New Generation Solar Reflective Shingles

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• Why solar reflective (SR) roofs?
• Current asphalt shingle technology
• Color versus solar reflectance
• Next generation solar reflective shingles
• Field testing and aged performance
• Summary
Why solar reflective (SR) roofs?

• **Higher energy efficiency**
  – US spends ~$40 billion/year to cool buildings
    • 1/6 of all energy consumed
    • Reduced solar heat flux into conditioned space may reduce AC load

• **Approaches**
  – Insulation
  – Ventilation
  – Radiant barrier
  – SR Roof
Annual cooling energy saving of 10.4 TWh
Annual energy cost saving of $735m

Data Source: Ronnen Levinson, Hashem Akbari, in *Energy Efficiency*, 3(1), pp.53~109
Why solar reflective (SR) roof?

• Achieve higher energy efficiency
  – US spends $40 billion/year to cool buildings (1/6 of all energy consumed)
  – Reduce solar heat flux into conditioned space may reduce the AC load

• Mitigate “Urban Heat Island” effects
  – Increase surface Albedo to promote “global cooling”
  – Potential reduction in CO$_2$ emissions
  – Potential suppression in “smog” formation – reduce NO$_x$, SO$_2$ emissions

Source: Center for Architecture Science and Ecology

Source: NASA Defense Meteorological Satellites Program

Data Source: Ronnen Levinson, Hashem Akbari, in Energy Efficiency, 3(1), pp. 53 ~ 109
Global Cooling: Increasing SR to 0.25 would yield significant offset of CO$_2$ emission

<table>
<thead>
<tr>
<th>Row</th>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Area of the earth</td>
<td>$510 \times 10^{12}$ m$^2$</td>
</tr>
<tr>
<td>2.</td>
<td>Land area (29% of Earth area)</td>
<td>$147 \times 10^{12}$ m$^2$</td>
</tr>
<tr>
<td>3.</td>
<td>Dense and developed urban areas (1% of land area)</td>
<td>$1.5 \times 10^{12}$ m$^2$</td>
</tr>
<tr>
<td>4.</td>
<td>Roof area (25% of urban area)</td>
<td>$3.8 \times 10^{11}$ m$^2$</td>
</tr>
<tr>
<td>5.</td>
<td>Paved surface area (35% of urban area)</td>
<td>$5.3 \times 10^{11}$ m$^2$</td>
</tr>
<tr>
<td>6.</td>
<td>Potential emitted CO$_2$ offset for cool roofs [Row 4 × Row 6a Table 4]</td>
<td>24 Gt CO$_2$</td>
</tr>
<tr>
<td>7.</td>
<td>Potential emitted CO$_2$ offset for cool pavements [Row 5 × Row 8a Table 4]</td>
<td>20 Gt CO$_2$</td>
</tr>
<tr>
<td>8.</td>
<td>Total potential emitted CO$_2$ offset for cool roofs and cool pavements [Row 6 + Row 7]</td>
<td>44 Gt CO$_2$</td>
</tr>
<tr>
<td>9.</td>
<td>Projected 2025 world CO$_2$ emissions$^a$</td>
<td>37 Gt CO$_2$/year</td>
</tr>
</tbody>
</table>

Source: H. Akbari, S. Menon, A. Rosenfeld, *Climate Change*, 94, pp. 275~286
Asphalt shingles – current technology

• A proven choice of roofing materials
  – Lasting performance
  – Aesthetically pleasing
  – Class A fire rating
  – Ease of installation
  – Choice of colors & styles
  – Low cost to consumers
Asphalt shingles – current technology

• Traditional asphalt shingles are not designed to be solar reflective

- Asphalt with Fillers
- Glass Fiber Mat
- Colored Granules
- Back Surfacer

• A large portion of shingle surface is covered by roofing granules
Roofing granules – current technology

- Traditional roofing granules are designed for functionalities & aesthetics, but not for SR
  - Protecting asphalt from UV radiations
  - colored for aesthetics
  - Earth tone colors are among the popular choices

<table>
<thead>
<tr>
<th>Color Description</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
<th>Averaged solar reflectance, %</th>
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</thead>
<tbody>
<tr>
<td>Black</td>
<td>22.91</td>
<td>-0.11</td>
<td>-0.67</td>
<td>4</td>
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<tr>
<td>Gray</td>
<td>31.34</td>
<td>0.05</td>
<td>0.32</td>
<td>6.2</td>
</tr>
<tr>
<td>Dark brown</td>
<td>26.90</td>
<td>5.66</td>
<td>8.08</td>
<td>5.9</td>
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<tr>
<td>Brown</td>
<td>39.97</td>
<td>13.29</td>
<td>18.98</td>
<td>15.0</td>
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<tr>
<td>Buff</td>
<td>41.50</td>
<td>10.67</td>
<td>21.19</td>
<td>15.4</td>
</tr>
<tr>
<td>Olive</td>
<td>36.25</td>
<td>0.33</td>
<td>5.75</td>
<td>10.0</td>
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<tr>
<td>Light gray</td>
<td>48.53</td>
<td>-3.66</td>
<td>2.84</td>
<td>16.8</td>
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<tr>
<td>Light buff</td>
<td>55.92</td>
<td>6.41</td>
<td>19.65</td>
<td>25.4</td>
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<tr>
<td>White</td>
<td>67.54</td>
<td>-0.44</td>
<td>1.28</td>
<td>31.3</td>
</tr>
</tbody>
</table>
Granules for solar reflective roofs

- Roofing granules have rough surfaces that may reduce solar reflectivity

Standard non-SR granules in light grey color under microscope
SR roofing granules: challenges

- Color vs. SR: how to maintain the color and the coolness at the same time?

More than 50% of solar heat is in the NIR radiation!

Data source: R. Levinson, Urban Heat Island Group, LBNL
SR roofing granules: current technology

• “cool” colorants to enhance the SR
  – Commercially available “cool” pigments
  – High cost; limited in colors
  – Improvements are not drastic

• Use of white reflective base coat followed by a 2nd color coat
  – More efficient for SR increase
  – Higher cost; loss of color saturation
SR granules: current technology

- Standard non-SR granules
- SR granules with white base coat

\[ R^2 = 0.9411 \]

\[ R^2 = 0.9743 \]
SR granules: new generation

- Improved coating efficiency yields SR roofing granules that meet Title 24 and Energy Star® requirements in traditional earth-tone colors
New SR shingles in traditional earth-tone colors

- Traditional shingles
- New Generation SR shingles
  - 25% total solar reflectance
- Traditional shingles
Potential energy savings by the new generation SR shingles:

- DOE Cool Roof calculator shows typically ~10% saving in cooling load

<table>
<thead>
<tr>
<th>Fresno, CA</th>
<th>Energy Costs</th>
<th>Cooling Load</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Base (Btu/ft² yr)</td>
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<tr>
<td>R19</td>
<td>Summer Elec. $/KWH</td>
<td>3515</td>
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<tr>
<td>R30</td>
<td>0.1434</td>
<td>2227</td>
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<tr>
<td>R38</td>
<td>Natural Gas $/THERM</td>
<td>1785</td>
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<tr>
<td></td>
<td>1.173</td>
<td></td>
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<tr>
<td>Elpaso, TX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R19</td>
<td>Summer Elec. $/KWH</td>
<td>3904</td>
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<tr>
<td>R30</td>
<td>0.1258</td>
<td>2479</td>
</tr>
<tr>
<td>R38</td>
<td>Natural Gas $/THERM</td>
<td>1991</td>
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<tr>
<td></td>
<td>1.384</td>
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New generation SR shingles

WUFII simulations predict ~10° cooler roof temperatures
Field testing and aged performance

- Outdoor exposure testing (hot/wet, hot/dry, cool/wet climates)
- Excellent color and SR retention after 3 years
New generation SR shingles: aging performance

• Accelerated artificial aging test also confirms the color and solar reflectance are maintained
Future of solar reflective shingles: Shingles that go beyond 25% SR

- Shingles SR values $\geq 40%$

IR camera image showing temperature differences between traditional non-SR shingles and shingles with SR at 40%
Summary

• The solar reflectance of traditional shingles can be improved by increasing the solar reflectance of their covering roofing granules.

• With improved coating technology, new generation solar reflective roofing granules can deliver both the high SR and desirable earth-tone colors.

• 3-year field weathering tests in various climates show that the SR and color are maintained.

• Significant energy savings can be accomplished with the use of solar reflective shingles.
Thank You !