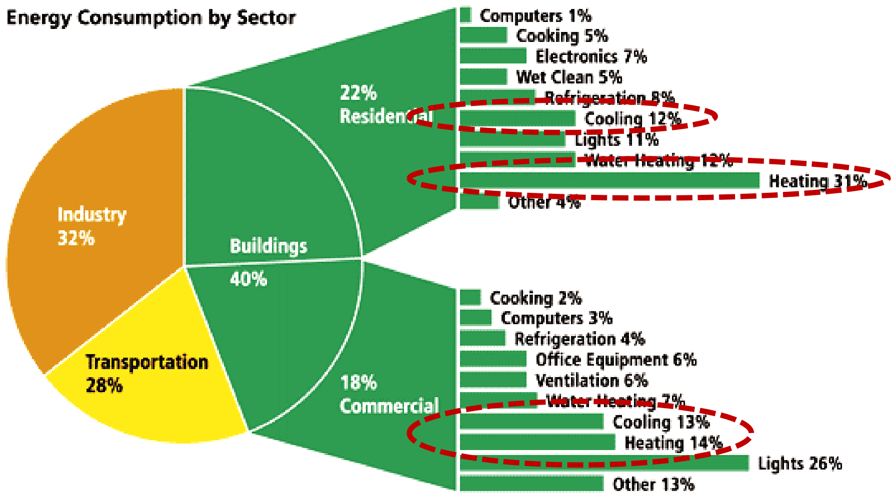
NREL Transforming ENERGY

Learning Objectives

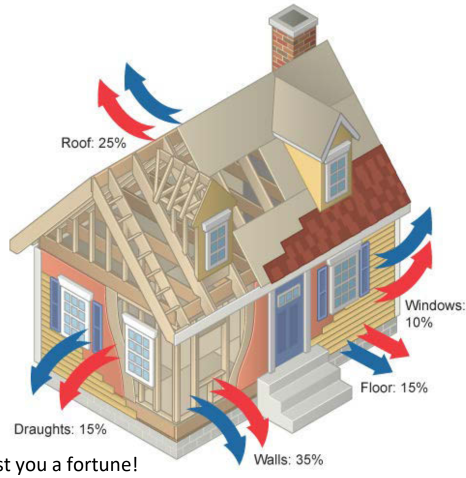
- Describe the difference between latent and sensible storage
- Define Phase Change Materials
- Provide an overview of how PCMs can improve building thermal performance when incorporated to the building envelope
- Explain to HVAC designers how to become familiar with design issues unique to thermal mass

Background



Source: Phase Change Composite Materials for Energy Efficient Building Envelopes
www.seas.ucla.edu/~pilon/PCMIntro.html

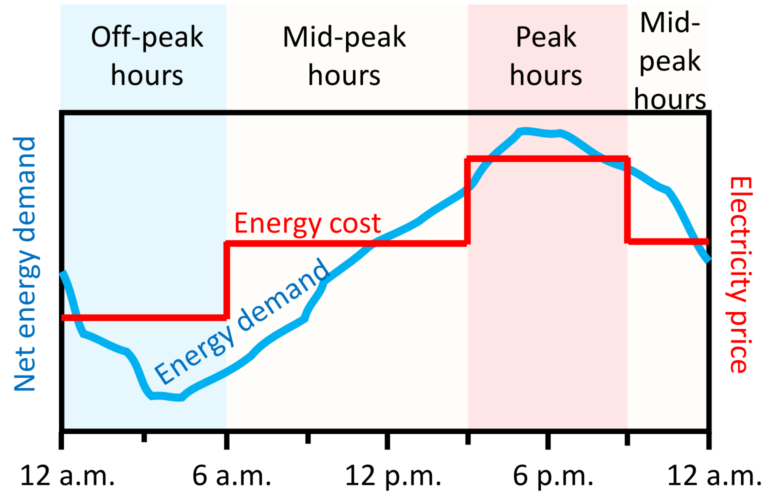
- Buildings consume nearly 40% of primary energy use globally
- Building sectors in the US annually consume about 75% of total electricity consumption
- Building operation accounts for approximately 30% of greenhouse gas emissions



Source: Energy loss can cost you a fortune!
www.coynerco.com/our-process/energy-loss/

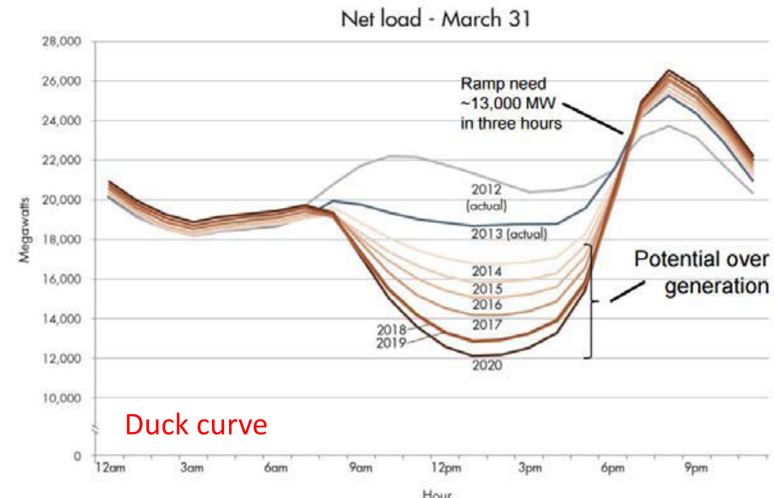
- Heating and cooling loads account for nearly 1/3rd of buildings' total energy use
- Nearly 35% of heat leakage occurs through walls of a typical building

Demand vs Supply and Time-of-use Pricing



- Net Energy demand (Utility-scale) is not uniform over the course of a day
- Utilities could charge higher electricity rates during peak hours

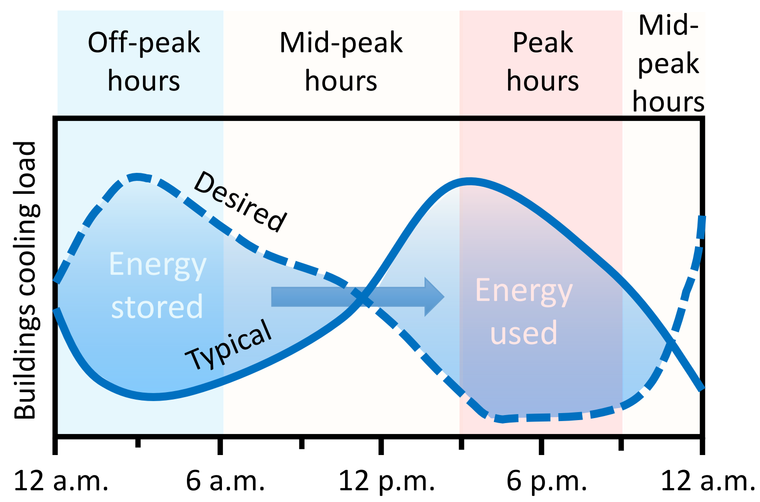
- With increasing contribution of renewable energy in total energy mix, the timing imbalance between demand and supply is becoming critical



California Independent System Operator, What the duck curve tells us about managing a green grid. www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

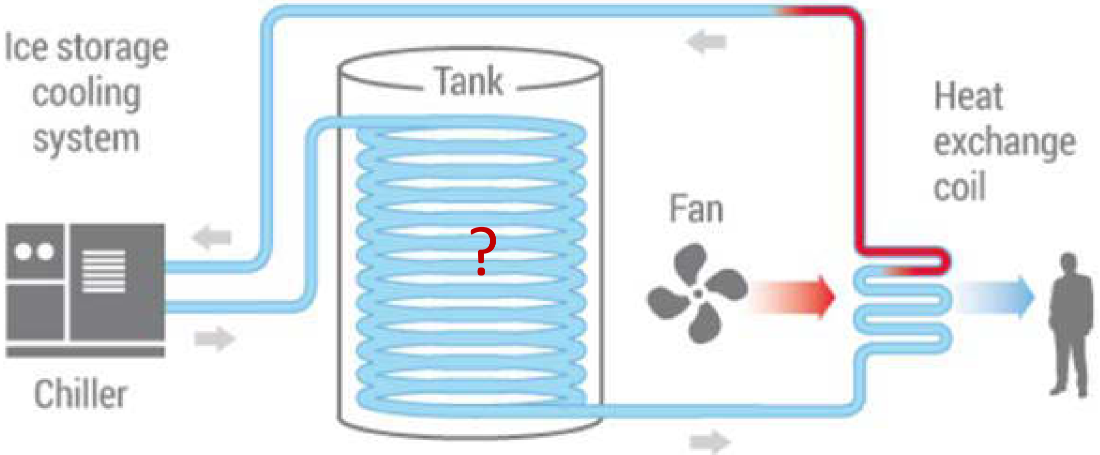
Complexity, Challenges, and Opportunity

- Buildings energy use peaks during peak hours
- Buildings load curve needs to be reshaped
- Thermal energy storage can be used to store excess energy in off-peak hours



Thermal energy storage (TES)

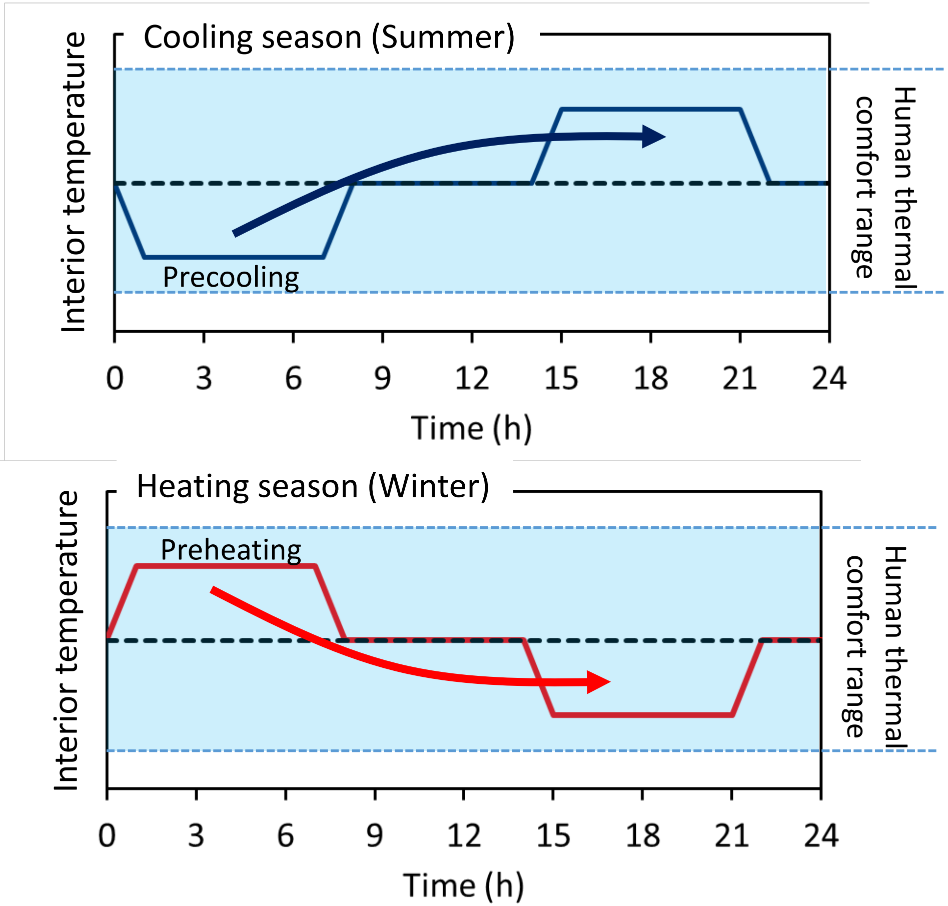
- A method of storing thermal energy by heating or cooling a storage medium
- Energy stored during off-peak hours can be used to partially/ completely offset the peak load
- Three classes of TES:
  - sensible heat storage
  - latent heat storage
  - thermochemical storage



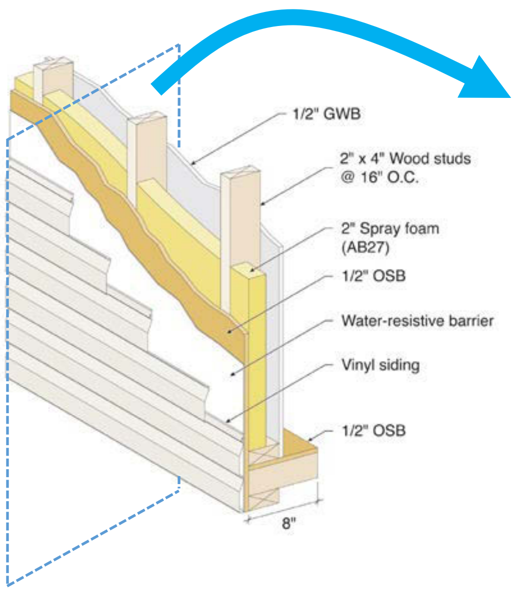
Source: Zero Energy Buildings should make nice with ice
www.treehugger.com/renewable-energy/zero-energy-buildings-should-make-nice-ice.html

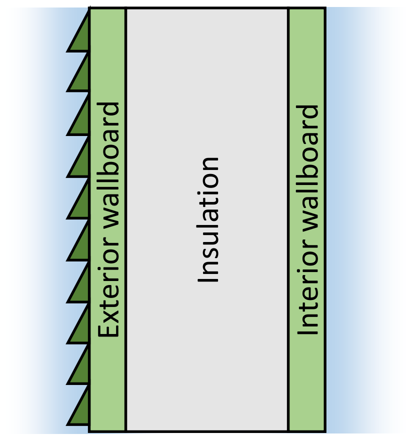
TES using Buildings Thermal Mass

- Thermal mass of the building can be utilized for TES
- However, this method works well for high thermal mass buildings, such as those with concrete structures

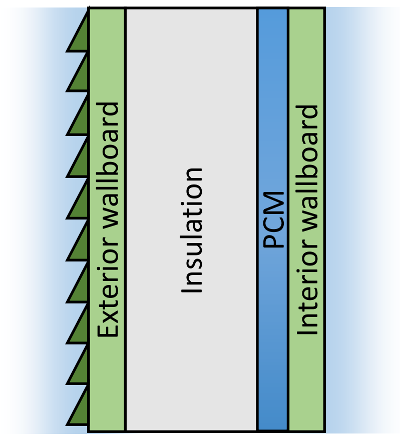


PCM-integrated Wall

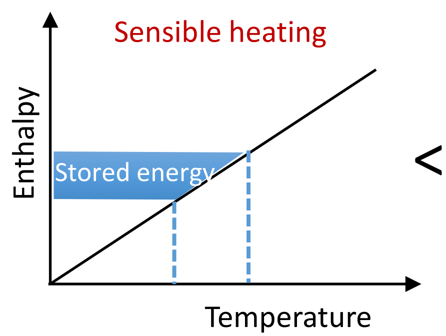




(A) Vertical cross-section of a typical building wall



(B) Vertical cross-section of a PCM-integrated building wall



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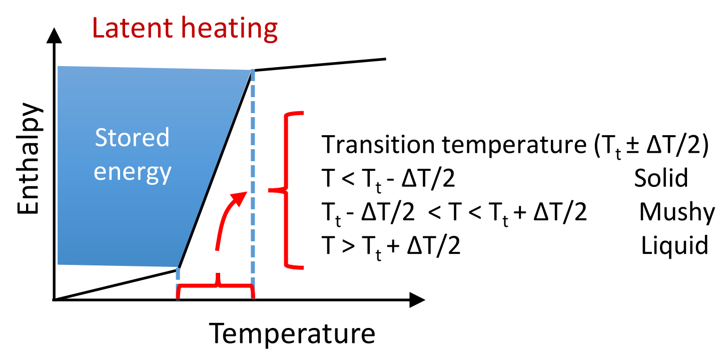
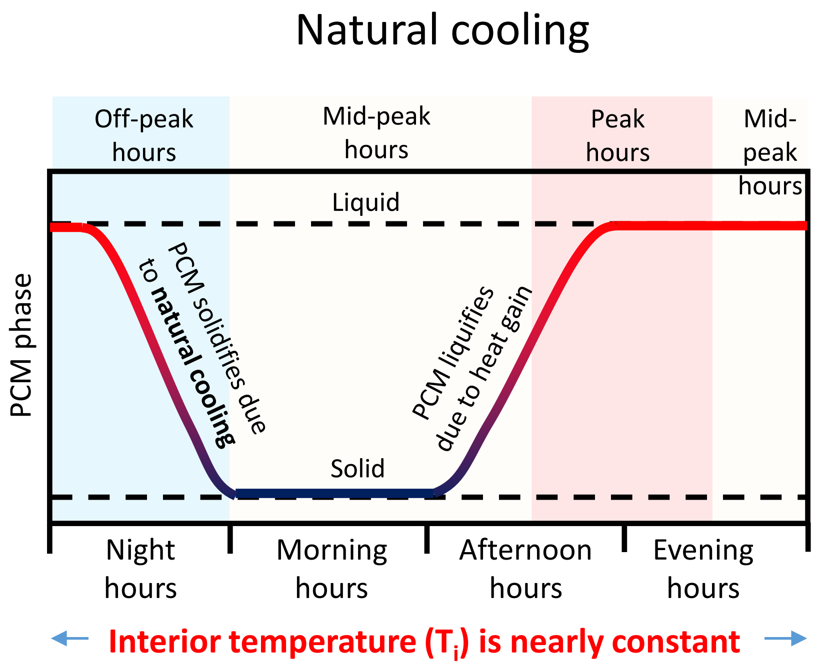
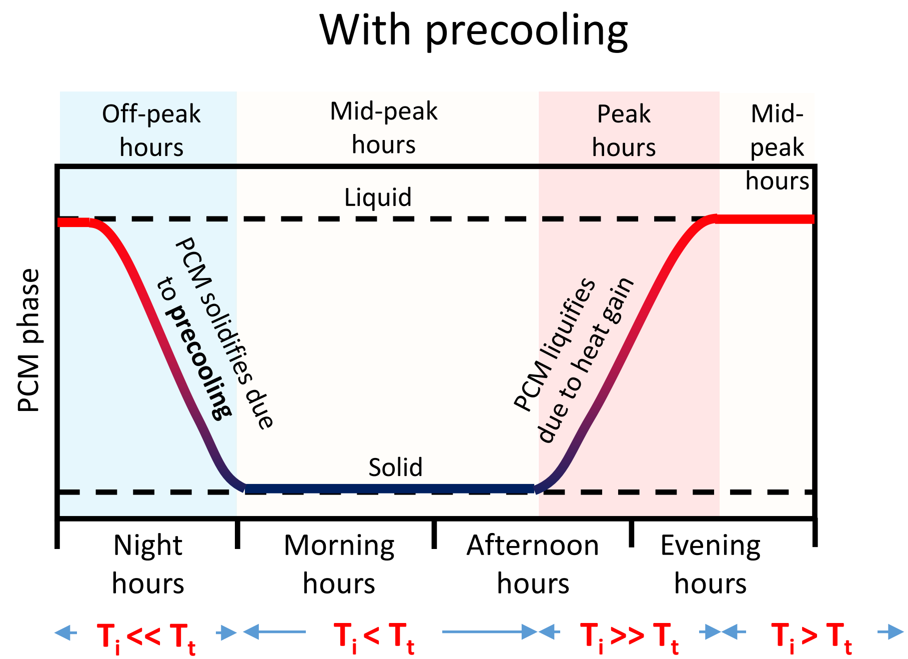


Natural cooling versus Precooling



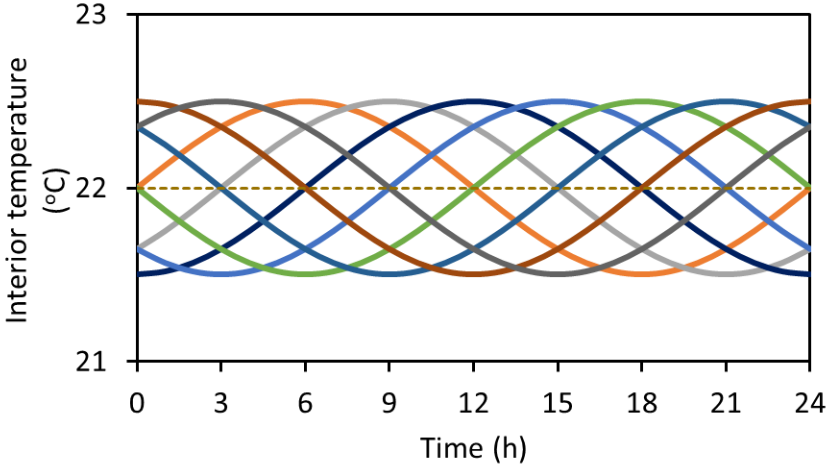


There is no control over the PCM as phase change is determined by exterior conditions

Precooling provides control over phase change, providing us the ability to reshape the buildings cooling load

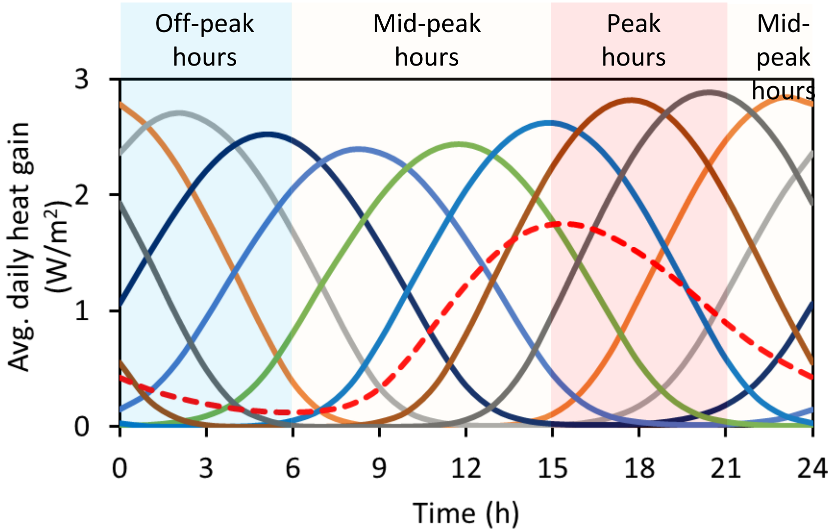
Optimizing Precooling Profile for a PCM-integrated Wall in Baltimore

Precooling profiles



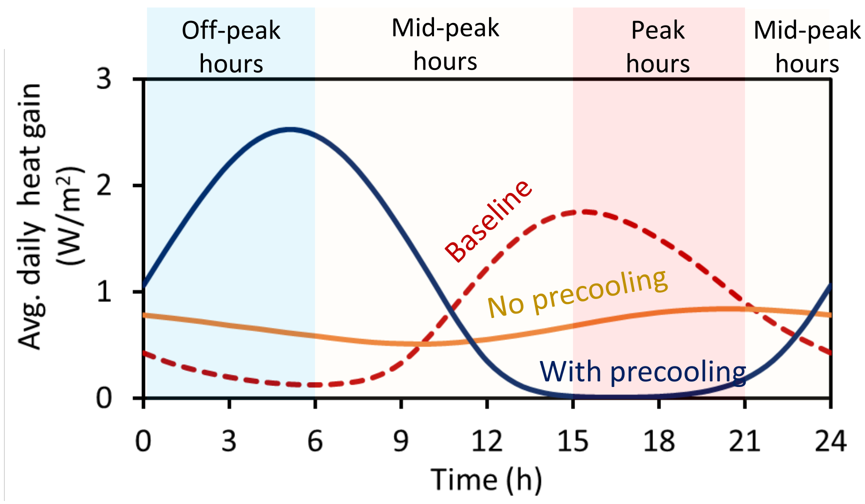
Interior temperature was varied sinusoidally to obtain various precooling profiles.

Heat gain profiles

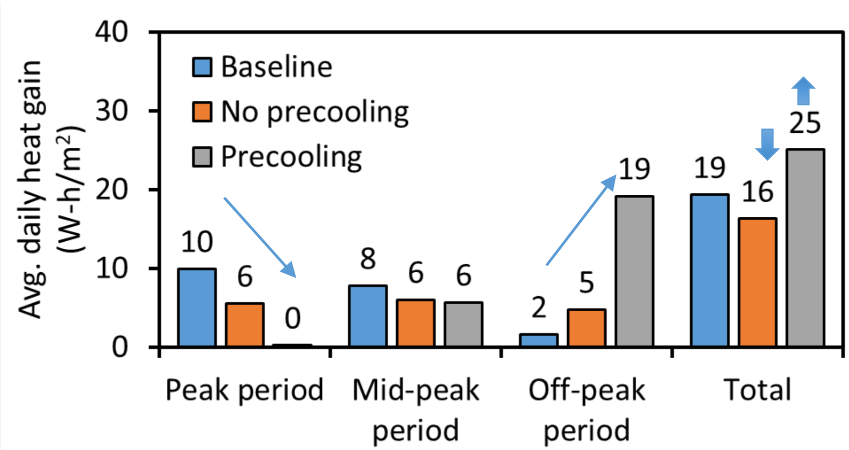


Each precooling profile results in a unique heat gain curve (Results obtained using heat transfer model in COMSOL Multiphysics).

Load Modulation using PCM-integrated Wall



PCM-integrated wall provides peak load shedding and shifting capacity



An optimized precooling profile can reduce the wall-related heat gains during peak hours to zero

Conclusions

- Integrating PCM in building envelopes is a recognized technique for thermal energy storage
- PCM-integrated envelope can provide substantial energy saving as well as peak load shedding and shifting in buildings
- The perform, however, depends on several factors such as building type, exterior and interior temperatures, and PCM’s thermophysical properties
- PCM-integrated envelopes should be optimized using suitable Building Energy Model (BEM) to maximize its energy saving potential

Questions?

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