Phase Change Materials: Are They Part of Our Energy-Efficient Future?

Brian James
Emerging Technologies Program
October 17, 2012
Overview

- Introduction
- How PCM Works
  - Products & Applications
  - PCM Properties
  - PCM vs. Conventional Thermal Mass
- What climates make the most sense?
- Commercial Market Sectors
- Technical Potential
- **Simulations**
- Challenges
- Future Work
Introduction

• GOAL:
  – Investigate current PCM market and PCM’s future in commercial buildings

• FOCUS:
  – PCMs in commercial building applications to offset cooling and heating loads

• BIG PICTURE:
  – California Long Term Energy Efficiency Strategic Plan

• SCE’s ROLE:
  – ET Program assessing the viability of EE technologies for adoption into incentive programs
How PCM Works

PCMs absorb excess heat when it's too hot.

PCMs actively absorb, store and release heat in order to maintain a targeted temperature range.

PCMs release heat if the temperature is lower than target.
## Products & Applications

### Micro-encapsulated Paraffin Wax
- Wallboard
- Ceiling Tile
- Floor Panel
- Interior Wall Construction

### Bio-based (Organic) Materials
- Interior Wall Construction
- Attic/Drop Ceiling Plenum Floor

### Eutectic Salt Mixtures
- Interior Wall Construction
- Attic/Drop Ceiling Plenum Floor

*Many others!*

---

**Phase Change Energy Solutions 2011, Jaworski, Abeid 2004**
## PCM Thermal Properties

<table>
<thead>
<tr>
<th>PCM Product</th>
<th>Melting Temperature Range (°F)</th>
<th>Heat of Fusion (Btu/lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro-encapsulated Paraffin Wax&lt;sup&gt;1, 2&lt;/sup&gt;</td>
<td>73-80</td>
<td>75</td>
</tr>
<tr>
<td>Bio-based (Organic) Materials&lt;sup&gt;3&lt;/sup&gt;</td>
<td>73-79</td>
<td>71-86</td>
</tr>
<tr>
<td>Eutectic Salt Mixtures&lt;sup&gt;4&lt;/sup&gt;</td>
<td>77-80</td>
<td>55-81</td>
</tr>
<tr>
<td>Water</td>
<td>32</td>
<td>144</td>
</tr>
</tbody>
</table>


- Thermal properties can be “tuned” by manufacturers to obtain melting temperatures suitable for desired application
PCM vs. Conventional Thermal Mass

Source: Konstantinidou 2010
What climates make the most sense?

- CA has 16 climate zones (CZs)
- Ideal CZ will have a diurnal temperature swing that fluctuates around the PCM melting temperature
- For simplicity, assumed PCM melting temperature was 80°F
- Typical Meteorological Year (TMY) 3 data
Climate Zone Summary

CZ 6

CZ 9

CZ 10

CZ 13
Climate Zone 6

- Diurnal swing below melting temperature
- PCM should be tuned to low 70s
- Potential application for high internal load buildings
Climate Zone 9

- Diurnal swing fluctuates around PCM melting temperature
- Ideal for absorbing daytime heat and recharging PCM at night
Climate Zone 10

- Greater potential for PCM due to larger diurnal fluctuations
- PCM charged/discharged quicker due to low nighttime and high daytime temperatures
Climate Zone 13

- Sufficient diurnal swing to charge/discharge PCM
- Longer cooling hours will lead to greater likelihood to mechanically recharge PCM
- Potential to reduce HVAC system capacity
# Commercial Market Sectors

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Floor Stock (kft²)</th>
<th>Cooling Electricity Usage (GWh/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Office ( &lt; 30,000 ft²)</td>
<td>157,884</td>
<td>460</td>
</tr>
<tr>
<td>Large Office ( ≥ 30,000 ft²)</td>
<td>227,225</td>
<td>899</td>
</tr>
<tr>
<td>Restaurant</td>
<td>61,623</td>
<td>483</td>
</tr>
<tr>
<td>Retail</td>
<td>309,601</td>
<td>863</td>
</tr>
<tr>
<td>Food Store</td>
<td>63,820</td>
<td>229</td>
</tr>
<tr>
<td>School</td>
<td>176,999</td>
<td>279</td>
</tr>
<tr>
<td>College</td>
<td>64,809</td>
<td>138</td>
</tr>
<tr>
<td>Refrigerated Warehouse</td>
<td>30,031</td>
<td>15</td>
</tr>
<tr>
<td>Unrefrigerated Warehouse</td>
<td>353,765</td>
<td>122</td>
</tr>
<tr>
<td>Health</td>
<td>106,471</td>
<td>454</td>
</tr>
<tr>
<td>Lodging</td>
<td>112,405</td>
<td>196</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>477,725</td>
<td>659</td>
</tr>
</tbody>
</table>

Source: California Commercial End-Use Survey 2006
What does this translate to?

Technical Potential Energy Savings

- Assume 10% energy savings
  - 335 GWh/yr

- Assume 30% energy savings
  - 1,005 GWh/yr
Simulations

- 11,000 sf commercial office building
- CZ 9, 10, 14, 15, 16 simulated with PCM “bubblepack” in ceiling plenum of drop ceiling
Simulations

Living / working space of a typical commercial building

Active / Circulating Plenum Airspace

Forced-Air Return

Forced-Air Supply

Drop Ceiling

Phase Change Material on top of drop ceiling
Simulations Results

- We need large room temperature swings to take advantage of PCM
- CZ 16
Simulations Results

- Peak cooling loads are reduced with PCM in ceiling plenum
- CZ 16
Simulation Results

- Setting thermostat at constant temperature shows little results
- Sensible cooling peak reduced by cooling at night at allowing temperature to float during the day
- Peak cooling reduced on order of 25%
- Monthly and annual heating and cooling requirements were reduced in ALL climate zones
- Diurnal room temperatures need to be larger than PCM transition range
Challenges

• Application of PCM is DELICATE

• Installation specific design/analysis
  – Too many variables!
  – Powerful simulation tools recommended

• HVAC control strategies needed
  – Cycle on/off AC to fully charge/discharge PCM
  – Don’t “set it and forget it”

• Fire Code
Future Work

• Further simulation studies for PCM installation
  – Building type
  – Climate zone
  – PCM melting temperature
  – PCM application

• Field monitoring
  – Multi-family PCM wallboard
  – Small commercial retail PCM integrated HVAC
For More Information

Brian James
Southern California Edison
Design and Engineering Services
brian.james@sce.com
626-633-7125