Decision-Making Process for Green Options in Reroofing

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Abstract

By definition, sustainable roofing systems should be long-lasting, recyclable, and reduce a building's effect on the environment. Good roofing practice also requires that the roof system be durable and repairable. In many cases, a roof is a staging area for servicing mechanical equipment, window washing, façade access, and maintenance; it must be durable enough to support these functions. Green roofing has placed a few new demands on the roof system: the ability to reduce the energy burden of the building, reduce contributions to the heat island effect, offer storm water retention, and provide new green space. While meeting all of these requirements, a green roof must also be functional and maintain a watertight condition during its expected useful life (EUL).

In order to enhance the roof's contribution to environmental requirements, "green" roofing has evolved in to one of two categories: highly reflective or "cool" roof systems, and vegetative roof systems. To most of the general public, vegetative roof systems have become the default definition of a green roof. Vegetative roof systems have captured the interest of many municipalities as the answer to the need for sustainable roofing, with many tax incentives being based around promoting its use. Both

vegetative roof systems and cool roof systems offer challenges when assessing appropriate replacements for existing roof systems.

Cool roof systems that rely on a high solar reflectance index (SRI) offer a generally easier path to sustainable roof systems that meet current environmental-based requirements. The challenge of a cool roof system as a reroofing option is to ensure wind-uplift and durability requirements are met with an exposed membrane and meet building code requirements. Repairability of an exposed membrane offers advantages over vegetative roof systems or protected membrane roof assemblies (PMAs). A vegetative roof system is difficult to repair because of the buried nature of the membrane. Additionally, the added weight of a vegetative roof system and PMA can necessitate upgrades to the building structural frame in order to increase structural capacity.

The purpose of this paper is to present a practical decision-making process for selection and design of a sustainable or green, reroofing system. The process will consider the various assemblies currently available in the market today, compare the advantages and disadvantages of each, and illustrate which assemblies meet cool roofing and vegetative roofing guidelines. Specific aspects of the roofing systems to be compared will include the following:

- wind-uplift resistance
- fire rating
- thermal resistance
- membrane durability and expected life cycle
- potential for reusing insulation and insulation durability

- leak identification and repair methodologies
- reduction of heat island effect
- Solar Reflectance Index (SRI)
- storm water retention
- roof top accessibility
- roof top use considerations
- fall protection, façade access and window washing rigging
- mechanical equipment staging
- parapet heights and aesthetic effects
- structural implications,
- social, economical, and environmental effects of each system.

It is expected that the reader will take away from this paper a better understanding of “green” roof options that are viable to reroofing.

Author

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Body of Paper

The list of items to consider when designing a roof system is extensive, including wind-uplift, flashing heights, R-values, permeability, Underwriters Laboratories Inc. ratings, FM Global ratings, code approvals and more. These are the typical considerations that may come to mind when a roof consultant is asked to design a roof system. Whether a new roof system or a roof system replacement, the above considerations are all applicable to some extent. Many times designers get wrapped up in the above considerations mentioned, sometimes forgetting that what our client really wants are durable, economical, long-lasting roof systems. Not to be forgotten are a roof system's sustainable aspects of the roof system including stormwater management, decreased urban heat island effect, potential for re-use, and solar reflectance. This paper presents seven critical components to roof system design based on the author's experience that will help us all achieve these goals. This may not sound like a revelation, but it is a departure from the normal design process where the roof system selection process often is driven by cost, and is driven toward using specific types of roofing products and adapting those products to the widest range of building systems possible.

In the process of introducing new roofing materials, blending old and new technologies, and the drive for sustainability, the basic rules of sound design criteria should not change. A common sense approach to low-slope roof system design can lead to increased service life and reduced maintenance costs for more successful new roofing and roof system replacement projects. This approach to more durable roof systems integrates the following seven critical components: slope, drainage, attachment, material durability, constructability, maintenance, and sustainability.

Each building's structure has, or will have, its own set of criteria that should lead to choosing a roof system that's right for the building. This means each building may have an optimal attachment method, set of material durability characteristics, construction methods, and maintenance characteristics that must be considered carefully when choosing a roof system. The application of one type of roof system won't likely apply in all cases. In this paper much of the design methodology that has been in the roofing industry for many years is assembled into an organized thought process that leads to a better roof and takes into account the conditions a roof system should meet and overcome.

Component One: Slope

Slope is an important factor in a roof system's proper functionality. Adequate slope may compensate for lesser material and construction quality. The concept of always providing positive roof slope seems to have been lost in the U.S. during the late 20th century. Because there were minimal code requirements governing roof slope in the U.S. until the late 1990's, thousands of buildings were constructed with virtually no roof slope. Roof assemblies were required to weather the burden of ponded water, often without the protection of redundant layering of membrane material. Only coal-tar membranes were uniquely suited to handle ponded water. Roof membranes tended to become thinner when the use of single-ply roofing became a popular method to reduce the cost of roof systems and reduce the reliance on asphalt-based products. This provided an opportunity for designers to economize roof systems, thereby saving on overall construction cost.

The current International Building Code requires a minimum roof slope of ¼:12 or about 2 percent. The National Roofing Contractors Association (NRCA) recommends positive drainage and suggests criteria for judging proper slope, “that there be no ponding water on the roof 48-hours after a rain during conditions conducive to drying”. The NRCA also recommends that the designer consult the code regarding slope requirements.

The importance of the first key factor in common-sense design is to always provide positive slope to drain. A slope of at least ¼:12 (2 percent) has been shown repeatedly to work well in low-slope roof system situations, and even more slope is better. Adhering to this design basic is a key factor for designing longer lasting, more durable roofs.

Component Two: Drainage

Roof drainage and slope are two distinctly different things. An adequately sloped roof can have inadequate drainage, and a flat roof deck can have adequate drainage. Inadequate drainage on a well-sloped roof can lead to slower water runoff, which can tax a roof’s flashing systems, adding live load, and potentially leading to roof leaks. A relatively low-slope roof system can have adequate drainage (per code), which becomes a requirement when designing PMAs. Adequate drainage becomes a more difficult as roof slope approaches dead level.

Simply put, drainage refers to the roof system’s ability of the roof system to carry water away. Building codes usually dictate the minimum amount of drainage required for a roof system, maximum tributary area per drain and guidance on the required size of the drain leaders. Codes have local rainfall rates. Although codes typically may not require upgrades to overflow protection for roof system replacements, common sense design would dictate that overflow protection should be added wherever possible.

Drainage is a simple design element in new building construction and code requirements should be followed without fail. Adding drainage to an existing roof can be challenging, but the techniques for improving drainage are numerous and there are nearly always methods to improve the situation. The addition of new internal drains, scuppers and downspouts, gutters, sumps, and tapered insulation edges are several ways to improve roof drainage.

Component Three: Attachment

Attachment is the single most critical factor that drives the choice of a new or replacement roof system mainly because the deck type, code required loads, and other factors are set before the roof is designed. Attachment is a critical design factor to allow a roof system to stay in place under wind loads, and most design codes have very specific requirements for wind-uplift resistance. Attachment methods often are force-fit to a deck that does not readily lend itself to the method.

The three most commonly used roof attachment methods are loose-laid ballasted, mechanically-fastened, and fully-adhered (adhesive or asphalt). A fourth method, the Protected Membrane Assembly (PMA), is a hybrid of the basic attachments because the roof membrane may or may not be fully adhered, but the insulation clearly requires ballast to keep it in place. Vegetative roof systems are a form of PMA.

Inappropriate selection of the attachment methods in roof system design occurs when the differences between nailable and non-nailable deck systems are not respected. It has been widely recognized in the roofing industry that these two major classifications of roof decks exist. Roofing manufacturers generally have classified roof decks as nailable or non-nailable for more than 30 years. The nailable or non-nailable designation refers to the deck's ability to accept a "standard" fastener. In the case of steel decks, self-tapping screws would be the fastener of choice. In the past (prior to 1983), hot asphalt attachment of rigid insulation to a steel deck (ribbon or spot-mopping)was an accepted practice. This is no longer the case and mechanical fasteners and adhesives are generally required to achieve appropriate wind-uplift resistance ratings with steel decks.

Mechanical fastening to concrete and other non-nailable deck systems often is attempted; where alternative, less expensive, and more effective attachment methods could be used. Common problems with mechanical attachment to non-nailable decks are fastener backout, membrane damage, deck damage, resulting in loss of uplift resistance. Ultimately, each roof system type has a compatible attachment method. It is up to the designer to choose a system that has a proven track record in meeting code-required wind-uplift requirements and minimizes material incompatibility or installation issues such as fastener backout.

Table 1 is an approach to choosing a compatible fastening system for each of the common types of low-slope roof membrane and roof deck systems. The table is not intended to show all possible attachment methods, or even to show all commonly accepted practices in each region of the country or the world.

Table 1. Recommended Attachment Methods for Each Major Roof Type

Insulated Systems		**Attachment Method by Typical Deck Type**		
Roof Membrane Type		Steel	Concrete	LIF
- Built-up	Insulation	MF	FA	MF/BS – FA
	Membrane	FA	FA	FA
- Modified Bitumen	Insulation	MF	FA	MF/BS – FA
	Membrane	FA	FA	FA
- Single-ply/ Sheet	Insulation	MF or LL (1)	FA or LL (1)	MF or LL (1)
	Membrane	MF, FA or LLB	FA or LLB	MF, FA or LLB
Membrane Direct-to-Deck (Protected Membrane Assembly)		**Attachment Method by Typical Deck Type**		
Roof Membrane Type		Steel	Concrete	LIF
- Built-up	Membrane	Needs Base	FA (2)	MF/BS
	Insulation	LLB	LLB	LLB
- Modified Bitumen	Membrane	Needs Base	FA (2)	MF/BS
	Insulation	LLB	LLB	LLB
- Single-ply/Sheet	Membrane	Needs Base	Needs Base	Needs Base
	Insulation	LLB	LLB	LLB

Key:

MF – Mechanically Fastened	LLB – Loose-laid Ballasted
FA – Fully Adhered	MF/BS – Mechanically Fastened Base Sheet
MF/BS – FA – Mechanically Fastened Base Sheet, Fully Adhered Insulation	Needs Base – Requires base of rigid board insulation between deck and roof assembly
LIF – Lightweight Insulating Fill	LL – Loose-laid
Note 1: Loose-laid insulation would require a mechanically fastened or loose-laid ballasted membrane to provide uplift resistance, thus, a fully adhered membrane would be appropriate over mechanically fastened insulation only.	
Note 2: In a PMA, the fully adhered method of attachment may require modification to include an insulation board as a separator between the deck and the membrane in the case of precast concrete deck systems with frequent joints.	

If the general guidelines in Table 1 are followed, one will be led to the choice of attachment method that is compatible with the given roof deck, insulation, and membrane system, and provides a commonly accepted attachment method. Although the table is intended as a guideline, common sense and code requirements for wind-uplift resistance in choosing attachment methods should be followed.

Component Four: Material Durability

Material durability refers to a roof system's ability to resist the spread of fire, weathering and natural or man-made effects without resulting in dramatic changes to a membrane's functionality. A system should be rated for its ability to resist the spread of fire within a building, and the surface must be resistant to the spread of fire.

Membrane type and thickness, material additives, and surface treatments significantly affects fire resistance and roof system durability. Not only must the roof membrane and surfacing have the ability to resist the spread of fire, but the membrane also must be able to expand and contract to prevent splits and tears from temperature changes. Those capabilities should be present when a roof is constructed, and they should remain at adequate levels throughout its life cycle. Thus, in order for a roof system to perform adequately, it must have adequate material durability when it’s constructed, and not have a tendency to lose those characteristics as it ages. Many manufacturers have multiple membrane products for numerous surfacing configurations. Often, the manufacturer will have similar membrane products, some of which are rated for surface burning characteristics based on systems testing, others of which are not. Best practice is to carefully research the previous use of the chosen roof system product and demand a solid track record of performance over many years. If this is not done, the owner should be advised of the risk of using materials and systems that do not have a proven track record in the climate required.

Roof system traffic will generally have a significant effect on a roof system’s service life. This author believes that thin, unreinforced membranes are not likely to have the same resistance to roof traffic as a multilayer, built-up membrane product. Even reinforced single-ply products may be more susceptible to cuts, tears, and puncturing than a multi-layer, built-up membrane. The amount of serviceable equipment on the roof should be considered before deciding on an appropriate membrane and surfacing. The durability of the roof surface is a key factor in achieving longer service life. Table 2 is the author's general rating system of the durability of a roof surface relative to roof traffic.

Table 2. Resistance to Roof Traffic

Roof System	Surfacing	Traffic Resistance
Built-up	Gravel	High
(3 or 4-ply)	Smooth Surfaced	Moderate to High
Modified Bitumen	Gravel	High
(2-ply)	Granular Surface	Moderate to High
	Smooth Surfaced	Moderate to High
Single-ply	Unsurfaced/Exposed Membrane	Low to Moderate
	Ballasted	Low to Moderate
PMA or VEGETATIVE ROOF SYSTEM	Ballasted Insulation (Membrane beneath)	High

Ultimately, the roof system designers are responsible for selecting roof systems that meet all of the durability requirements. These durability requirements may be code or standard-mandated such as: fire resistance, puncture or tear resistance, elongation, and weatherability. Other durability requirements may be imposed by the climate in which the roof system is intended to serve, and by the traffic the roof system may be required to endure. Although these requirements are rarely code-mandated, the designer should pay as close attention to those requirements as to those that are code-mandated.

Component Five: Constructability

Constructability refers to the construction factors involved in placing a roof system on a particular building, taking into account building location, height, construction type, use, and occupancy. The design process should take constructability into account when choosing methods such as hot asphalt application, cold adhesives, fasteners, ballast, roof access, and numerous other factors. The following is a partial listing of other factors that play into a roof system's constructability:

- Durability of the membrane during construction
- Roof deck construction
- Roof deck structural capacity
- Interior conditions and finish.

Constructability factors should be considered when choosing a new or replacement roof system. How the roof system interacts with the building's other systems is important, as well as how easily the roof system is constructed and maintained. It also is important to determine how well the expertise of the contractors who likely will be performing the construction matches the specified system.

Component Six: Maintenance

All roof systems require maintenance during their life cycles. Properly maintained roof systems will have extended service lives and ultimately reduce ownership costs. Maintenance practices will generally not vary significantly by roof type; however, some roof types are considered more easily maintainable than others. Granular-surfaced built-up and polymer-modified bitumen membrane systems are easily maintained because surface damage to the membrane is visible and often obvious. In the case of an exposed, coated, gravel, or granular-surfaced membrane, routine inspection of the membrane should be performed. This also applies to exposed-membrane single-ply roof systems (fully adhered and mechanically fastened) where membrane damage can be visually detected and repaired.

Traditional gravel, ballasted roof membranes, PMA, and vegetative roof systems membranes are not visible, and many consider these membranes to not be as easily maintainable. It is unlikely that any routine inspection process should or would require ballast removal or insulation and ballast removal in order to carry out the inspection process. This process may do more harm than good by damaging the membrane during the ballast removal and replacement process.

Even though all membrane and covering systems are not created equal with respect to inspection and maintenance, most of the other roof system components are as equally maintainable regardless of roof type. Most roofs have exposed flashing and drainage systems that require periodic inspection and cleaning. Metal flashing systems are common to most roof system types even though metal type will vary. Most roof systems also contain flexible sealants, expansion joints, and penetration flashings that can be monitored and maintained. All roof drains, scuppers, collector heads and gutters should be inspected and cleaned at least two times per year, or more often when wind-borne debris and leaves are a factor.

The important factor regarding maintenance is that the designers recognize which portions of the roof system will require maintenance and alert owners regarding which systems require maintenance and to what level of detail. Designers may provide a maintenance manual or schedule to building owners. Maintenance may also include periodic leak repair. A difficult-to-maintain membrane such those buried under a ballasted or PMA roof system should require a membrane type that is high on the durability scale in order to reduce the demand for leak repairs. If it is not, an Owner may spend an inordinate amount of time moving ballast or uncovering protected membrane assemblies to chase leaks. Thus, a roof's "maintainability" becomes an important design factor.

Component Seven: Sustainability

When the first six components are taken into consideration, the aspects of sustainability can then be considered as a seventh component. The aspects of slope, drainage, attachment wind-uplift resistance, fire rating, thermal resistance, membrane durability, constructability, expected life cycle, and maintenance must all be considered before moving into the realm of sustainability. If all these factors are not first considered, a roof will fail to be truly sustainable because of the high likelihood of early replacement.

Sustainable characteristics of a roof system include the reduction of heat island effect, SRI, storm water retention, and the environmental factors such as manufacturing, installation, removal, and disposal. Table 3 below is this author's rating of typical membrane systems reviewed in this paper with respect to their relative sustainability factors.

Table 3. Sustainability Factors

Roof System	Heat Island Effect	Solar Reflectance Index	Stormwater Retention
Component	7A	7B	7C
Built-up	Increase	Minimal with gravel surfacing	No Capacity
(3 or 4-ply)			
Modified Bitumen	Moderate Increase	Reflective cap sheets available	No Capacity
(2-ply)		to increase SRI	
Single-ply (white)	Decrease	SRI of 0.85 or Greater	No Capacity
Single-ply (black)	Increase	None	No Capacity
PMA (light colored ballast)	Moderate Increase	Minimal	Minimal Capacity with gravel ballast
VEGETATIVE ROOF SYSTEM	Decrease	Minimal	Highest Capacity

Table 4 on this page outlines the environmental factors for each of the typical roof systems. It also could be said that for a roof system to be truly sustainable it must accommodate all the loads placed on it without becoming damaged or deteriorated. This includes all previous components of design plus roof top use considerations such as; fall protection systems, façade access and window washing rigging, and mechanical equipment staging. See Table 5 for a summary of loads placed on a roof system based on this author's experience.

Table 4. Environmental Factors

Roof System	**Manufacturing**	**Installation**	**Removal**	**Disposal**
Component	7D	7E	7F	7G
Built-up (3 or 4-ply)	Asphalt and felt production byproducts.	Asphalt fumes.	Cutting of roof system releases contaminants in air.	Currently not many recycling programs available. Potentially recyclable as paving material.
Modified Bitumen (2-ply)	Similar to Built-Up.	Asphalt or adhesive fumes or VOCs.	Similar to Built-Up	Similar to Built-Up
Single-ply (white)	Chemicals used in manufacture create harmful byproducts	MF – Clean with minor odor. Adhesive - VOC	Removal process is generally low-impact	Recycling available but materials stored in landfill contaminate soils over time.
Single-ply (black)	Less impact than PVC but some chemicals are still harmful	VOC and odor from adhesives and primers.	Removal process is generally low-impact	Recycling available but materials stored in landfill are flammable.

MF- Mechanically-Fastened
VOC- Volatile Organic Compound

Determining the best roof system for a given application requires consideration of all the components and factors listed in this paper. An issue that has developed with sustainability and government interaction with requiring a certain type of sustainable roof is that many times specific roof types are forced to fit applications for which they do not satisfy the criteria mentioned. For example, in many jurisdictions, there are now incentives in the form of tax credits for increasing roof SRI, increasing roof stormwater retention, and decreasing the urban heat island effect. As was shown in Table 3, the most effective way to reduce stormwater runoff and the one acknowledged by most jurisdictions is the vegetative roof system. But the cost of installing these systems can be prohibitive and in many reroofing cases the additional structural load requires structural modifications or cannot be accommodated. Conversely, the most effective way to increase roof SRI is to install a white, light-colored membrane, but at the cost of stormwater retention and in some cases durability.

Table 5. Loads on Roof Systems

Load Type	*Description or Components of Each Load Type Loads Specific to LWIC Shown in Italics*
Pre-Construction	
Manufacturing	Internal stresses in the material created from the manufacturing process, blowing agents, chemical reactions, heating and cooling, *and/or curing*.
Storage	Sustained loading while in stacked storage, damage resulting from warehouse or other traffic, warehouse temperature and humidity concerns, compromised protective coverings *or torn bags*.
Shipping	Stacking of pallets, transport within the warehouse, forklift damage, transport on trucks to the site, damage resulting from road hazards, *or time on the road or in the mix truck.*
Delivery	Lifting by crane or hoist to the roof level. Man-handling into elevators, stairwells, or through hatches. On-site storage and exposure to the elements. *Hydraulic forces when pumping to the roof.*
Construction	
Insulation Installation	Effects of dropping tools on the material. Storage of other roofing materials on top of the insulation. Cutting material to fit. Stresses induced by the installation process including heat from asphalt cooling, adhesive curing, primer flash-off, screw penetration, *or heat of hydration and drying shrinkage.*
Construction Traffic	Movement of people or products across completed roof sections.
Wind Uplift *(also a Service Load)*	Force exerted because of suction on the roof from wind moving across the roof. The insulation may need to accommodate the wind

	uplift before membrane installation.
Ultra-Violet Radiation *(also a Service Load)*	Exposure to sunlight before membrane installation. Exposure resulting from wind scour in PMA systems.
Membrane Installation	Effect of dropped rolls on the roof, fastened installation, adhesive or primer application, or screwing of fasteners.
Service Loads	
Heat Transfer	Resistance to heat flow across the material, typically addressed by R-Value and thickness of the material.
Vapor Transmitance	Resistance to the flow of water vapor across the material, typically addressed by permeance or adding a vapor retarder at the deck level.
Leak Migration	Resistance to the movement of liquid water through the insulation.
Live Load	Support of code required live loads such as snow and ice on the roof, rain, ponding, or personnel.
Dead Load	Support of material self-weight.
Roof Traffic	Activity on the roof because of service personnel and other trades. Façade access equipment on the roof.
Reroofing Loads	
Membrane Removal	Potential for damage to the insulation during removal of the existing membrane, storage of trash on the roof,
Reroofing	Installation of the new roof membrane over the old insulation.

Summary

If roofing professionals recognize these seven key factors of roof system design, the average service life of a roof system could be extended significantly. Using these design concepts adds little to the roof system's construction or replacement cost and can have a significant positive effect on service life and will reduce life cycle cost. Following is a summary of the key factors is listed below.

1. **Slope** – Provide a minimum of ¼:12 slope and direct water to drains with crickets, saddles, etc. for low-slope roof applications.
2. **Drainage** – Provide at least the minimum drainage and overflow protection as required by code, and err on the side of more drainage than required when designing roof systems for small areas, multiple levels, and unusual shapes.

3. **Attachment** – Choose attachment methods carefully, and use proven, code-required, tested attachment methods appropriate for the deck system.
4. **Durability** – Make roof system durability an important design factor and use life-cycle cost analysis to help the Owner choose the most cost-effective roof system.
5. **Constructability** – Each roof type has advantages and disadvantages when it comes to constructability; choose a system that can be built on a particular building.
6. **Maintenance** – All roof systems require some type of an often similar maintenance, however, all membranes are not created equal; if the roof membrane is to be covered, make membrane durability and longevity of the membrane a high priority.
7. **Sustainability** – Specify systems that are appropriate for the application, not force-fit for tax incentives or other social ideals that aren't appropriate for the particular building. Maintain an objective and professional view when dealing with sustainability aspects, the best way to be truly sustainable is to install a roof that meets or exceeds its expected useful service life.

Consideration of several roof systems and their relative advantages related to the seven design factors discussed herein is shown in Table 6. This table is not meant to be an exhaustive search of all roof systems or specific to any one manufacturer. In general, the table shows which systems appear to have an advantage with respect to the seven factors discussed in this paper. For sustainability, the factor has been divided into seven subcategories (7A-7G) for tabulation purposes. Tables 4 and 5 elaborate on the various sustainability factors are elaborated on in Tables 4 and 5. The information in Table 6 is meant to serve as a quick reference for designers and contractors to determine whether a particular system may have a notable advantage over another in a particular application.

Remember that all roof systems are not equal, and each building has different requirements. There is no single roof system that is applicable in all situations. It is not the choice of material or specific manufacturer that will make a roof system work, it is a combination of all of these design factors taken in total that will provide longer-lasting roof systems.

Although these are not the only factors a designer may encounter, they provide the basis for sound design judgment and should lead to more durable roof systems with longer service lives. The durable roof of the future will use technology to design for slope and improved drainage; better adhesives and fasteners for solid attachment to meet wind-uplift requirements under a variety of deck conditions; more durable, thicker materials to stand up to weathering and ultraviolet radiation; worker and occupant-friendly materials to enhance constructability; design with maintenance of the total roof system in mind; and all these factors together should lead to a sustainable roof that outlasts its anticipated or design life-cycle.

Table 6. Advantages of Certain Roof Systems

							Sustainability						
Roof System	**1**	**2**	**3**	**4**	**5**	**6**	**7A**	**7B**	**7C**	**7D**	**7E**	**7F**	**7G**
Built-Up													
Coal Tar Flat on CD			√	√									
Asphalt Flat on Concrete Deck (CD)			√	√									√
Low-Slope (LS) Asphalt on CD	√		√	√									√
Modified Bitumen (torched)													
Flat on CD in PMA			√	√				√		√		√	
LS on CD in PMA	√		√	√				√		√		√	
Flat on CD in VEGETATIVE ROOF			√	√			√		√	√		√	

SYSTEM													
LS on CD in VEGETATIVE ROOF SYSTEM	√		√	√			√		√	√		√	
LS on MD w/ FA Tapered Insulation (TI)	√	√			√	√	√	√		√		√	
LS on MD with MF TI	√	√			√	√	√	√		√		√	
Modified Bitumen (asphalt set)													
Flat on CD in PMA			√	√				√		√		√	
LS on CD in PMA	√		√	√				√		√		√	
Flat on CD in VEGETATIVE ROOF SYSTEM			√	√			√		√	√		√	
LS on CD in VEGETATIVE ROOF SYSTEM	√		√	√			√		√	√		√	
LS on MD with FA	√	√				√	√	√		√		√	
LS on MD with MF TI	√	√				√	√	√		√		√	
Modified Bitumen (cold set)													
Flat on CD in PMA			√	√				√		√		√	
LS on CD in PMA	√		√	√				√		√		√	
Flat on CD in VEGETATIVE ROOF SYSTEM			√	√			√		√	√		√	
LS on CD in VEGETATIVE ROOF SYSTEM	√		√	√			√		√	√		√	
LS on MD with FA TI	√	√			√	√	√	√		√		√	
LS on MD with MF TI	√	√			√	√	√	√		√		√	
Single-Ply (Thermoplastic)													
Flat on CD in PMA			√					√			√	√	√
LS on CD in PMA	√		√					√			√	√	√
Flat on CD in VEGETATIVE ROOF SYSTEM			√				√		√		√	√	√
LS on CD in VEGETATIVE ROOF SYSTEM	√		√				√		√		√	√	√
LS on MD with FA TI	√	√			√	√	√	√			√	√	√
LS on MD with MF TI	√	√			√	√	√	√			√	√	√
Ballasted (light-colored)							√	√			√	√	√
Single-Ply (Thermoset)													
LS on CD in PMA	√		√					√		√	√	√	√
LS on CD in VEGETATIVE ROOF SYSTEM	√		√				√		√	√	√	√	√
LS on MD with FA TI	√	√			√	√	√	√		√	√	√	√
LS on MD with MF TI	√	√			√	√	√	√		√	√	√	√
Ballasted (light-colored)							√	√		√	√	√	√
Fluid-Applied (Flat in PMA or VEGETATIVE ROOF SYSTEM)													
Hot-Rubberized Asphalt on CD			√	√			√	√	√		√	√	
Cold Fluid Applied w/ reinforcing on CD			√		√		√	√	√		√	√	

Table Notes:

Factor 1 (Slope): Check means that the system has the advantage of being sloped to drain. Generally, low-slope roofs are not checked and ballasted roofs considered are less than ¼-inch per foot and typically do not drain well.

Factor 2 (Drainage): It is assumed that all systems would be installed with code-compliant drainage. The check appears for systems that have a clear advantage in drains not accumulating blockages because of the aspects of the roof system.

Factor 3 (Attachment): Those systems with the least variability in attachment inherent to the application method.

Factor 4 (Durability): Systems with proven records of long-lasting performance.

Factor 5 (Constructability): Those systems that install with comparatively less labor, steps, staging, materials, or weight.

Factor 6 (Maintenance): Those systems that are readily maintainable, typically exposed-to-view membranes (i.e. no overburden).

Factor 7A (Heat Island Effect): Systems that do not contribute to or reduce the effect.

Factor 7B (Solar Reflectance): Those systems that can increase SRI.

Factor 7C (Stormwater Retention): Those systems that can provide this benefit.

Factor 7D (Manufacturing impacts): Systems that do not adversely affect the environment in their manufacturing.

Factor 7E (Installation Impacts): Systems with low or no volatile organic compounds (VOCs) or other harmful effects.

Factor 7F (Removal Impacts): Systems where harmful VOCs are not generated during demolition.

Factor 7G (Disposal Impacts): Materials with established recycling programs available.