Evolutions in Cool Roofing
Challenges, Opportunities & Perspectives
Frank Klink & Rebecca Everman, 3M Industrial Mineral Products Division
Evolutions in Cool Roofing
Challenges, Opportunities and Perspective

Organization
1. 3M Overview & Sustainability Commitment
2. 3M Involvement in the evolution of granulated & cool roofing
3. Challenges and Opportunities
   - Granulated cool roofs
   - Smog reducing roofing
4. Perspective
   - Which “envelope” to optimize
   - The CRRC’s unique role
   - Resilience & Sustainability
3M at a glance

• Sales in ~200 countries
• $32.8 billion in sales
• Four business groups
• 93,000 3Mers globally
• 115,000 patents
• 100+ straight years of dividends
• One of 30 companies on the Dow Jones Industrial Index
Our four Business Groups

Safety & Industrial

Transportation & Electronics

Health Care

Consumer
3M Industrial Mineral Products
Safety & Industrial Business Group

Began in Wausau, WI in 1929
Product Offerings

- Prime Colored Granules
- Algae Resistant Copper Granules
- Cool Roofing Granules
- Smog Reducing Granules
- Headlap Granules
- Mineral Fines for Ceramic Tile and Construction

Technical Advancements

1929 – 3M purchases competitor Wausau Abrasives and enters the roofing granules market.
1937 – 3M’s Houston test deck established.
1961 – Cyanobacteria identified as cause of dark streaks
1970 – First patent awarded for algae-resistant granules
1991 – Algae-resistant granules launched
2006 – 3M™ Cool Roofing Granules introduced.
2011 – DREW technology introduced to suppress dust and reduce oil shading
2018 – 3M introduces Smog Reducing Granules
2019 – 3M introduces Highly Reflective Granules for Commercial Roofing
2020 – 3M introduces Smog Reducing Granules
<table>
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<tr>
<th>Technology</th>
<th>Manufacturing</th>
<th>Global capabilities</th>
<th>Brand</th>
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<tr>
<td>Ability to share and combine elements of 3M’s broad technology portfolio to produce unique, differentiated products, translating to premium margins</td>
<td>Utilization of 3M manufacturing footprint and technology, including process trade secrets, leading to higher-performing products and lower unit costs</td>
<td>Subsidiary front- and back-office footprint that allows for the effective development, adaptation and commercialization of products</td>
<td>Brand equity in the 3M brand and in strategic brands that are shared across business groups</td>
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Our vision

Our Vision

3M Technology Advancing Every Company
3M Products Enhancing Every Home
3M Innovation Improving Every Life

Vision | Strengths | Priorities | Values
Advancing sustainability

<table>
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<tr>
<th>Pollution Prevention Pays</th>
<th>2025 Goals</th>
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<tr>
<td><strong>44 years</strong></td>
<td><strong>25 percent</strong></td>
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<td>Started in 1975</td>
<td>Increase renewable energy to 25% of total electricity use</td>
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<td><strong>15,300</strong></td>
<td><strong>10 percent</strong></td>
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<td>3P Projects</td>
<td>Reduce global water use by an additional 10% indexed to sales</td>
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<td><strong>2.5 million</strong></td>
<td><strong>50 percent</strong></td>
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<td>Tons of pollutants prevented</td>
<td>Ensure GHG emissions at least 50% below 2002 baseline</td>
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<tr>
<td><strong>$2.2 billion</strong></td>
<td><strong>250 million tons</strong></td>
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<td>Saved (USD)</td>
<td>Help customers reduce GHG’s by 250M tons with 3M products</td>
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Leading and **innovating** for a more sustainable future
Applying our science to improve every life

**Focus areas:**

**Science for Circular**
Design solutions that do more with less material, advancing a global circular economy.

**Science for Climate**
Innovate to decarbonize industry, accelerate global climate solutions and improve our environmental footprint.

**Science for Community**
Create a more positive world through science and inspire people to join us.

**Aspirations:**

**Actions:**

Every new 3M product that enters our new product commercialization process must have a Sustainability Value Commitment.

We’re committed to renewable energy. We power our headquarters with 100% renewable electricity and aim for 50% globally by 2025.

We are making a difference in the world through STEM education, science advocacy, skills-based volunteerism and training the workforce of the future.
Roofs should:

- Protect the underlying structure from moisture
- Be fire resistant
- Be durable & weatherable (to wind driven rain, hail, ice & snow)
- Be attractive (especially steep slope)
- Maintain their appearance (resist soiling, staining & biological growth)
- Be affordable (installed cost)
Evolution of Granulated Roofing

Early Asphalt Roofing had no granules
- Burlap coated with crude tar or pitch
- Organic felt mat coated with asphalt
- Could be easily coated & mass produced
- Asphalt available as cheap by-product from developing Petroleum Industry

Advantages
- Water Resistant
- Inexpensive
- Light weight
- Flexible & easy to attach

Drawbacks
- Became stiff and cracked rapidly on aging
- Not very resistant to wind or hail
- Unattractive
Granulated Roofing
Advantages & Challenges

Innovation: *Coat the asphalt with an inexpensive mineral*

Advantages
- Inexpensive
- Still pretty little weight
- Easier to unroll / mineral keeps roll / shingles from sticking together
- More attractive – especially if the granules are colored

Key Observation
- Some mineral types fall off in just a few years
Granulated Roofing
Advantages & Challenges

Innovation: *Coat the asphalt with an inexpensive mineral that blocks UV Radiation*

High energy UV radiation rapidly degrades the asphalt

**Solar Energy Distribution**
- 5% ultraviolet (300-400 nm)
- 43% visible (400-700 nm)
- 52% near-infrared (700-2500 nm)
Granulated Roofing

Granule Benefits

- Inorganic mineral and ceramic coating construction – durable & highly resistant to UV radiation
- Non-combustible with heat capacity
- Economical platform for color
- Scattering minimizes specular reflectance (glare)

Desired Coated Granule Attributes

- Opaque to UV radiation
- Tough and durable in handling and use
- Accept ceramic coating with minimal spall on firing
- Blocky shape (to minimize positional embedment)
- Consistent grade distribution (to cover asphalt)
- Stain-resistant
- Low dust
- Adhere well (initially and with weathering) to asphalt
Roofs should:
✓ Protect the underlying structure from moisture
✓ Be fire resistant
✓ Be durable & weatherable to (wind driven rain, hail, ice & snow)
✓ Be attractive (especially steep slope)
✓ Maintain their appearance (resist soiling, staining & biological growth)
✓ Be affordable (installed cost)

Cool Roofs need to do all that and:
✓ Exhibit, and maintain, enhanced radiative properties
Granulated Cool Roofing

Challenge = Rough Surface + Exposed Asphalt + Enable Color* 

* for Steep Slope
Granulated Cool Roofing
Rough Surface + Exposed Asphalt

Each interaction with the substrate is another opportunity for absorption.

(Exposed black asphalt decreases SR)
Granulated Cool Roofing

Rough Surface

Surface roughness effects on the solar reflectance of cool asphalt shingles

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Abstract

We analyze the solar reflectance of asphalt roofing shingles that are covered with pigmented mineral roofing granules. The reflecting surface is rough, with a total area approximately twice the nominal area. We introduce a simple analytical model that relates the “micro-reflectance” of a small surface region to the “macro-reflectance” of the shingle. This model uses a mean-field approximation to account for multiple scattering effects. The model is then used to compute the reflectance of shingles with a mixture of different colored granules, when the reflectances of the corresponding mono-color shingles are known. Simple linear averaging works well, with small corrections to linear averaging derived for highly reflective materials.

Reflective base granules and reflective surface coatings aid achievement of high solar reflectance. Other factors that influence the solar reflectance are the size distribution of the granules, coverage of the asphalt substrate, and orientation of the granules as affected by rollers during fabrication.

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Keywords: Cool roofing; Asphalt shingle reflectance; Rough surface

Fig. 2. The relation between shingle macro-reflectance and granule surface micro-reflectance for several values of \( p \). The ratio of total shingle area to nominal area is approximately \((1-p)^{-1}\).

Eq. (1) can be rewritten in terms of \( R \) and \( r \) only as

\[
R = \frac{r(1 - p)}{1 - pr}.
\]  

\( p \) is the probability that a photon leaving the rough surface will again encounter the surface.
Granulated Cool Roofing
Enabling Color

Solar Energy Distribution
- 5% ultraviolet (300-400 nm)
- 43% visible (400-700 nm)
- 52% near-infrared (700-2500 nm)
Granulated Cool Roofing

Enabling Color

Solar Energy Distribution
- 5% ultraviolet (300-400 nm)
- 43% visible (400-700 nm)
- 52% near-infrared (700-2500 nm)
Granulated Cool Roofing
Enabling Color

Pigments like TiO$_2$, or materials that scatter light in the visible band, increase the solar reflectance, but at great cost to color.

Solar Energy Distribution
- 5% ultraviolet (300-400 nm)
- 43% visible (400-700 nm)
- 52% near-infrared (700-2500 nm)
Granulated Cool Roofing
Enabling Color

Pigments that reflect or predominantly scatter in the infrared band, increase the solar reflectance, while preserving color.

Solar Energy Distribution
- 5% ultraviolet (300-400 nm)
- 43% visible (400-700 nm)
- 52% near-infrared (700-2500 nm)
Cool Roofing Granules

- 1880 Silver
- 1580 Spice
- 1780 Saffron
- 1180 Sable
- 1680 Sage
- 1280 Shale
- 1380 Suede
- 4980 Buff
- 6680 Sienna
- 7480 Blue Grey
- 9380 White
- 9900 HR White

Graph showing the relationship between TSR and L*.

- Highly Reflective White
- Premium Cool
- Standard Cool
- CA Cool
- Standard Colors

Colors:
- 9900 HR White .77
- 4980 Buff .31
- 6680 Sienna .29
- 7480 Blue Grey .29
- 9380 White .34
- 1180 Sable .21
- 1680 Sage .27
- 1280 Shale .24
- 1380 Suede .26
- 1880 Silver .27
- 1580 Spice .31
- 1780 Saffron .31
Granulated Cool Roofing
Enabling Color

Solar Energy Distribution
- 5% ultraviolet (300-400 nm)
- 43% visible (400-700 nm)
- 52% near-infrared (700-2500 nm)
Opportunity
Radiative Cooling Panels - Subcooling

Integration mode: subcooling

- **Average runtime**
  - SCS Panels: 5.6 min
  - Baseline: 10.1 min
  - Runtime Reduction: 44% reduction

- **Average energy use per runtime**
  - SCS Panels: 0.19 kWh
  - Baseline: 0.35 kWh
  - Runtime Reduction: 45% reduction

- **Increase in # of times on per day:** 102 vs 70

- **Net Energy Savings:** 20.4%
NO₂ in our environment

The US EPA lists NO₂ as one of the six criteria pollutants for which the Clean Air Act requires setting National Ambient Air Quality Standards (NAAQS).

The current NAAQS for NO₂ are 100 ppb for a 1-hour exposure, and an annual standard of 53 ppb. NO₂ primarily gets in the air from the burning of fuel (coal, oil, diesel fuel, and natural gas).

The challenge NO₂ presents to cities, is that it is generated across a large urban geography and is concentrated along transportation corridors.

https://www.epa.gov/criteria-air-pollutants
https://www.epa.gov/no2-pollution/basic-information-about-no2#WhatisNO2
https://www.epa.gov/air-pollution-transportation/smog-soot-and-local-air-pollution
Granulated Roofing Opportunity
Use roofs to help clean the air

Utilize the very large surface area of granulated roofing as a durable & economical catalyst support to harness the power of the sun’s high energy UV radiation to photolyze NO\textsubscript{x} pollutants.
Perspective

Our past no longer predicts our future
Why Roofs?
The **Building Envelope** or the **Urban Envelope**?

**Baton Rouge, LA**

*Source: NASA/Marshall Space Flight Center, November 1998*
If not us, who?

The Cool Roof Rating Council was created in 1998 to develop accurate and credible methods for evaluating and labeling the solar reflectance and thermal emittance (radiative properties) of roofing products and to disseminate the information to all interested parties.
Resilience in the era of a changing climate

The Importance of Adaptation

“The goal of climate change adaptation is to take actions today to reduce losses tomorrow...

Lead with the Roof; Solve with Research on Vulnerability and Loss; and Prevent Avoidable Damage.”

Testimony by Roy Wright, President and CEO of the Insurance Institute for Business & Home Safety to the House Ways and Means Committee Hearing; "The Economic and Health Consequences of Climate Change." – May 15, 2019
Improving Building and Community Resilience

Roofing real estate can be used to:

Improve building protection and performance
  - Wind
  - Rain
  - Hail
  - Snow & Ice
  - Fire

Mitigate urban heat islands
Reduce peak electricity demand
Be a platform for energy generation and thermal energy collection & rejection
Reduce toxic air pollutants
Reduce stormwater runoff
And probably even more...
“A society grows great when old men plant trees in whose shade they shall never sit”
- Greek Proverb

Thank You
### Acknowledgements

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