

RE: Cool Roof Coatings for Overheating Mitigation

RDH was retained by the City of Vancouver to conduct research and provide recommendations for the promotion of cool roof coatings to mitigate overheating in multi-unit residential buildings in Vancouver. Research included outreach to local roofing industry associations and roofing manufacturers, assessment of cool roof feasibility for a sample of buildings as part of the City of Vancouver Existing Multi-Family Buildings and Overheating: Thermal Resilience Retrofits Feasibility Study, and selected review of journal articles, conference papers, and reports. This memorandum is a summary of our findings.

1. Introduction

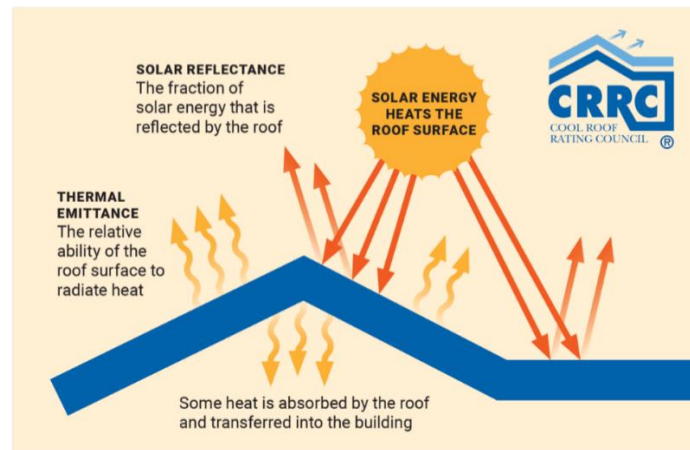
Cool roofs are a name for high reflectance roofs coverings which directs and/or re-radiate a high proportion of incoming solar energy away from a building, reducing the amount of energy absorbed by the material and in turn, reducing surface temperatures. In residential buildings, this has the potential to decrease heat transfer that can contribute to overheating, especially in top floor suites.

This potential has led to municipal led initiatives, such as the NYC Cool Roofs program in New York City, which promotes the retrofit application of cool roof coatings over existing roofing membranes. The City of Vancouver (CoV) is interested in exploring whether similar programs could deliver meaningful benefits for buildings in the Lower Mainland of British Columbia. This memo summarizes RDH's findings, considerations, and recommendations related to the use of cool roof coatings, with specific focus on Vancouver's climate conditions and prevailing building practices.

2. Types of Cool Roofs

The performance of cool roofs is a function of two material properties: solar reflectance and thermal emissivity. These properties are commonly summarized using the solar reflectance index (SRI), a calculated value that combines solar reflectance and thermal emissivity, as compared to reference materials. The SRI of most roofing materials is between 0-100, with higher numbers indicating more reflectance (cool roofs are often called high-SRI roofs). The basic heat transfer mechanisms of a cool roof are noted below in Figure 1. The Cool Roof Rating Council (CRRC) provides a third-party rating program for cool roof products in the North American market. The SRI and other technical data for rated cool roof coatings is provided in the CRRC's Rated Roof Products Directory [1].

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/ Figure 1: Mechanisms of heat gain and rejection from roofs. Graphic source: [2]

Cool roofs are commonly installed in hot and sunny climates where buildings experience high outdoor temperatures and significant solar exposure. They are not as ubiquitous in cool humid climates like Vancouver's with shorter, cooler summers and frequent overcast days, however higher SRI roof systems can be observed throughout the city. A high SRI value can be an inherent property of a roofing membrane or can be added to a roofing system as a post-applied coating. While this memo focuses on post-applied coatings, it is important to note the differences between these two approaches in a renewal application. A comprehensive overview of cool roofing materials, as well as benefits, comparison to other roofing systems, and design considerations are provided in "A Practical Guide to Cool Roofs and Cool Pavements: Primer" [3].

High-SRI Roofing Systems

High-SRI roofing products are commonly available from most roofing system manufacturers and suppliers in British Columbia. High-reflectance modified bitumen membrane cap sheets (e.g. SBS), as well as high-reflectance asphalt shingles, are manufactured using light-coloured granules. Thermoplastic and thermoset roofing membranes (e.g. EPDM, TPO, and PVC), also known as single-ply roofing membranes, are commonly manufactured in light colours. Light-coloured metal roofing provides high solar reflectance. Gravel built-up roofs can be installed with white gravel to increase its reflectance. A high-SRI roof material would be specified either as part of the roofing system in new construction, or as part of a roofing membrane replacement where the existing membrane is at the end of its service life and needs to be removed.

Post-Applied Cool Roof Coatings

Existing low-reflectance roofs can be converted to cool roofs using a fluid-applied high-SRI coating that is applied over top of the existing membrane. These high-reflectance coatings are typically rolled or sprayed onto the existing roof surface, like a paint, to increase solar reflectance, as shown in Figure 2. These coatings are also intended to add a new layer of waterproofing over the existing membrane to extend the life of the existing roof. Note, these coatings are designed for exposed-membrane (conventional) roof assemblies but not protected-membrane (inverted) roofs. Other light-coloured finishing products may be available for paver overburden on inverted roofs, which are beyond the scope of this memo.

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/ Figure 2: Application of a cool roof coating over a modified bitumen membrane. Image source: [4]

Based on a preliminary review of available cool roof coating products in the North American market, coatings are available for most roofing types, including modified bitumen, smooth built-up roofing, modified bitumen, TPO, EPDM, PVC, metal roofs, and previously coated roofs. Coatings are commonly acrylic elastomeric or silicone elastomeric. Polyurethane or polymethyl methacrylate (PMMA) fluid-applied roof membranes can also be applied as a reflective coating. A limited number of available products were identified that are recommended for use on asphalt shingles. Technical data is unavailable online for these products and their performance is unknown.

3. Overheating Impact of Cool Roofs

Regardless if it is a high-SRI roofing membrane, or post-applied coating, numerous experimental and modelling studies have consistently demonstrated that cool roofs significantly reduce roof *surface temperatures*, confirming the physical mechanism by which they limit solar heat absorption and heat transfer into buildings (e.g. [5], [6]). However, a recent literature review found limited empirical information about the impact of cool roofs on reducing indoor overheating risk [7]. Available studies identified in the review and by RDH suggest that the magnitude of this effect is small to modest in multi-unit residential buildings (MURBs). Findings include:

- An unpublished study by RDH on a six-storey MURB, constructed in 2020 and located in the Lower Mainland, found that a combined strategy of cool roofs and cool exterior walls reduced overheating hours (defined as hours with operative temperature above 26°C) by an average of 15%. The study did not isolate the effect of the cool roof alone, limiting conclusions about the independent contribution of roof coatings.
- An overheating evaluation conducted by the National Research Council found that cool roofs could reduce overheating risk in four-storey MURB, located in Ottawa, ON, by up to 6% depending on the building construction [8].
- A study of a top-storey office in London found that hours with indoor air temperature above 25°C were reduced by 25% following the implementation of a cool roof [9].

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The effectiveness of cool roof membranes and coatings in reducing interior temperatures and cooling loads MURBs is highly dependent on the specifics of the building and building site. Building and site characteristics impacting the cool roof effectiveness include:

- **Insulation:** The effectiveness of cool roofs for overheating mitigation decreases as roof insulation levels increase [10]. When roofs are renewed and additional insulation is added, conductive heat gains through the roof are reduced, diminishing the incremental impact of cooler roof surfaces on indoor temperatures.
- **Roof system type:** Roof coatings are generally only applicable where roofing membranes are exposed (i.e. conventional roofing). These systems cannot be applied to inverted roofs with protected membranes under most types of overburdens.
- **Building form:** Any benefits are predominately limited to top-floor suites, which are directly exposed to roof heat gains. The impact on suites is reduced the farther away from the roofing level they are. Therefore, the greatest benefits are for buildings with wider footprints and higher roof to wall ratios, typically low-rise buildings. The impacts on mid-to high-rise buildings may be limited.
- **Roof features:** Some building features, including roofs, allow for heat to build in specific areas. Concrete buildings can absorb significant amounts of solar heat due to their thermal mass. On roofs, exposed concrete features such as parapets which bypass the insulation absorb more solar heating over the course of a day and radiate this heat to the suites below into the evenings. High-SRI coatings over these features could help reduce this impact.
- **Vented roofs:** Vented roof assemblies with low-SRI membranes can experience heat build-up above the insulation level within the vented cavity, particularly where air movement in the vented cavity is limited. In assemblies with minimal air exchange, high-SRI coatings effective at limiting heat accumulation within these air spaces. Where there is significant air exchange in the assembly, convective cooling reduces the risk of heat build-up, reducing the effectiveness of high-SRI coatings.
- **Air leakage:** As noted above, attic and vented roof cavities in wood-frame buildings can build up significant heat during the summer months. If there are significant gaps in the roof air barrier between the top-level suites and the attic or roof cavity, air leakage can bypass the insulation and potentially drive this overheated air into the suites. A cool roof coating could help reduce the temperatures within the roof space; however, this still indicates issues with the roof air barrier.
- **Building exposure:** Shading of the roof by other buildings, landscaping or existing building features can change how long a roof is exposed to solar gains. If a building or specific roof areas are significantly shaded, or exposed for a limited amount of time, a high-SRI material will not have a major impact on reducing heat gain.
- **Other heat gains:** The influence of cool roof coatings on overheating is also affected by the relative importance of other heat-gain sources, such as solar gains through windows, internal gains from people and equipment, and heat emitted from uninsulated domestic hot water distribution systems. In buildings where these other sources dominate, roof-related interventions have a smaller effect on indoor temperatures and may not make a tangible difference.

These building-specific characteristics can have a large impact on the degree of cooling load reduction or indoor temperature reduction in Vancouver MURBs. Therefore, we anticipate large variations in the effectiveness of cool roof coatings, even between adjacent buildings.

4. Other Considerations

Coating Soiling

The long-term performance of cool roof coatings depends primarily on their ability to maintain high solar reflectance over time. Soiling of roof surfaces, as seen in Figure 3, reduces solar reflectance which in turn reduces the thermal performance benefits associated with cool roofs.

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/ Figure 3: Algae growth on cool roof membrane, reducing its solar reflectance. Image source: [11]

Limited research is available on the in-situ, long-term reflectance of cool roof coatings [12] and no research in the Pacific Northwest (PNW) or similar climates was identified. However, some local information is available for high-SRI modified bitumen SBS membranes.

Vancouver's climate creates conditions that may accelerate roof soiling relative to drier or colder regions. High annual precipitation and mild temperatures create ideal conditions for organic growth such as algae and moss, which can accumulate on roof surfaces and reduce reflectance. The relatively high tree cover and low- and mid-rise building archetypes in Vancouver also lead to more debris build up on MURB roofs outside of the downtown core. In addition, recent wildfire smoke events have deposited more particulate matter onto roof membranes than in previous years. Therefore, SRI degradation of cool roof in Vancouver may be more significant than other climates. Field monitoring of a white-coloured SBS roofing membrane in the Lower Mainland provides some insight into durability trends under local climatic conditions: the research found negligible degradation in solar reflectance over the first three years of exposure, however over a six-year period solar reflectance decreased by approximately 38% (ranging from 31% at roof high points to 44% at low points) [13]. While cool roof coatings have different material surface properties, similar degradation of reflectance is expected due to the climactic and debris conditions.

Hygrothermal Performance of Roofs

Cool roof coatings affect the hygrothermal behaviour of roof assemblies. Condensation on roof sheathing in vented roof assemblies is common in the Pacific Northwest [14], [15], which can lead to premature degradation of building materials. This condensation is linked to night-sky cooling and humid ambient conditions. Under clear night conditions, roof surfaces can cool to temperatures below ambient air temperature, increasing the likelihood of condensation on the underside of the roof sheathing. Persistent condensation can lead to staining, mold growth, and, in some cases, deterioration of wood components. The extent and impact of this condensation depends on several interacting factors including roof thermal mass of the roof, air leakage rates, insulation levels above the roof deck, and ventilation effectiveness within the roof cavity [14], [16]. All these factors influence the risk for an existing roof, and it is not always clear what the tipping point may be for an existing roof to then be negatively impacted by increased condensation. Changing an existing low-SRI roof to a high-reflectance membrane is likely to alter the balance between wetting and drying within the roof assembly. By reducing roof surface temperatures, cool roof systems reduce the potential for drying of the roof assembly. This mechanism has been identified in both analytical [17] and field-informed [18] research. While reduced drying does not inherently result in failure, it can increase the likelihood that

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moisture introduced through air leakage, vapour diffusion, or leaks persist for longer periods, and suggests careful design and review is needed before changing the hygrothermal characteristics of a roofing system in the Vancouver climate.

Due to these concerns, light-coloured membranes have been recommended only for roof assemblies with exterior insulation [14]. This recommendation reflects the improved hygrothermal resilience of exterior-insulated assemblies, which maintain warmer sheathing temperatures and greater drying capacity.

Overall, converting an existing roof to a high-SRI membrane is expected to increase the frequency or magnitude of condensation at the roof sheathing in vented wood-frame assemblies. The consequences of this increased condensation—such as whether moisture accumulation reaches levels associated with material degradation—are difficult to assess without invasive investigation. In most cases, evaluation would require selective openings and short-term hygrothermal monitoring to characterize existing moisture conditions and to assess the risk of increased condensation.

Existing Roof Membrane Conditions

The condition of the existing roofing membrane will have a large impact on whether the application of a cool roof coating is worthwhile. Some roof coatings can be used to increase the service life of an existing membrane and there are often manufacturer-specific coating products designed for this purpose, in addition to providing a higher SRI. There are limitations on when these roof coatings can be applied to existing roof membranes, such as the extent of cracking or deterioration. Roof membrane preparation may require significant roof cleaning and preparation for the coating to be applied. Typically, an optimal candidate for roof coating is a membrane that is in good to fair condition, has no current leaks, and is not in need of immediate replacement but is reaching towards the end of its typical service life (typically 20-25 years). Several roofing manufacturers offer warranties of 10 years or more for their cool roof coating products, some of which include coverage of the existing roof system below. Note not all high-SRI roof coating products are considered waterproofing membranes and therefore not all coatings will extend roof durability.

If a roof is not in the optimal condition for a coating, then it is likely the roof will require a membrane replacement in the near future, at which time a higher SRI cap sheet could be considered.

Energy Consumption

While cool roofs can reduce energy consumption for mechanical cooling systems, it may also increase heating demand during colder months. Whether the reduction in cooling energy overcomes the increase in heating energy is dependent on the specifics of the building but is more likely in buildings with low levels of roof insulation – typical of many older MURBs in Vancouver. The ratio of cooling energy reductions and heating energy increase will change in the future as Vancouver's climate warms.

Heat Island Effects

In addition to reducing temperatures within the building during the cooling system, cool roofs have an additional benefit of reducing the urban heat island due to reduced surface temperatures [19]. This benefit is beyond the scope of this memo but should be noted when holistically assessing the benefits of cool roofing in urban environments.

5. Overall Recommendations

Based on the available evidence and findings from overheating assessments completed to date, cool roof coatings may be appropriate in limited and well-defined circumstances within the Vancouver MURB building stock. While there are benefits to using cool roof coatings in the Vancouver region, it is highly dependent on the specifics of the building and building site, and additional review and design should be carried out to ensure it does not create any negative impacts on the existing roofing system due to the hygrothermal risks.

It is expected there is a limited proportion of MURBs in Vancouver where high-SRI roof coatings may impactfully reduce overheating risk compared to other overheating mitigation measures. Cool roof coatings were recommended in two of eleven

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buildings assessed as part of the Existing Multi-Family Buildings and Overheating: Thermal Resilience Retrofits Feasibility Study. These buildings are good candidates for cool roof buildings as they have low-slope roofs with insulation above the roof deck, which mitigates the risk of moisture damage due to reduced drying potential. The buildings are four storeys tall, creating higher overheating reduction impact than high-rise buildings due to their roof-to-wall ratio. The existing roof membranes are in fair condition, and their lifetime may be extended with the application of a high-SRI waterproof coating. However, owners should seek additional review and design before undertaking these projects.

Based on the findings of this research, we do not recommend the widespread promotion of cool roof coatings as an overheating reduction strategy in Vancouver without additional guidance and oversight. This includes the following:

- From a hygrothermal and roof durability perspective, it is recommended that cool roof membranes or coatings be applied only to roof assemblies which have insulation above the roof deck. Exterior-insulated roof assemblies provide improved moisture resilience by maintaining warmer sheathing temperatures and reduced condensation risk. This limits the number of eligible buildings for cool roof coatings: of the eight assessed MURBs which reported overheating concerns in the Thermal Resilience study, two buildings do not have insulation above-deck.
- For well-insulated roofs, the expected reduction in overheating from cool roof coatings is low relative to other passive cooling measures, such as exterior shading, improved glazing performance, or ventilation-based strategies. Coatings that provide additional waterproofing benefits could be considered for this building types if the membrane reaches the end of its service life and is still in relatively good condition. However in this case, the coatings would be primarily recommended for waterproofing, with overheating reduction as a secondary benefit. Cool roofs provide an additional benefit of reduced urban heat island effect, which reduces overheating risk when implemented at a large scale.
- In buildings without insulation above the roof deck, cool roof coatings could be considered as a short-term measure to reduce overheating prior to a planned roof renewal that includes the addition of exterior insulation. This approach may be appropriate where overheating risks are acute and where a full roof replacement is anticipated in the near- or medium-term. In these cases, the condition of the existing roof sheathing should be assessed at the time of roof renewal, and repair or replacement may be required to address potential moisture-related degradation. BC Housing's Builder Insight 21, "Retrofit and Renewal of Low Slope Vented Wood-Frame Roofs," provides a moisture risk assessment flowchart for renewal of low-slope vented roofs which may be used to inform cool roof condensation risk [14].
- Ongoing maintenance is essential to maintain the effectiveness of cool roof coatings. Periodic inspection and cleaning to remove debris, algae, and moss is recommended by coating manufacturers. Without cleaning, soiling-related reductions in solar reflectance can significantly reduce thermal performance over time, particularly in Vancouver's climate.

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