To: City & County of Denver Green Roofs Review Task Force
From: Ellen Thorp, on behalf of the EPDM Roofing Association and additional signatories
Date: May 18, 2018
Subject: White/reflective roof requirements in new and existing buildings

CONTENTS

These comments apply to the Green Building Policy Proposal, Draft Proposal from the Green Roofs Review Task Force, May 8th, 2018 edition; and specifically address the New Building Proposal on page 6 and the Existing Building Proposal on page 9.

INTRODUCTION

The EPDM Roofing Association is a trade association that represents Carlisle SynTec, Firestone Building Products, and Johns Manville, all of whom manufacture a diverse portfolio of roofing products including dark colored and reflective roofing membranes. **As manufacturers of both dark colored and reflective membranes,** the members of the EPDM Roofing Association (ERA) and other manufacturers like Versico Roofing Systems are experts on the use of roof color and frequently present to codes and standard setting bodies on issues of roof color, including the list below. Reflective roof mandates in climate zones 4 and above (Denver is in climate zone 5) have already been proposed and overruled in the following national model codes and standards:

- ASHRAE 189.1 (a national model green building standard) in 2013;
- ASHRAE 90.1 (a national model energy efficiency standard) in 2009;
- IECC (International Energy Conservation Code) in 2013;
- IGCC (International Green Construction Code) in 2014;

and in the

- City & County of Denver Building Codes Review Committee in 2015

The Association encourages the Task Force to remove the cool roof requirement. While the Association and it's supporters are cognizant of the unique position of the Task Force in modifying the Ordinance while still supporting the will of the voters, it doesn't negate the need for evidence-based decisions on sound building science. It's hard to understand why urban heat island mitigation and cool roofs are such significant portions of the draft modifications (all new buildings are required to have a cool roof) when there is no mention of either in the title of the ballot measure (which the voters saw) nor in the full text of the measure (which the voters had access to). **How can it then be the will of the voters to have reflective or cool roofs in Denver, when it wasn't part of what they were voting on?**

This set of comments provides an exhaustive review of the science supporting the use of either reflective or dark membranes in various climates, with the intention to provide clarity for and bring balance to the frequently confused black-vs.-white debate.

Overview

The growing awareness of climate change, as well as the related issues of urban heat islands and steadily increasing energy costs, has led to a growing interest in the effectiveness of reflective, or "cool" roofing. Proponents of reflective roofing and major manufacturers of reflective roofing like GAF, Duro-Last, Sika Sarnafil have recommended its use throughout the US to save energy, and some cities have moved toward mandating the use of white roofs on all new construction, roofing removal and replacement as well.

But a roofing assembly and system is complex in that it involves many different considerations (detailed in the section on Roof design and roof system components considerations).

Denver already has a history of action on this issue, with policy setting bodies voting to maintain the role of building owners and their advisors/consultants in choosing the best roofing assembly and membrane for their building, rather than having one component mandated.

In January 2015, the Denver Community Planning and Development received a proposed amendment from the U.S. Green Building Council's Colorado Chapter and the Global Cool Cities Alliance to "require that new low-sloped roofs … have a minimum aged solar reflectance index of 64. This proposal is intended to accelerate the deployment of highly reflective, 'cool' roofs to improve Denver's capacity to address climate change without increasing costs." At it's meeting in March 2015, the Building Code Review Committee voted with an overwhelming majority to not accept the amendment as part of its adoption process of the new version of the International Energy Conservation Code. The City Council upheld this decision in March of 2016 when they voted to accept 2016 Denver Building Code.

Opponents of the "one size fits" all approach pointed to the logic of using dark roofs in northern climates like Denver: they pointed out that while white roofs reflect the sun's heat and should be used in hot, southern climates, black roofs help absorb the sun's heat and are the most efficient choice in heating-dominated central and northern climates like Denver. Evolving energy codes and green building codes have followed this logic as a basis for mandating cool roofs (with certain exceptions allowed) in the southern regions of the U.S., particularly Climate Zones 1-3 as shown in Figure 1, and the roofing community has generally agreed with these actions. But thanks in part to manufacturers of reflective roofing membranes insisting that reflective roofs are a good choice everywhere and all the time, disagreement persists about the appropriate approach for Zone 4 and moving north (Denver is in climate zone 5). Decision makers and policy makers ask the questions: Where do the benefits of using black roofs to save energy in colder seasons start to outweigh the benefits of using white roofing in the warmer months of the year? Where do high levels of thermal insulation make the issue of a roof cover color a moot point? And what are the other issues to consider in choosing between reflective and dark roofing membranes? **The simplicity of the black-vs.-white logic begins to break down as one considers the application of cool roofs in the more northern cold climates (Climate Zone 4 or greater in Figure 1) and the right answer is typically more black than white.**

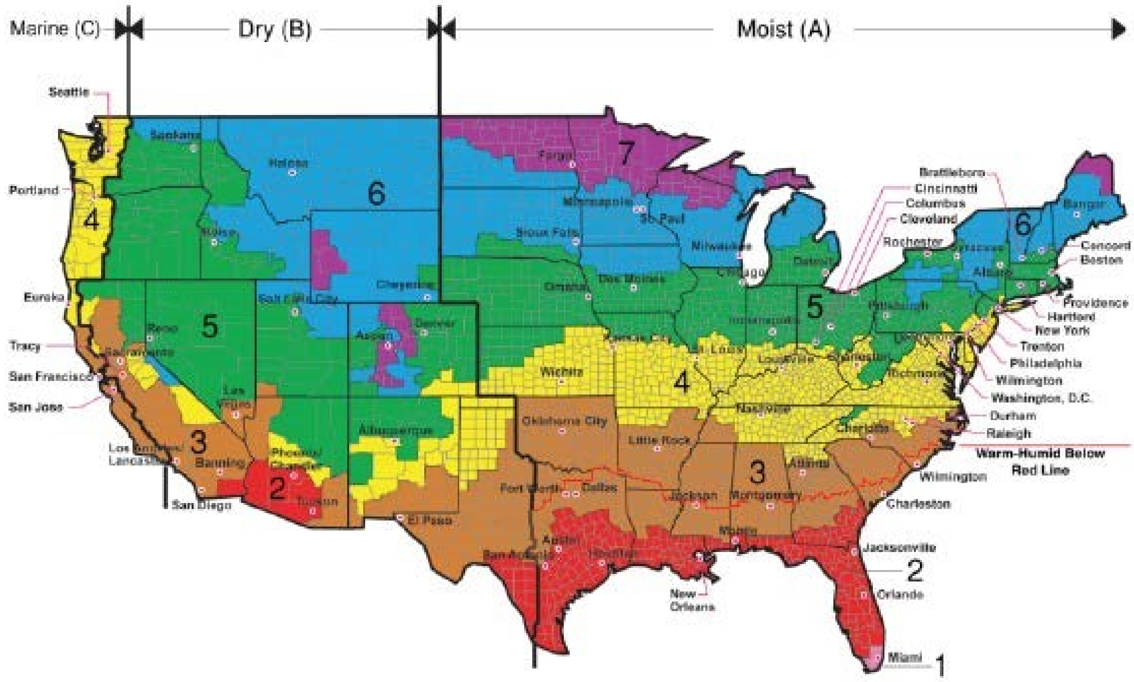

Figure 1. US Climate Zones
Source: EPA

The application of cool or white roofs becomes problematic in northern climates like Denver for two important reasons: (1) loss of energy savings benefits and (2) potential for increased moisture accumulation risk in the roof system. While there are other issues with cool roofs to consider in any climate, including a number of unintended consequences (Yang, et al 2013) and uncertainties in the actual urban heat island and global warming benefits (Jacobson and TenHoeve 2011), these other issues are beyond the scope of this article. But, a collective consideration of all of the issues does lend support to a pragmatic or "selective use" approach for cool roofs as called for by Jacobson and TenHoeve (2011). This draws a stark contrast to the effort to mandate white roofs across broadly defined climate zones without regard to many important factors that influence the performance outcome. Such an indiscriminate approach becomes even more problematic as one moves into northern climate zones (e.g., Climate Zones 4 and greater). For example, within Climate Zone 4 (Figure 1), the level of solar irradiance (Figure 2) varies from about 3,500 to 7,000 Watt-hour per square inch per day. A factor of two difference in incident solar radiation must certainly have significant performance implications for cool roofs that should be considered from a "selective use" standpoint.

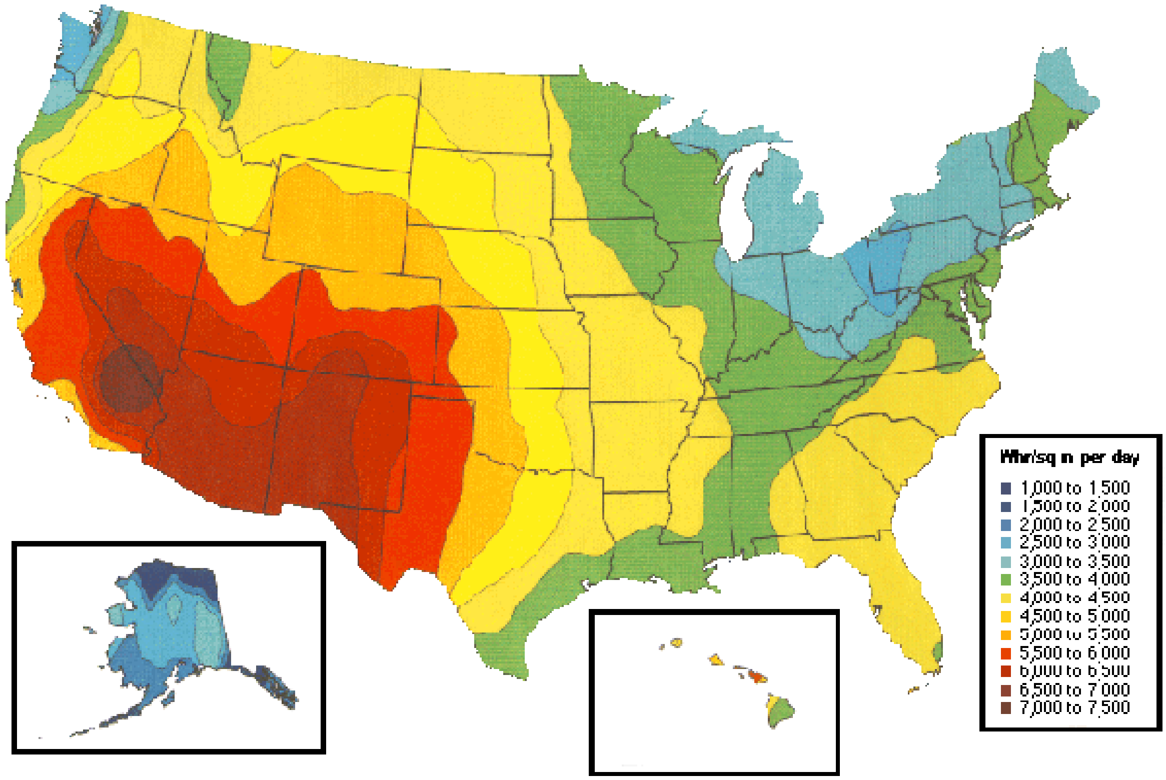

Figure 2. Solar Irradiation Intensity Map of the U.S.
Source: NREL

The comments that follow will cover four primary issues that the GRRTF needs to be aware of and not mandage a white/reflective roof, including: the unintended consequence of condensation and other related moisture management issues; energy efficiency; additional views on heat island causes and mitigation; and the numerous and varied components that need to be taken into account when designing a roof.

MOISTURE CONTROL IMPLICATIONS (CONDENSATION)

One of the unintended consequences of white/reflective roofs in ASHRAE climate zones 4 and above (Denver is in climate zone 5) is the potential for condensation (and mold) to develop within the roofing assembly. This remains a significant concern throughout ALL facets of the roofing industry: contractors, consultants, owners, facility managers, architects.

Moisture vapor control is a concern for all roof systems. It is also important to recognize that there may be distinctions in how different roof systems perform and that roof color plays a role in the moisture performance of a compact, low-slope roof that must dry to the interior not through the roof membrane. Also, this issue is not so "black and white" that one roof membrane is considered bad and the other is considered good. Instead, there are shades of gray for moisture accumulation risk. What this means is that there may be modest differences in moisture risk that should be considered and perhaps mitigated if white roofs are intended to perform at least equivalently to dark roofs in northern climates like Denver. Historically darker colored roof surfaces promoted downward drying, which is not a characteristic of cool roofing and thus moisture accumulation can be cumulative.

The concern with increased moisture accumulation risk below cool roof membranes is recognized in the U.S. Department of Energy's guideline for selecting cool roofs (Urban, Bryan, and Roth 2010) and the following statement serves as basis for one recent study into the matter (Kehrer and Pallin 2013): "There have been questions raised about the sustainability of using cool membranes in northern U.S. climate zones due to the potential of moisture accumulation below the membrane."

The following summarizes some of the key findings reported by Kehrer and Pallin (2013) and Bludau, Zirkelbach, and Kunzel (2009) related to the relative moisture control performance of cool roofs and dark colored roofs.

1. The two most dominant factors governing moisture performance and risk are air-leakage rate into the roof and indoor relative humidity.
2. Moist indoor air leakage into the roof system can be greater in mechanically attached roof membranes (typical of cool roofs) due to fluttering or billowing caused by wind.
3. While all roofs are sensitive to indoor relative humidity and air-leakage, white roofs show a greater sensitivity.
4. Compared to a traditional black roof, the amount of accumulated moisture during the winter can be two to three times greater in a cool roof construction.
5. For a given climate such as Chicago and for a roof system with all other factors equal, a white roof could cause wood sheathing to exceed a maximum acceptable moisture content of 20% whereas a black roof was predicted to keep wood sheathing moisture contents in a safe range between 11% to 16%.
6. Once 1mm of condensation accumulation is exceeded, the risk of problems becomes greater. In most of the normal humidity data points, black membrane stayed below 1 mm.

Because of the above differences in modeled performance, some researchers recommend that roof systems using a cool roof in northern climates like Denver should be designed based on "…hygrothermal simulations in order to avoid critical water content in the construction. If necessary, a darker color roof surface should be considered." (Bludau, Zirkelbach, and Kunzel, 2009).

While not associated with any detrimental effect, a field study of several white and black roofs and hygrothermal modeling of those roofs indicated a tendency of white roofs to accumulate a greater amount of moisture during the winter and to dry more slowly during the summer (Ennis and Kehrer, 2011). (Most designers and certainly all the researchers perform the hygrothermal analysis through solid insulation when in fact it is the joints that are of concern. This is especially important that if a single layer of insulation is used that air loss to the underside of the membrane be considered, which will provide dramatically different results than if modeled on solid insulation. Here is where the modeler needs to have a using knowledge of roofing.)

In a study by Kunzel, Zirkelbach, and Schafaczek (2012) where a roof system's solar absorptivity (the inverse of reflectance) was decreased from 0.6 to 0.3, the roof system changed from one that was annually drying to one that was showing annually increasing moisture levels. The increase in roof reflectivity reduced the solar-driven inward drying effect to a point where it was unable to keep up with moisture accumulations occurring during winter months.

These findings demonstrate that an appropriate use of a white roof in a northern climate may require additional moisture control considerations such as improved air-leakage control and indoor relative humidity control. Alternatively, they may be "selectively used" on buildings where conditions are inherently less risky (e.g., occupancies with lower internal moisture generation and inherently lower indoor relative humidity levels in the winter).

ENERGY EFFICIENCY

Many times, people think that a white reflective roof is automatically a more energy efficient option. While this is most often true in climate zones 1-2 and may be true sometimes in climate zone 3, it is very rarely the case anymore in climate zones 4 and above. While the modifications to the Green Roof Ordinance don't specifically mention the white reflective roofs provision as contributing to the energy efficiency of the building, since these misunderstandings sometimes exist, we felt it important to set the record straight here.

The energy efficiency benefits of cool roofs in any climate are dependent on a number of variables including:

- Average temperature in that climate
- Sunniness or cloudiness of the climate
- Amount of roof insulation: more insulation (greater thermal resistance) means the roof color (or solar reflectance) matters less
- Cleanliness of the roof surface to maintain assumed solar reflectance
- Roof area: Schools, warehouses versus smaller less square footage buildings
- Height of the building - the taller the building the less significant the roof color or insulation level to overall building energy efficiency, and
- Internal heat loads within the building: higher internal loads increase the cooling season length and, thus, improve benefits of cool roofs
- Building type
- Use of space below the roof

Multiple studies have investigated the energy saving potential of cool roofs with varying assumptions regarding the above parameters and others. In some cases, assumptions have been made that tend to inflate the energy-saving value of cool roofs, particularly in northern climates like Denver where there is sometimes a fine line between an "energy saving" or an "energy wasting" outcome. For example, a recent study by the University of Arizona (Yang, et al. 2013) included a critical review of a study by Lawrence Berkeley National Laboratory and found that "…the fantastic savings demonstrated are dependent on unrealistic assumptions used in the study and are of great uncertainty." While there is no shortage of such examples giving reason to question the assumptions and results of various studies, one seemingly consistent finding in many studies is that the savings, if not negative in the northern climates like Denver, are generally very small.

The erosion of cool roof benefits in northern climates like Denver occurs because (again depending on assumptions) the heating penalty of a cool roof during the heating season (e.g., fall/winter/spring) is significant and it tends to negate or exceed the cooling energy savings in the summer. For example, even when favorable assumptions are made for cool roofs in northern climates like Denver as done in a study by Konopacki et al. (1997), the estimated annual energy savings (+) or losses (-) range from about +$0.02/ft2 to - $0.02/ft2 for commercial and residential buildings in various cities or regions within Climate Zones 3 through 5. Thus, in these moderately cold or mixed climates, the annual energy savings or losses are a meager +/- 2 cents per square foot of roof area. **That savings does not justify the use of a white roof given the other unintended consequences and conflicting research that suggests that reflective roofs may even heat the atmosphere.**

When other costs are considered, such as periodic roof cleaning necessary to maintain the effectiveness of a reflective roof surface, the meager energy savings (if any) for a particular cool roof application may be quickly consumed. For example, Roodvoets, Miller, and Desjarlais (2004) indicate that a typical cost to power wash a roof is about 1 cent per square foot. Consequently, they found that the cost-benefit of washing a cool roof was positive in Phoenix, AZ (a hot and sunny climate). But, in Knoxville, TN located in less sunny Climate Zone 4, the cost of cleaning a white roof to maintain its solar reflectance could not be justified by the energy saving benefits of doing so. Wilen (2014) suggests the cost of cleaning a cool roof can be as much as 5 cents per square foot - five times greater than the previous reference (and others in the industry suggest a cost as much as 10x greater)! Thus, as one moves into more northern climates, the economic justification of a cool roof becomes much more difficult to achieve and may be realized only for a "selective use" where an ideal set of application conditions exist (e.g., high internal heat load, sunny climate, one-story building, low window-to-wall area ratio, etc). This is not meant to be an argument for not cleaning roofs to maintain reflectivity or for other reasons. It is merely a realization that the cost-benefits of a cool roof are closely associated with and dependent on keeping the roof reasonably "shiny" so it can perform its intended energy saving purpose. One only needs to make a casual inspection of roofs while flying into an airport to see that this degree of cleanliness is often not achieved in the real world.

HEAT ISLAND CAUSES AND MITIGATION STRATEGIES

While the popular media and a simplistic thinking may suggest that a white/reflective roof will cure all ills related to urban heat islands, not all researchers agree. There are other studies to consider, in addition to the issue of anticipated life cycle of a reflective membrane. Researchers agree that increasing vegetation and utilizing reflective pavements are the best ways to mitigate urban heat islands. In addition, one must consider the emissivity/impact of the roof area as a contributor vs asphalt pavement and side wall materials (steel, glass, concrete). The roof contributes far less to the UHI than these other components.

Reflected Heat may increase Global Warming Potential. A 2011 Stanford University study concluded that white roofs may actually contribute to global warming. White roofs reflect heat back into the atmosphere where it mixes with black and brown soot particles, contributing to global warming and smog formation. "Cool" white roofs may make sense in warm, southern cities where the cooling benefit decreases energy consumption and CO_2 emissions, but in heating-dominated climates like ASHRAE Zones 4 and above, they will increase natural resource consumption for heating purposes and therefore increase CO_2 emissions which are thought to contribute to global warming.

Cool roofs may have a negative impact on air quality. A collaborative study between Notre Dame and the City of Chicago published in 2016 examined the efficacy of green or cool roofs using a regional climate model to simulate various real-world urban rooftop conditions. The research team also evaluated wind patterns from Lake Michigan to understand how reducing UHI could impact wind within Chicago. By using green or cool roofs to reduce the temperature of the city, there will be less pressure difference caused by cool air from the lake mixing with relatively less hot air of Chicago, thus decreasing lake-breeze within the city. These results have revealed additional urban climate research questions. For example, when there is a reduction in lake-breeze and UHI in the city, there is also less vertical mixing of air. Based on current findings, it appears that this could stagnate air near the ground and potentially cause air quality issues.

Changes in Rainfall Patterns. A study by Arizona State University indicated that widespread adoption of reflective white roofs can have an unintended effect on rainfall patterns. White roofs reflect heat back up into the atmosphere and change the evapotranspiration rate, which results in less precipitation in some geographic areas, while increasing precipitation in others.

Sustainability/Weatherability. Darker-colored EPDM rubber membranes typically perform better than cool plastic roofs in Xenon Arc accelerated weathering tests and real world testing of 30-year-old weathered membrane. In general, black EPDM has 2-3 times greater UV resistance than alternative white roofing membranes. White TPO and PVC are plastic-based membranes and are prone to accelerated heat aging, which is why they are not sold in darker colors for roofing.

Increased Reroofing Frequency and Landfill Waste. White thermoplastic TPO and PVC membranes must be internally reinforced and only have 20-25 mils of weathering material over the reinforcing scrim. Comparatively, non-reinforced EPDM membranes have a have a minimum of a full 45 mils of weathering material. Xenon Arc accelerated weathering tests indicate that Black EPDM (at 41,580 kJ/m^2) provides much greater UV resistance than most white TPO and PVC membranes (approximately 12,000 to 20,000 kJ/m^2). Reinforced membranes must be replaced once the reinforcing scrim is showing through. The end result is white roof membranes wear out faster and have to be replaced more often sending more construction-generated waste to landfills.

Roof System Holistic Design Considerations

A roof is a system composed of many parts that work synergistically together to protect the interior from the climate of the interior. Roof system design cannot be regulated to a single component. See my series of articles in Roofing from the past 4 years that were composed component by component from the roof deck up.

Parameters Considered in Roof System Design Include:

- Structure
  - Roof Structure
    - Material Type
    - Spacing
  - Walls
    - Material
    - Structural or infill
    - Cavity, metal panel, precast, frame
    - Opening such as overhead doors
- Parapet
  - Height above ground
  - Height above the roof
  - Material
    - Stud
    - Masonry
    - Precast
    - Metal panel
- Roof Deck
  - Material
  - Type
  - Gauge
  - Attachment
- Roof Edge
  - Gravel Stop
  - Parapet
  - Gutter
  - Construction
  - Metal cladding
    - ANSI – SPRI ES1 Compliance
- Interior Building Use
  - Wet – Pool, gym, locker rooms, shower rooms
  - Cold
  - Freezer
  - Humid
  - Hot
  - Dry
- Interior Occupancy

- Full time
- Work day
- Transient
- Machinery

- Interior Occupants
  - Young i.e. students
  - Old - Retirement home
  - Infirmed – Hospital
  - Families
  - Business
- Time of year roof will be constructed
- Geographic Location of Building
- Climatic impacts
  - Rain
  - Solar Sun
  - Solar UV
  - Winds
  - Snow
  - Ice
  - Sand
  - Heat
  - Cold
  - Damp
  - Humidity
  - Volcanic
  - Fire
  - Hail
- Building Orientation
- Vapor Retarder
  - Yes/ No
  - Material type
  - Material installation
  - Location within the roof system
  - Installation method
  - Availability
  - Contractor familiarity
  - Compatibility with the other roof system components
  - Impact on the interior environment
  - Provide by mfr. so as to be included in the warranty

- Substrate Board
  - Material
  - Method of attachment to roof deck
  - Thickness
  - Span ability
  - Compatibility with vapor retarder and roof deck

    - Provide by mfr. so as to be included in the warranty
- Insulation
    - Material
    - Thickness
    - Facer type: Reinforced paper, coated fiberglass
    - Density: 18, 20, 22, 25 min
    - Number of layers
    - Availability
    - Flat or tapered
    - Method of attachment
        - Hot asphalt
        - Mechanical fastener
            - Rate of fasteners
            - Type of fastener and stress plate
            - Gauge and thickness
            - Length
        - Polyurethane foam adhesive
            - Full spray coverage
            - Bead
                - 4”, 6” 8” 12” o.c
        - Loose laid
- Cover Board
    - Material
    - Thickness
    - Facer type
    - Density
    - Availability
    - Method of attachment
        - Hot asphalt
        - Mechanical fastener
            - Rate of fasteners
            - Type of fastener and stress plate
            - Gauge and thickness
            - Length
        - Polyurethane foam adhesive
            - Full spray coverage
            - Bead
                - 4”, 6” 8” 12” o.c.
- Membrane
    - Type: EPDM, PVC, PVC with KEE, TPO, BUR, Mod. Bit
    - Color
    - Thickness
    - Method of attachment
        - Ballast
        - Adhered

        - Solvent
        - Low Solvent
        - Solvent free
        - Water based
      - Mechanically Fastened
  - Surfacing
      - Gravel
      - Garden Trays
      - Ceramic granules
      - Slate granule
      - Coated
      - Paver
        - Concrete
        - Wood
  - Seam Treatment
      - 3” 6” seam tape
      - Cover Strip
      - Welded
      - Tee joint patch
  - Flashings
      - Material
      - Thickness
      - Height
      - Attachment
      - Termination
      - Counter Flashed
  - Sheet Metal
      - Material
        - Alum
        - Steel
        - Copper
        - Stainless steel
        - Zinc
      - Finish
        - Raw
        - Hot Dipped Galvanized
        - Pre-finished
      - Gauge
        - 22, 24 gauge
        - .040, .050, .063, .080
        - 16, 24, 32, 48 oz.
      - Copings, gravel stops, fascia
        - Attachment
        - Joint treatment
      - Gutters

        - Sized appropriately
        - Hanger type
        - Bracket type
          - Clad
      - Counter flashing
        - Surface mounted
        - Reglet
        - Integral with through wall flashing
  - Protective walk ways
    - Material
      - Concrete
      - Wood
      - Rubber
      - TPO
    - Thickness
    - Size
    - Location
  - Coordination with and method of integration
    - Plumbing
    - HVAC
    - Fall Protection
  - Warranty
    - Type
    - Length
    - Full System
    - Material
    - Workmanship

RESEARCH STUDIES ON COOL ROOFS

There is a wide body of research that questions the wisdom of mandating reflective roofs in northern climate zones like Denver. Below is merely a partial list of research that raises concerns based on condensation and energy efficiency issues and also provides additional information about the factors that contribute to and mitigate urban heat islands.

Study Name	Published In Journal	Publication Date	Full Citation
A study on the heat transfer and energy performance implications of cool roofs	Georgia Tech Theses and Dissertations	11/26/2013	Zhang, Tianyao (2013), "A study on the heat transfer and energy performance implications of cool roofs", Georgia Tech Theses and Dissertations, 2013
Assessment of the Impact of Cool Roofs in Temperate Climates through a Comparative Experimental Campaign in Outdoor Test Cells	Buildings	12/19/2016	Barozzi, B.; Pollastro, M.C. Assessment of the Impact of Cool Roofs in Temperate Climates through a Comparative Experimental Campaign in Outdoor Test Cells. *Buildings* **2016**, *6*, 52.
Comparative Roof Testing At Onondaga County Correctional Facility	EPDMroofs.org	9/15/2011	
Condensation Problems in Cool Roofs	Interface, RCI	8/2009	Bludau, Zirkelbach, Kunzel (2009), "Condensation Problems in Cool Roofs", Interface, RCI, August 2009
Condensation risk of mechanically attached roof systems in cold climate zones,	OSTI.gov	1/1/2013	Pallin, Simon B. *Condensation Risk of Mechanically Attached Roof Systems in Cold Climate Zones*. United States: N. p., 2013. Web.
Cool Roofs In Use In Northern Climates: A Case Study	Building Enclosure Online	10/1/2014	Fenner, M., DiPietro, M., Graveline, S. "Cool Roofs in use in Northern Climates: A Case Study", Building Enclosure, 2014
Effects of Urban Surfaces and White Roofs on Global and Regional Climate	Journal of Climate	9/12/2011	Jocobson, M., Ten Hoeve, J., "Effect of Urban Surfaces and White Roofs on Global and Regional Climate", Journal of Climate, 2011.
Green and cool roofs to mitigate urban heat island effects in the Chicago metropolitan area: evaluation with a regional climate model	IOP Science	6/1/2016	Sharma, A. et al, "Green and cool roofs to mitigate urban heat island effects in the Chicago metropolitan area: evaluation with a regional climate model" IOP Science, 2016.
Guidelines for Selecting Cool Roofs, U.S. Department of	Office of energy Efficiency &	7/2010	Urban, Bryan, and Roth, (2010). "Guidelines for Selecting Cool Roofs,"

Energy: Building Technologies Program,	Renewable Energy		U.S. Department of Energy: Building Technologies Program, Washington, DC
Modelling the effect of air leakage in hygrothermal envelope simulation,	BEST 3 Conference	2012	Kunzel, H.M., Zirkelbach, D., and Schafaczek, B. (2012). "Modelling the effect of air leakage in hygrothermal envelope simulation," BEST 3 Conference, Atlanta, GA
Seasonal hydroclimatic impacts of Sun Corridor expansion	Environmental Research Letters	9/7/2012	Georgescu, M., Mahalov, A., and Moustaoui, M., "Seasonal hudroclimatic impacts of Sun Corridor expansion", Environmental Research Letters, 2012.
Simulated Influence of Roof Reflectance on the Building Energy Balance in Two Northern Cities,	ASHRAE	2006	Freund, S., Dettmers, D.J., and Reindl, D.T. (2006) "Simulated Influence of Roof Reflectance on the Building Energy Balance in Two Northern Cities," 4838, ASHRAE Transactions: Research, Vol. 112, Part I, pp.171-180
Sustainability of Rooftop Technologies in Cold Climates: Comparative Life Cycle Assessment of White Roofs, Green Roofs, and Photovoltaic Panels	Journal of Industrial Ecology	4/6/2015	Cubi, E., Zibin, N., Thompson, S., and Bergerson, J., "Sustainability of Rooftop Technologies in Cold Climates: Comparative Life Cycle Assessment of White Roofs, Green Roofs, and Photovoltaic Panels", Journal of Industrial Ecology, 2015.
The joint influence of albedo and insulation on roof performance: An observational study	Energy and Buildings	2/16/2015	Ramamurthy, P., Sun, T., Rule, K., Bou-Zeid, E., "The joint influence of albedo and insulation on roof performance: An observational study", Energy and Buildings, 2015.
Unintended Consequences, A Research Synthesis Examining the Use of Reflective Pavements to Mitigate the Urban Heat Island Effect,	ASU National Center of Excellence on Smart Innovations	10/23/2013	Yang, J. et al. (2013). Unintended Consequences, A Research Synthesis Examining the Use of Reflective Pavements to Mitigate the Urban Heat Island Effect, Arizona State University, National Center of Excellence for Smart Innovations
Urban adaptation can roll back warming of emerging megapolitan regions	Proceedings of the National Academy of Sciences of the USA	2/2014	Georgescu, M., Morefield, P., Bierwagen, B., and Weaver, C., "Urban adaptation can roll back warming of emerging megapolitan regions", Proceedings of the National Academy of the Sciences of the USA, 2014.

CONCLUSION

In hot and sunny climates like climate zones 1 and 2, the logic of cool roofs to save energy is generally accepted (although the effect is diminishing with greater insulation levels required under current version of the IECC in climate zone 3) … and so are some benefits. However, in northern climates like Denver, the heating penalty virtually always outweighs or offsets the cooling benefit and moisture control or condensation risks are greater than experienced in conventional black roof membranes. This reality necessitates a “very selective use” approach for cool roofs. Such an approach strives to identify the limited cases where specific end use conditions may provide a benefit while also considering appropriate measures like the addition of air/vapor barriers to mitigate increased moisture accumulation risks. For cool roofs in northern climates like Denver, one has to understand the heating penalty, moisture accumulation potential as well as the other performance trade-offs associated with their selection and use.

Good roofing practice must be the dominant criterion in any roof design. The licensed design professional, an Architect/Engineer, has long-term experience and access to science to effectively weigh the broad variety of issues that inform the choice of a roofing membrane. These include not only the color of the membrane, but also issues such as the durability of the membrane, the method of attaching the membrane, the choice of insulation, and the use of air or vapor barriers. Ultimately, the licensed designer should be relied upon to make the correct roof system design choices, including that of roofing membrane for any individual building project.

For these reasons, we urge the Green Roofs Review Task Force to remove the cool roof mandate portion of the proposed modifications.

SIGNED IN SUPPORT BY THE FOLLOWING DENVER AREA ROOFING PROFESSIONALS

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SYNTEC SYSTEMS

Firestone
Firestone Building Products

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