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Roofing: Staying on Top of Technology and Change

Towards Sustainable Roofing

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Abstract

With increasing public awareness of climate change and sustainable development, roof designers have made progress in three key areas of sustainability — minimizing the burden on the environment, conserving energy, and extending roof system life spans. This paper presents an overview of and design considerations for three viable sustainable roofing systems — garden roofs, reflective roofs and roof-mounted photovoltaics.

1. Introduction

A sustainable roof is one that is designed, constructed, maintained, rehabilitated, or demolished, with an emphasis throughout its life cycle on the efficient use of natural resources and the maintenance of the global environment [1]. In 1995, an international committee (CIB W83/RILEM 166 RMS) was formed to help designers understand the concept of sustainable roofing and provide a framework for new design methods. Through extensive review of research papers and input from the committee members, a task group identified three key areas where improvement could be made: the environment, energy and durability. In 2002, the committee summarized best practices in a one-page document entitled "Tenets of Sustainable Roofing" [2]. The tenets were categorized as follows:

Minimize the Burden on the Environment

1. Use products made from raw materials whose extraction is least damaging to the environment.
2. Adopt systems and working practices that minimize waste.
3. Avoid products that result in hazardous waste.
4. Recognize regional climatic and geographical factors.
5. Where logical, use products that could be reused or recycled.
6. Promote the use of "green roof systems," which support vegetation, especially on city roofs.
7. Consider roof system designs that ease the sorting and salvage of materials at the end of the life of a roof system.

Conserve Energy

8. Optimize the real thermal performance of roof systems, recognizing that thermal insulation can greatly reduce heating or cooling costs over the lifetime of a building.
9. Keep insulation dry to maintain thermal performance and the durability of a roof system.
10. Use local labour, materials and services, when practical, to reduce transportation.
11. Recognize that embodied energy values are a useful measure for comparing alternative constructions.
12. Consider roof surface colour and texture with regard to climate and their effect on energy and roof system performance.

Extend Roof System Life Span

13. Employ designers, suppliers, contractors, trades people and facility managers who are adequately trained and have appropriate skills.
14. Adopt a responsible approach to design, recognizing the value of a robust and durable roof system.
15. Recognize the importance of a properly supported structure.
16. Provide effective drainage to avoid ponding.
17. Minimize the number of penetrations through a roof system.
18. Ensure that high-maintenance items are accessible for repair or replacement.

19. Monitor roofing works in progress, and take corrective action as necessary.
20. Control access onto completed roof systems to reduce punctures and other damage by providing defined walkways and temporary protection.
21. Adopt preventative maintenance with periodic inspections and timely repairs.

With increasing public awareness of sustainable development, building owners are demanding roofing systems that are more compatible with the environment. Roof designers and manufacturers have responded by

- using materials that are made by more environmentally friendly processes
- producing more durable products, and
- developing system designs that improve life-cycle costs.

The Canadian Green Building Council (CaGBC) has a LEED (Leadership in Energy and Environmental Design) rating system. Based on building performance, points are credited in five principal categories: sustainable sites, water efficiency, energy and atmosphere, materials and resources, and indoor environmental quality.

Improved building performance is certified with ratings — Certified, Silver, Gold or Platinum — based on the total number of points earned by a project. Many new public and institutional buildings in Canada now require LEED certification. For example, Public Works and Government Services Canada has adopted a LEED-based Green Building Policy, and the Greater Vancouver Regional District and other local governments are considering the adoption of LEED for their municipal buildings. Also, the numbers of professionals trained in LEED and of buildings registered for LEED certification have been increasing rapidly over the past few years. Three viable roofing systems that focus on sustainable roofing are discussed in this paper.

2. Sustainable Roofing Options

2.1 Garden Roof Systems

2.1.1 What is a Garden Roof System?

Garden roof systems are specialized roofing systems that support vegetation growth on rooftops. In addition to the roofing membrane, this type of system consists of several major components: a root-resistant layer, a drainage layer, a filter layer, a growing medium and vegetation. The components act together to provide a suitable environment that supports plant growth while maintaining the waterproofing function of the roofing membrane [3]. These systems can be installed on both conventional and protected membrane systems and can be categorized by weight as either extensive or intensive. Extensive garden roof systems are lightweight, have a shallow growing medium with small plants and require a low level of maintenance. Intensive garden roof systems, on the other hand, are heavier and contain more growing medium to support shrubs and small trees. They require a higher level of maintenance, similar to that of a normal garden. Figures 1 and 2 show examples of both extensive and intensive garden roof systems.

Figure 1. An extensive garden roof system (150-mm growing medium planted with grasses) on the NRC-IRC Field Roofing Facility in Ottawa

The cost of such a system depends on the components (e.g., the type and depth of the growing medium and the type of vegetation) and the need for building upgrades (e.g., reinforcement of the existing roof structure, the addition of safety railings and an irrigation system). In general, the initial cost of a garden roof system ranges from \$160-550/m^2 compared to \$75-110/m^2 for a built-up roof, or \$90-160/m^2 for a protected membrane roofing assembly [4].

Figure 2. An intensive garden roof system (350-mm growing medium planted with ornamental grasses) on the Vancouver Public Library in Vancouver

2.1.2 Why are Garden Roof Systems Sustainable?

Conserve Energy. Garden roof systems can reduce the energy demand on space conditioning [5] by reducing heat flow through the roof by shading, insulating, evapotranspiration and thermal mass. Foliage intercepts incident sunlight and reduces the amount of solar radiation reaching the roof underneath. The insulation is provided by the growing medium and the plants. Evapotranspiration is a process in which the leaves and the soil convert incoming solar energy into latent heat through the evaporation of water, preventing it from being converted into sensible heat. With moisture available, evapotranspiration can significantly cool the air temperature at the surface of the roof. The growing medium also acts as a thermal mass that temporarily stores incident solar energy.

The NRC Institute for Research in Construction has conducted field monitoring to study the thermal performance of garden roof systems. Figure 3 shows the cumulative heat flow through a conventional roofing system both with and without a garden roof system (150 mm of lightweight growing medium planted with wild flowers). The heat flow through the roof was about the same for both roofs during the winter months (January to March) because of the frozen growing medium and snow coverage. However, the garden roof system greatly reduces the heat flow through the roof in spring and summer (April to September), as indicated by the diversion of the heat flow curves, starting around the end of March. The two curves begin to rise at a similar rate again in early fall (October). This study showed that garden roof systems can reduce heat flow through the roof (the annual reduction was about 50%), thus lowering energy demands for space conditioning, and that they are more thermally effective in the summer than in the winter.

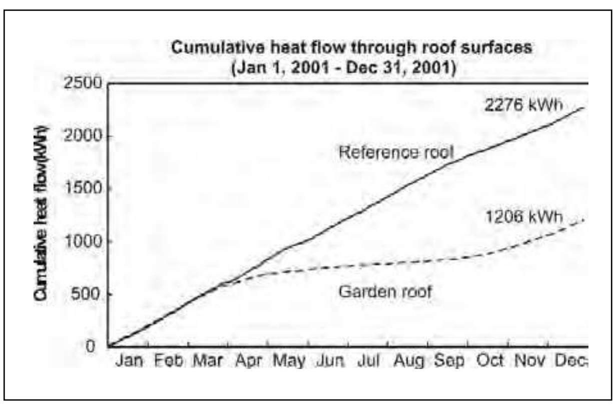

Figure 3. Field monitoring at the NRC-IRC roofing facility in Ottawa showed that a garden roof system (150-mm growing medium planted with wild flowers) could significantly reduce heat flow through the roofing system, particularly in the spring and summer.

Extend Life Span. The roof membrane on a conventional roof is exposed to ultra violet (UV) radiation, extreme temperatures and potential physical damage from hail and traffic on the roof. Garden roof systems can extend the roof's service life by protecting the roof membrane from these damaging factors. NRC-IRC's field study showed that these systems can lower the maximum temperature and reduce the diurnal temperature fluctuation (the difference between the daily maximum and minimum temperatures) experienced by the roof membrane [3]. High temperatures accelerate the rates of chemical degradation while diurnal temperature fluctuations induce thermal stresses (expansion and contraction) in the roof membrane; both factors affect the long-term performance of the membrane. Therefore, garden roof systems contribute positively to the durability of the roofing membrane.

Preserve the Environment

Storm Water Management. Garden roof systems can be used as a control tool as part of the storm water management strategy in urban areas. Some of the rain is temporarily stored in the growing medium, where it is taken up by the plants and returned to the atmosphere through evapotranspiration. NRC-IRC's monitoring of garden roof systems in Ottawa, Toronto and Vancouver showed that they could delay and reduce the rate and amount of roof runoff. The delay is particularly important from a storm water management point of view, as it reduces the "rush hour effect" in the storm water infrastructure at the beginning of a heavy rain event and lowers the incidence of combined sewage overflows (where water from the storm sewers overflows into the sanitary sewers). The delay and reduction depend on many parameters including the type and depth of the growing medium, the type of vegetation and coverage, and the presence of a water retention mat (optional component in garden roof systems), as well as the intensity and duration of the rain events. In general, an extensive green roof system can retain about 50 to 70% of the annual rainfall [6-7].

Urban Heat Island. Dark building materials absorb solar energy, causing the temperature of the surface and the air around them to rise. This is further compounded when there is little vegetation to provide shade, intercept solar radiation and cool the air through evapotranspiration. These factors create an urban heat island, where the temperature in the urban area is 2 to 3°C higher than that of the surrounding rural area. The excess heat not only increases the energy demand for air conditioning in the summer but also the probability of smog formation. Garden roof systems, however, can reduce the urban heat island by replacing heat-absorbing surfaces with vegetation. Simulation studies conducted by Environment Canada [8] showed that with the availability of moisture for evapotranspiration, moderate coverage provided by garden roof systems in Toronto could reduce the city-wide summer temperature by 1 to 2°C.

Air Quality and Biodiversity. About 30% of Canada's electricity comes from fossil fuel combustion, making it a significant source of greenhouse gas (GHG) emissions. A reduction in cooling energy demand in the summer would mean less GHG emission from energy production. In addition, plants can remove particulate from the air, and garden roof systems can provide recreational space for urban dwellers, as well as habitats for birds and insects [5].

2.1.3 Design Considerations for Garden Roof Systems

Currently there are no standards for garden roof systems in North America. ASTM International has formed a Green Roof Task Force under its subcommittee, E06, but this has not yet resulted in standards for public use. As part of an ongoing research consortium (Rooftop Garden Consortium), NRC-IRC is developing a design guide for the use of these systems in cold climates. "The Guidelines for the Planning, Executing and Upkeep of Green-Roof Sites" [9] published by the Landscaping and Landscape Development Research Society (FLL) in Germany is probably the most advanced standard on garden roof systems in existence today. It contains information on specifications, construction, material testing, planting, maintenance and safety. Some of the technical requirements of particular interest to roofing designers and professionals are highlighted below.

Roof Slope. The roof slope should be at least 2% for extensive systems. As the slope increases, the rate of water runoff also increases. For slopes greater than 5%, growing mediums with fairly high water-storage capacity, or plants that have low water demand, should be used to compensate for the greater amount of runoff. As the slope increases, special consideration should be given to protecting the system from shear and slide; slopes greater than 45° are not recommended because of the risk of sliding.

Root Penetration. It is important to protect the membrane against root penetration. This can be achieved by using protective sheeting, full surface treatment or waterproof concrete. The roots of certain plants, such as bamboo and some Chinese reeds, can be extremely aggressive and may require multiple root-penetration barriers. The resistance to root penetration should be tested by subjecting the root-penetration barrier to aggressive plant roots for a specified period of time.

Drainage. Roof outlets should be permanently accessible and not covered with greenery or loose gravel. Plants must not be allowed to grow into the gutters, blocking the drainage paths. Roof drains located within vegetation areas should have inspection ports to ensure that no plants are obstructing them (Figure 4). Outlets that are located away from vegetation areas are left lying loose in a strip of gravel or allowed to lie flush with the upper edge of paving in paved areas. For steep-slope roofs, the use of overhanging plants with vigorous growth should also be avoided around the eaves to ensure free drainage.

Figure 4. Roof drains on garden roof systems should be easily accessible and regularly inspected to ensure proper drainage. (Photo courtesy of Hydro-Tech Membrane Corp.)

Wind Uplift. When the waterproofing and root-penetration barriers are not fully adhered, the growing medium needs to serve as ballast to prevent wind uplift. At edges and corners where wind uplift forces are highest, gravel, and concrete or stone slabs, could be used. A deeper growing medium is sometimes needed in certain areas to strategically increase the resistance to wind uplift. Larger plants can be anchored on the roof.

Fire Resistance. Dried plant materials are susceptible to fire propagation. According to the FLL Guidelines, extensive garden roof systems may be deemed to have sufficient fire resistance if (a) the growing medium meets a composition and depth requirement (b) the vegetation has a low fire load or (c) there is a minimum space of 500 mm (20 in.) between the vegetation areas and any roof penetrations. In addition, the use of succulents will provide more fire resistance than grasses. An irrigation or sprinkler system further reduces the risk of fire.

2.1.4 Cautions

Designers need to give careful consideration to garden roof systems. As is the case for other roof systems, good design requires experience and attention to detail, and for this type of system there is a particular need to coordinate with the additional trades (e.g., landscapers, horticulturists). Since leaks can be difficult to locate and costly to repair, performing a membrane leak-detection test before and after the installation of the overburden should be considered. Building owners should also be made aware of the maintenance issues (costs and work required) for both waterproofing and vegetation.

It is confusing and potentially misleading to directly equate the thermal effectiveness of garden roof systems and thermal insulation. Garden roof systems are more effective in reducing heat gain in the summer than in stopping heat loss in the winter (Figure 3) because of the heat transfer mechanisms involved. The additional growing medium material provides higher insulation, larger thermal mass and evapotranspiration to keep the building cool in the summer. However, the insulation value of the growing medium greatly diminishes when it freezes in the winter [10]. Thermal insulation, on the other hand, reduces heat flow all year round. Therefore, the garden roof system cannot be considered a substitute for thermal insulation in cold climates.

2.2 Reflective Roofs

2.2.1 How Does a Reflective Roof Work?

The temperature at the surface of the roof is affected by several heat transfer mechanisms (Figure 5). When solar radiation hits the roof surface, it can either be reflected or absorbed. Absorbed heat raises the surface temperature. Some of the heat can be removed from the roof surface by convection (convective cooling by wind depends on the local climate and the roof geometry) and some dissipated into the atmosphere by radiation. The remaining heat is transferred into the building by conduction, which can be reduced by using thermal insulation in the roof system. As well, roofing designers can minimize the amount of solar radiation entering the building by modifying the surface characteristics of the roof.

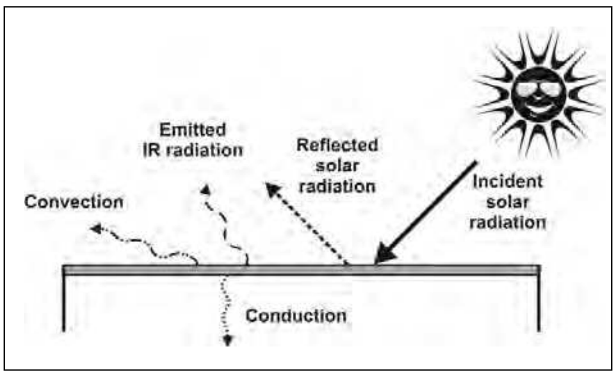

Figure 5. Heat transfer mechanisms of a reflective roof

There are two properties that affect the incident solar radiation at the roof surface: solar reflectance and infrared emittance. Solar reflectance (reflectivity or albedo) is the fraction of incident solar energy that is reflected from the surface, while infrared emittance (or emissivity) is a measure of the surface's ability to shed the absorbed solar energy in the form of infrared radiation. Therefore, to keep a roof surface cool in the sun, it is best to use products that have high solar reflectance (that reflect the sun's energy away from the roof so that it is not absorbed) and high infrared emittance (that radiate the absorbed energy away from the roof).

Table 1 shows the surface characteristics (solar reflectance and infrared emittance) of some common roof surface materials [11]. The temperature rise is the increase in surface temperature above the air temperature, resulting from the surface characteristics as estimated by basic heat transfer equations. Conventional roofing materials have a solar reflectance of 0.05 to 0.25. Reflective roof coatings can increase the solar reflectance to more than 0.60. Most roofing materials have a high infrared emittance of 0.90 or higher with the exception of metals, which have a low infrared emittance of about 0.25. Therefore, even though they are very reflective (solar reflectance greater than 0.60), bare metal roofs and metallic roof coatings tend to get hot since they cannot emit the absorbed heat effectively through cooling from radiation. Roofing coatings can raise the infrared emittance of metal roofs.

Table 1. Typical values of solar reflectance and infrared emittance of common roofing materials [11]

Roof Surface	Solar Reflectance	Infrared Emittance	Temperature Rise (°C)
EPDM - black	0.06	0.86	46
EPDM - white	0.69	0.87	14
TPO - white	0.83	0.92	6
Bitumen - smooth surface	0.06	0.86	46
Bitumen - white granules	0.26	0.92	35
BUR - dark gravel	0.12	0.90	42
BUR - light gravel	0.34	0.90	32
Shingles - generic black granules	0.05	0.91	46
Shingles - generic white granules	0.25	0.91	36
Shingles - white elastomeric coating	0.71	0.91	12
Shingles - aluminum coating	0.54	0.42	28
Steel - new, bare, galvanized	0.61	0.04	31
Aluminum	0.61	0.25	27
Aluminum - white coating	0.59	0.85	21

Table 1 also demonstrates that by increasing solar reflectance or infrared emittance, the roof surface temperature can be lowered (i.e., has a lower temperature rise). In general, white coatings have a higher solar reflectance than coloured coatings. The solar reflectance increases with coating thickness for some products. Asphalt shingles have a low solar reflectance — about 0.30 with white granules and less for coloured granules. This is attributed to several factors: a limited amount of pigment in the granule, surface roughness causing multiple light scattering, and imperfect granule coverage of the black asphalt substrate. A white elastomeric coating or an aluminum coating can raise the solar reflectance to more than 0.50. Reflective roof coatings cost \$10-\$20/m^2 for materials and labour. Installation costs, however, depend on many factors such as the condition and size of the roof, the number of penetrations or obstacles, and the ease of access to the roof [12].

2.2.2 Why is a Reflective Roof Sustainable?

Conserve Energy. A reflective roof can reduce the cooling energy demand on a building. Monitoring of reflective roofs in regions of the U.S. where cooling predominates showed that their use could reduce annual cooling energy use and peak demand [13]. When 10 buildings in California and Florida were monitored, it was found that highly reflective roof coatings reduced annual cooling energy use by 20 to 70%. The actual amount of savings in cooling energy is a complex function of several building-specific variables such as the amount of roof insulation, the building configuration, the type and efficiency of the cooling system equipment, the cooling loads and energy costs, as well as the local climate [14]. Computer programs have been developed to estimate the amount of energy saved by the use of reflective roofs. The U.S. Department of Energy's Oak Ridge National Laboratory's (ORNL) Cool Roof Calculator and the U.S. Environmental Protection Agency's (EPA) Energy Star Roofing Comparison Calculator will calculate the energy savings and help the user select a roof coating; however, climate data are available only for major U.S. cities at this time.

Extend Lifespan. The use of reflective roofs lowers the temperature of the roof membrane, thus reducing the rate of degradation. This cooler temperature also reduces the diurnal temperature fluctuations and the associated thermal stresses experienced by the roof membrane. Many reflective roof coatings contain white pigment (e.g., titanium dioxide) to make them opaque and reflective. These pigments are able to absorb the 5% or so of the sun's energy that falls in the ultraviolet range, protecting the roof membrane from UV damage.

Preserve the Environment. Reflective roofs can reduce the cooling demand and peak load during the summer, and reduce the GHG emissions associated with energy production. In addition, widespread use of reflective roofs in urban areas can reduce the urban heat island effect [15]. The lower air temperature also decreases the probability of smog formation.

2.2.3 Cautions

Dirt Accumulation. The solar reflectance of reflective roofs is degraded by weathering and dirt accumulation. Light-coloured roof surfaces are typically expected to lose about 20% of their initial solar reflectance over a period of several years, with the highest reduction occurring in the first year. The solar reflectance of most roofs can be restored to their initial values by simply washing them. A study on PVC roofing materials that have been in service for 15 to 22 years showed that wiping and rinsing with water (similar to the cleansing action of rain) restored the solar reflectance to 80% of the original level, if the roof surface was not covered with algae [16]. When covered with algae, washing with detergent and algae cleansers was required to restore the initial solar reflectance. Therefore, local air pollution levels, the product's resistance to dirt accumulation and the cost of cleaning should be considered when specifying a reflective roof.

In order for low-slope roof products to qualify for the U.S. EPA's Energy Star label, they must have an initial solar reflectance greater than or equal to 0.65 and an aged reflectance of 0.50 or more three years after installation under normal conditions. Cleaning of the roof surface is permitted before the solar reflectance of weathered products is measured. The Cool Roof Rating Council (CRRC) is another organization that rates reflective roof products based on initial and three-year solar reflectance and infrared emittance measurements. For this rating, washing or cleaning is not permitted before testing.

Climate Considerations. Reflective roofs do not save heating costs in the winter. Critics of reflective roofs have argued that the reflective properties that make the buildings easier to cool in the summer also make them more difficult to heat in the winter — the heating, or winter, penalty. In hot climates, the cooling benefits in the summer significantly exceed the heating penalty in the winter.

However, this is not the case in cold climates where heating rather than cooling requirements predominate. A recent study [14] showed that for the northern-most geographical band of the U.S., the energy savings from the use of reflective roofs were either non-existent or negative. This band includes many areas that have cold winter climates (e.g., Detroit, Milwaukee and Minneapolis) or cool, cloudy summer climates (e.g., Portland and Seattle). These findings demonstrate that it is important for building designers to perform detailed building energy calculations before specifying a reflective roof.

Consideration must be given to the climate (e.g., sun angle, snow accumulation) and the energy cost/structure (e.g., energy source, time-demand charges) of a specific location.

Thermal Resistance versus Solar Reflectance. As in the case of garden roof systems, trying to compare, or establish equivalency between, the cooling effects of reflective roofs and thermal insulation is confusing and misleading. Thermal insulation reduces heat flow through the roof all year round, keeping the building cool in the summer and warm in the winter. Reflective roofs reduce heat flow in the summer, lower the cooling load and peak demand, thereby producing the same effect as adding thermal insulation in the roof. However, reflective roofs incur a heating penalty in the winter. Thus reflective roofing cannot be considered as a substitute for thermal insulation in cold climates.

Glare and Visual Considerations. Designers should be aware that newly installed white reflective roof products can generate excessive glare and cause visual discomfort. The U.S. Federal Aviation Administration (FAA) has alleged that glare from reflective roofs near or on flight paths into airports can disorient pilots at certain times of the day and force them to use alternative runways [17]. Glare from reflective roofs can also cause visual discomfort to occupants in neighbouring buildings when they are "blasted with blinding light." In cases where the reflected light is focused on heat-absorbing materials on adjacent buildings, this focused heat build-up can cause physical damage to building components such as lesser-quality vinyl sidings and windows.

The highly reflective nature of reflective roof products also poses health and safety hazards to installers, as glare from reflective membranes can temporarily blind workers and cause disorientation. In addition to direct sunlight, indirect reflected sunlight increases the UV exposure for the workers. Therefore, protective sunglasses and work clothes with adequate UV protection are recommended for installers.

Although white, reflective roof surfaces are the most effective in keeping a roof cool in the summer, coating manufacturers have developed cool roof coatings that make dark-coloured roof surfaces less hot. These cool roof coatings have low visible reflectance (i.e., they are dark-coloured) but high near-infrared reflectance (i.e., they are effective in reflecting heat) [18].

2.3 Photovoltaic (PV) for Roofs

2.3.1 What is Photovoltaic?

Photovoltaic (PV) devices convert sunlight directly into electricity. PV cells are made of semiconductor materials. Groups of cells are then interconnected and encapsulated to produce PV modules. Most PV cells are made from crystalline or amorphous silicon. The conversion efficiencies of commercial modules are generally higher for crystalline (12-15%) than for amorphous (around 7%) silicon.

PV modules generate direct current (DC) electricity, which is usually converted to alternating current (AC) through an inverter in order to be compatible with most appliances. "Grid-connected" systems allow excess solar energy generated on site to flow to the utility (turning the utility meter backwards), and utility power flows to the building when insufficient solar energy is generated on site. These systems are sophisticated and require approval from the local utility to ensure code compliance and safe operation. However, they are becoming more popular [19], especially in areas where net metering is permitted.

PV-integrated roofing products are significantly more costly than their conventional counterparts. For example, the cost of PV-integrated roof tiles is about $900/m^2, which is approximately 15 times that of clay or concrete tiles, while the cost of roof-mounted systems is about $910/m^2, which is about 14 times that of aluminum pitched roofs [19].

2.3.2 Design Considerations for Roof-Mounted Photovoltaic

Rooftops can be ideal locations for PV modules (particularly on south-facing sloped roofs in the northern hemisphere) because they are relatively free of obstructions. PV modules can be integrated into the roofing material, thereby saving on roofing costs, and can be installed on sloped or flat roofs (Figure 6). PV installation requires a combination of electrical, structural and roofing skills; thus it is important to coordinate between roofing professionals and PV installers to ensure success.

Figure 6. Integrated solar electric roofing system (flexible photovoltaic modules laminated on thermoplastic membrane) on Frito-Lay Distribution Facility, Los Angeles, California (Photo courtesy of Sarnafil Inc.)

Sloped Roofs. PV modules can be mounted on roof tiles (shingles) or profiles (panels). They can also be integrated into the roof tiles and shingles, which are installed with nails and battens in a similar fashion to traditional sloped-roof products. PV-integrated profiles can be installed on a new roof or mounted on an existing roof. Rubber joints are typically used to seal the panels in order to maintain watertightness.

Flat Roofs. PV modules can be mounted on the roof surface or integrated into the roof materials. Modules may be mounted in the same plane as the roof (to maximize the collection area) or inclined at an angle (to maximize solar intensity). The modules are either mounted on racks or ballasted on the roof. PV systems typically weigh 25 to 75 kg•m^{-2} [20] so the roof structure must have the required load-bearing capacity. There is a new trend that involves integrating the flexible PV modules into the roof membrane, which does not result in additional dead loads (Figure 6).

Wind Uplift. Wind induces pressure on roof membranes and may cause enough billowing of certain membranes (e.g., mechanically attached single-ply membranes) to displace roof-mounted PV modules. Wind loads are higher at the corners and edges of the roof, so additional attachments or ballast may be required to increase the uplift resistance in these areas. The mounting materials should have good wind fatigue resistance. They should also have a low thermal expansion coefficient to minimize contraction and expansion that could damage the PV system or the roof.

Other Considerations. In general, the life expectancy of a PV system is about 25 years. The age and condition of a roof should be considered before installing such a system. It makes better economic sense to install this type of system on a new roof or on a roof that is ready for re-roofing. Make sure when installing PV modules around roof penetrations and rooftop equipment to allow sufficient space for future access. It is also important to ensure that the PV installation will not adversely affect the drainage pattern on the roof.

3. Concluding Remarks

The roofing industry has been active in working towards sustainability, and has a history of reusing materials and recycling roofing waste. As sustainable roofing has increasingly become a requirement of building owners and designers, the roofing industry has responded by improving components and systems to address these needs — preserving the environment, conserving and generating energy, and building roofs that last longer. This demand for sustainability on the part of governments and owners continues to grow. Thus the roofing community must accept the challenge, and embrace the concept of sustainability to achieve a better future.

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