Specifying SPF Roofing Systems

by Mason Knowles and Will Lorenz

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FOR That•SPRAYED POLYURETHANE FOAM (SPF) NG ASSEMBLIES HAVE BEEN PRIMARILY MARKETED ON THEIR ENERGY-SAVING CHARACTERISTICS. CONSEQUENTLY, MUCH OF THE SPF ROOFING MARKET HAS FOCUSED ON PROPERTY OWNERS OR INSTITUTIONS THAT PAY THEIR OWN ENERGY BILLS. HOWEVER, WHAT ABOUT LEASED OR RENTED PROPERTIES, WHERE ENERGY COSTS ARE TRANSFERRED TO THE RENTER? EVEN WITHOUT CONSIDERING ENERGY COSTS, COULD SPF BE A COST-EFFECTIVE ALTERNATIVE TO MEMBRANE ROOFING?

Before delving into SPF economies and lifecycles, one must fully understand the nature of the material. Sprayed polyurethane systems consist of an application of specifically designed, closed-cell, water-resistant foam covered with an elastomeric coating (typically acrylic, silicone, or polyurethane) or aggregate covering to protect against ultraviolet (UV) rays. Such coverings can also be used for other purposes, including inhibiting vapor transmission, enhancing aesthetics, increasing impact/abrasion-resistance, and achieving flammability and code requirements.

Specialized equipment mixes two liquid components at the spray gun, which then applies the SPF to a prepared substrate. The mixed result expands many times its original volume in seconds, forming a rigid foam plastic that chemically bonds to the surface. Spraying the foam in 12 to 38-mm (0.5 to 1.5-in.) lifts allows the applicator to reach the desired thickness to fill in low areas, build up slope, and provide insulation.

SPF has good adhesion to a variety of substrates, including metal, wood, concrete, and built-up roofing (BUR). Since SPF adds little weight to existing roof coverings and can build slope to fill in low areas, it is frequently employed as a re-cover roofing system.'

While hail and wind-driven missiles (e.g. tree limbs, broken roof tile, and metal flashing) can damage SPF, this type of damage typically does not cause leaks and can be repaired later without compromising long-term performance. SPF roofing systems also excel when the following conditions exist:

- additional insulation is required;
- severe temperatures;
- substrate has numerous penetrations;
- deck is an unusual configuration;
- roof is in an area where high winds are likely to occur;
- lightweight materials are needed; and
- slope must be added to provide positive drainage.

Benefits with sprayed polyurethane foam

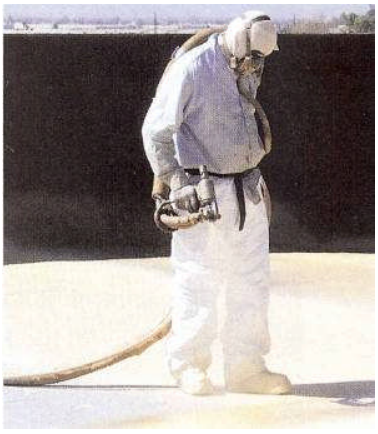
As stated earlier, the energy-saving characteristics and low maintenance costs of SPF systems have made these roofs well-suited to companies or organizations that own their own buildings and must pay their own energy and/or upkeep costs. However, the material also affords other advantages.

Leak resistance and wind-uplift resistance

According to Oak Ridge National Laboratory (ORNL), the principal causes of premature roof failure are moisture intrusion and lack of wind resistance. The former leads to dripping, accelerated failure of insulation and membrane, roof structure deterioration, depreciation of assets, and poor thermal performance. Similarly, the loss of a roof during a major windstorm not only causes structural damage, but also exposes the building contents to the elements.' Membrane roofing systems leak if the membrane is punctured or if it separates at the seams, flashing, or penetrations.

SPF roofing limits moisture intrusion because of the material's 90 percent closed cell properties. Damage to the system typically does not cause leaks into the building, and moisture intrusion is isolated to the areas of damaged foam cells. As reported by Rene M. Dupuis, PhD, PE, in his research for the National Roofing Foundation, "one unique aspect of SPF roof... is they are not in immediate danger of leaking, providing the penetration does not extend all the way through the foam."'

SPF roofing systems also have excellent wind uplift resistance. Field observations during Hurricanes Allen, Hugo, and Andrew led the industry to conduct laboratory testing of SPF systems at Underwriters Laboratories (UL) and Factory Mutual.[4] SPF's wind uplift resistance exceeded the capacity of UL's equipment. UL also observed SPF roofs applied over BUR and metal increased the wind uplift. Factory Mutual has given SPF roofing installed over concrete decks an 1-990 wind uplift resistance rating—the highest possible.



Sprayed polyurethane foam (SPF) is being applied to a prepared gypsum based underlayment board surface. Aside from the energy efficiency advantages, sprayfoam use can yield economic benefits over the long term.

Sustainable characteristics

At the 1996 Sustainable Low-Slope Roofing Seminar, ORNL described sustainable or green roofing systems as those that have "long life, [are] low [in] maintenance, save energy, add durability to buildings, control moisture in buildings, and contribute very little to the waste stream."[5]

Noting the renewability of the systems, low maintenance, resistance to roof leaks and reduction in construction debris, Dupuis has called SPF "one of the most sustainable roofing systems to date.'" Another researcher, Dean Kashiwagi (a teaching professor at the Del Webb School of Construction at Arizona State University), has been conducting surveys of thousands of SPF roofing systems since the 1980s. His work continues to reinforce the sustainable characteristics of SPF roofing systems.

For example, Kashiwagi's 1996 survey reported:

[T]he oldest performing SPF roofs are more than 26 years old, 97.6 percent did not leak, 93 percent had less than one percent deterioration, and 55 percent were never maintained.'

He continues to find similar results on SPF roofing systems today.

Many large companies and institutions have documented energy savings from SPF roofing systems. After studying more than 740,000 m^2 (8 million sf) of roofing, Texas A&M concluded the energy savings paid for the cost of SPF retrofits within three to four years. These dramatic results are achieved because sprayed polyurethane is applied as a seamless layer above the roof deck, covering fasteners, gaps, cracks, and other thermal bridges that rob membrane roofs of their insulation efficiency with a highly effective, high R-value. The insulation is applied above the roof deck, making it more effective; it is typically coated with a light-colored reflective coating that reduces the overall surface temperature.

SPF and membrane comparison

SPF roofing systems vary widely in cost depending on numerous factors, including:

- foam thickness;
- coating/covering type and thickness;
- degree of substrate preparation;
- labor;
- regional pricing structures;
- design complexity; and
- contractor availability in a specific region.

As with any type of roofing, there are high-end and low-end SPF options. On the high end are silicone and polyurethane-coated assemblies, while the low end is represented by acrylic-coated systems. The climate and environmental aspects of most regions in California and Arizona favor using acrylic coatings. These products are not only less expensive than the silicone or polyurethane coatings but they are also water-based (rather than solvent-based), thereby complying with California's strict volatile organic compound (VOC) requirements.

To determine how SPF stacks up against membrane roofing, the Spray Polyurethane Foam Alliance (SPFA) hired Michelson Technology LLC to conduct lifecycle assessments (LCAs); the 2003 research, published as "Lifecycle Cost Study of SPF Roofing Systems vs. Membrane Roofing Systems," was conducted by Theodore Michelsen, PhD, PE, former executive director of the Roofing Industry Educational Institute (RIEI).

Conducted in accordance with ASTM E 917-02, *Standard Practice for Measuring Life-cycle Costs of Buildings and Building Systems;* the study compared SPF roofing systems to membrane roofing systems in six different climate areas, including upstate New York, Central Florida, Southern California, and three cities—Fort Worth, Texas, Phoenix, Arizona, and Louisville, Kentucky.

The results show spray polyurethane foam has a 30-year lifecycle cost advantage over membrane roofs from a low of 12 percent (using a six-year re-coat schedule) to more than 56 percent (for an SPF system re-coated every 15 years).

For the study, Michelsen assumed a membrane roofing system would require tear-off and replacement in 10 to 15 years and the SPF roof would be re-coated to extend its service to at least 30 years. He added close to $1/sf for tear-off of the membrane roof and $0.25/sf for insulation. Michelsen also chose a seven percent discount rate and three percent inflation for the duration. He assumed the existing roof system would remain in place and that the new roofing systems would include installing R-5 insulation.

An energy-cost-saving benefit for reflective coatings was included in the conclusions. For the purpose of this article, the cost-saving benefit has been deducted (calculated at 12 to 15 percent over the 30-year lifecycle) to more accurately reflect the comparisons between membrane and SPF roofing. The information, provided in Figure 1 (page 66), has been modified to reflect only installation, maintenance, re-coats, tear-off and replacement costs.

As can be observed from the chart, even with the energy benefit deducted, the SPF roofing system re-coated every 15 years is still less to install and maintain than a very low-cost membrane roofing system. However, are the costs determined by Michelsen valid almost a decade later?

Figure 1 SPF Roofing Compared to Membrane Over 30 Years

1860-m² (20,000-sf) roof in Southern California	Cost of roof system over 30 years	Full cost after inflation	Initial cost per sf	Coating cost per sf	Tear-off and replacement cost per sf
25-mm (1-in.) SPF w/15-year re-coat	$89,124	$150,158	$3.15	$1.52	N/A
Three-ply built-up roof (BUR), 10-year system (R-10 fiberglass)	$89,681	$150,664	$1.25	N/A	$2.25

Figure ", SPF Roofing Compared to Membrane Over 30 Years Adjusted to 2009 Costs

1860-m² (20,000-sf) roof in Southern California	Cost of roof system over 30 years	Initial cost per sf	Coating cost per sf	Tear-off cost per sf
50-mm (2-in.) SPF w/10-year re-coat R 12-14	$138,000	$3.85	$1.52 (x2)	N/A
50-mm (2-in.) SPF w/15-year re-coat (R-12 to 14)	$107,400	**$3.85**	$1.52	N/A
Three-ply BUR, 10-year system (R-12 to 14 polyiso)	$246,600	$3.23 (x3)	N/A	$1.32 (x2)
Four-ply BUR, 15-year system (R-12 to 14 polyiso	$180,800	**$3.86** (x2)	N/A	$1.32

Figur' Roofing System Cost per *National Construction Estimator*

Item	Material cost (sf)	Labor cost (sf)	Total (sf)	With R-12 to 14 insulation
BUR three-ply smooth	$0.79	**$0.68**	$1.47	$3.23
BUR four-ply smooth	$1.31	$0.79	$2.10	$3.86
BUR three-ply w/light aggregate	$0.79	**$0.68**	$1.97	$3.73
BUR four-ply w/light aggregate	$1.31	$0.79	$2.60	$4.36
BUR three-ply w/heavy aggregate	$0.79	$0.68	$2.27	$4.03
BUR four-ply w/heavy aggregate	$1.31	$0.79	$2.90	**$4.46**
Modified bitumen	$2.25	**$0.84**	$3.09	**$4.85**
Roll roofing (double coverage)	$1.42	$0.30	$1.72	$3.48
Polyiso board insulation R-13	$1.36	$0.40	$1.76	N/A
SPF w/acrylic coatings R-15	$3.08	$79	$3.87	N/A

Bringing the data to the present

Michelson's lifecycle assessment was conducted more than seven years ago. Building material costs have increased significantly in the interim due to raw material shortages and increased international demand from Asia and Europe. How have expenses changed in the interim?

To determine whether Michelson's conclusions can be supported in today's market, this author compared prices reported in the 2009 edition of the *National Construction Estimator* by Dave Ogershok & Richard Pray (Craftsman Book Co.) of insulated membrane roof systems to equal R-value SPF roof systems.[8] The author validated the prices reported in the *Estimator* by a survey of California roofing contractors.'

As Figure 2 indicates, it is assumed the SPF roof would require one re-coat at the 15-year mark. The three-ply BUR would need a tear and replacement at the 10- and 20-year marks; the four-ply BUR would require tear-off and replacement at the 15-year mark.

Figure 3 contains estimates of membrane systems most commonly used in the western states. (Readers can extrapolate the data to calculate lifecycle costs for systems not provided in the article.)

According to contractors surveyed in California and Arizona, the most common insulation used in roofing applications is polyisocyanurate (polyiso) board. The *Estimator* installed cost of 51 mm (2 in.) is reported at approximately $1.76/sf.

Depending on the membrane roofing system used, the combined price of a membrane roofing system plus R-12 to 14 of insulation would range from $3.23 on the low end (e.g. three-ply smooth-surfaced BUR) to $4.85 on the high end (e.g. modified bitumen). An SPF roofing system rated at R-12 to 14 would have an installed cost of $3.87/sf. (Additional insulation would be required to provide slope as required to enhance system performance or to comply with local building codes.)

Single-ply systems would be included in the estimates. For example, a thermoplastic olefin (TPO) membrane would have similar costs to a four-ply insulated BUR system with aggregate or insulated atactic polypropylene (APP) modified bitumen. An insulated ethylene propylene diene monomer (EPDM) 1.14-mm (45-mil) unballasted roof would cost around 50 cents a foot higher than the insulated three-ply BUR with no aggregate.

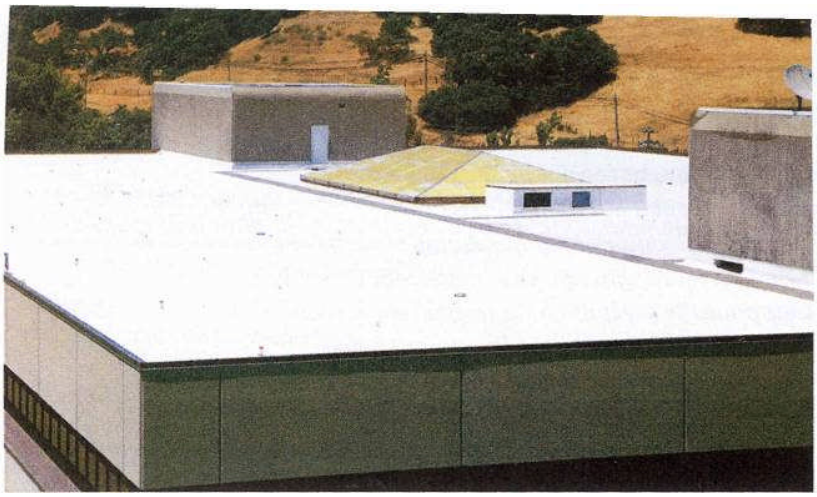
Data indicates SPF roofing systems have become more affordable compared to insulated membrane roofing systems between 2003 and 2009. Therefore, its lifecycle cost would provide even greater benefit to the building owner.

Further research on SPF lifecycles

As can be observed from Figure 2, even with the energy benefit deducted, an SPF roofing system re-coated every 15 years is still less costly to install and maintain than a very low-cost membrane roofing system. However, is this a fair comparison? How often do SPF roofing systems require a re-coating and how long do they really last?

In 1997 and 2003, Dupuis had been commissioned by the National Roofing Foundation (NRF) to conduct research on SPF roofing systems in six different climate zones in the United States.[m] Based on inspections and sampling of more than 300 sprayed polyurethane foam roofing systems, he concluded SPF roofs have an effective service life of more than 30 years.

The research also showed the physical properties of the foam change very little with age. This indicates SPF roof life expectancy primarily depends on the original application and long-term maintenance. In the first study, Dupuis reported the average service life of the SPF roofing systems before re-coat was 11 years. In the subsequent survey in 2003, the average re-coat cycle had increased to 15 years.



The skill of the applicator determines the relative smoothness of an SPF ro:

CONSIDERATIONS AND LIMITATIONS OF SPF ROOFING

When it comes to installing sprayed polyurethane foam (SPF) roofing systems, knowledge and experience are necessities. A relatively small crew can assemble large SPF roofs, but it requires a high degree of technical knowledge and experience. Years ago, there were fewer suitable contractors and less training available. Today, many courses are available from suppliers and from the Spray Polyurethane Foam Alliance (SPFA) to shorten the learning curve.

Blisters

When incorrectly installed, SPF layers can exhibit inter-laminar blistering. These most often occur by trying to stretch the application window, improper substrate preparation, or equipment problems. (Most foam blisters are considered an aesthetic issue and do not typically cause roof leaks. They are often repaired during re-coat applications or inspections.)

Environmental conditions

Like most roofing systems, SPF must be installed under suitable environmental conditions. The applicator should not proceed with a substrate temperature below the manufacturer's recommendations or humidity within 3 C (5 F) of dewpoint. Additionally, SPF and the protective coating should not be applied when there is ice, frost, surface moisture, or visible dampness present on the surface to be covered. Barriers may be necessary when wind conditions can affect foam quality or create overspray problems.

Contractor selection

Since applicator knowledge and experience is important to the successful installation of an SPF roof, the contractor should thoroughly investigate past performance when selecting the installer. Fortunately, the United States has high-quality foam contractors in every geographic region.

Overspray potential

SPF is spray-applied and is very lightweight. While the overspray outside of the application zone typically does not pose a health hazard, it can stick to many surfaces from great distances away. Building owners and contractors should have an overspray protection plan in place before starting a project.

Fumes

Some coatings can emit strong odors while curing, which may occur very quickly or over many hours. When installing an SPF roof, air-handling units (AHUs) should be turned off and covered if occupants are in the building. They should remain covered until the SPF is sprayed and the coating is cured.

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Depreciation versus maintenance

A common owner question concerns whether an SPF roofing system installed over an existing membrane roof is considered a new roof system (i.e. subject to long-term depreciation as a capital improvement) or as a repair to the existing roof (i.e. deductible as a maintenance/repair item).

Installing an SPF roofing system over an existing membrane is considered a new roof by the roofing industry and building codes. As such, it is depreciated as any other new roofing system as a capital improvement. Looking down the road 10 to 15 years, an SPF roof can offer significant tax benefits over a membrane roofing system. As previously discussed, sprayed polyurethane foam roofing systems are re-coated on a 15-year cycle. Most membrane roofing systems last 10 to 15 years before a replacement is required. Each time a membrane is replaced, the new roof is depreciated as a long-term capital improvement.

However, a re-coat on an SPF system is considered a maintenance item to the existing roof. Therefore, re-coats on an existing SPF roof system can be deducted as an expense rather than long-term depreciation. Over a 30-year lifecycle, this difference can add up to thousands of dollars saved by the building owner.

Other factors affecting lifecycle costs

There are myriad other factors that have an impact on the costs of a 30-year lifecycle.

Providing slope for building code approval

The 2009 *International Building Code (IBC)* and the State of California require new roofing systems to have a slope of $^{1}/4$ in. per foot. On a flat roof deck assembly, this may take as much as 254 mm (10 in.) of tapered insulation to achieve code-approved drainage. Tapered insulation can raise the cost of a new roof an additional $3 to $5/sf. Every time a roofing system is removed and replaced, this added cost would be part of the 30-year lifecycle.

However, when a new roof covering is installed over an existing roof membrane, building codes refer to this as a 'retrofit.' The slope of the new

membrane does not require the 1/4 in. per foot slope, but rather provide positive drainage to eliminate ponding (i.e. no consequential water standing 48 hours after rain).

Contrary to membrane roofing systems, an SPF assembly does not require additional tear-off over its 30-year life, and therefore would not need a 1/4-in. slope. An SPF applicator can build crickets, dams, and custom slope to existing roof decks so positive drainage can be achieved with significantly less slope. (SPF roofing systems frequently exhibit small 'bird baths' of water after rainfall, but these are not considered ponds and are acceptable.)

Damage caused by roof leaks

As reported by ORNL in multiple workshops on low-slope roofing, most deterioration in buildings comes from water or moisture issues." The majority of water damage comes from roof leaks. When membrane roofing systems wear out, the membrane tends to lose adhesion at the seams, flashing, and around parapets walls and penetrations. Consequently, most membrane roofing systems will experience roof leaks in their lifecycle before replacement.

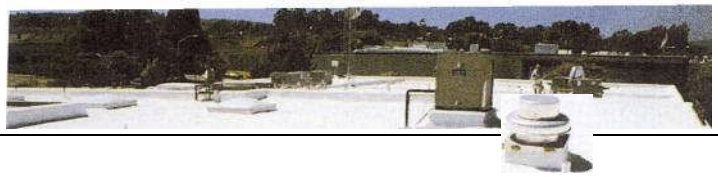
Maintenance agreements for membrane roofing systems frequently include leak repair costs not covered by warranties. Repairing roof leaks (i.e. including mold remediation and/or replacing ceiling tiles, drywall, and carpeting) should be considered in the 30-year lifecycle of the membrane systems.

Cost of maintenance

The studies conducted by Michelsen, Dupuis, and Kashiwagi indicate SPF requires significantly less time-consuming and costly maintenance than membrane systems. Michelsen estimated a moderate inspection and maintenance program in his study for membrane roofing systems. It consisted of a visual inspection every year (initially $1500, subsequently $350), with each resulting in $500 worth of repair work. Leaks were assumed to occur once annually for years five through 10, and then twice a year for the remaining five years. The total leak repair cost was $250 per occurrence. It averages out to $975 per year over 30 years.

Premium costs of landfill debris

According to the National Roofing Contractors Association (NRCA) 1999 annual survey, more than 68.5 percent of the $11.3 billion low-slope re-roofing market included tear-off and replacement of the existing roof membrane.`'- (While this has varied slightly over the years, the numbers are generally constant.) The State of California extracts a premium for disposing asphaltic-based materials in landfills. These costs are only going to get higher. Some membrane systems may require two tear-offs and replacement during the course of their 30-year lifecycles.



SPF roofing systems are self-flashing around protrusions, penetrations, and parapets. This eliminates the need for metal flashing in those areas.

The amount of debris from a 1858-m² (20,000-4) roof tear-off ranges between 7.6 and 15.3 m' (10 and 20 cy) of material, whereas a typical SPF roof application of the same size would yield less than 0.8 m³ (1 cy) of debris—mostly masking tape and plastic, HVAC equipment, windows, parapet walls, drains, and edges. This extra expense of debris removal must be considered when determining long-term costs of a roofing system.

Using the same inspection schedule, SPF roofing systems would average $350 annually. SPF has a very high impact-absorbing quality. This means while the foam surface can be damaged by impact from hail, wind-driven debris, or dropped tools, this typically does not cause leaks. Further, most ill effects can be repaired months later without compromising the roof's long-term performance. The majority of damage to the foam surface can be repaired with sealant at the time of inspection at no added cost to the owner. Figure 4 takes a few of these factors into consideration.

Conclusion

Based on Michelson's study, and updated material and labor expenses, SPF roofing systems demonstrate a cost savings over 30 years in comparison to membrane roofing systems—even without considering the energy-saving benefits. **CS**

Notes

[1] Caution should be used when specifying any re-cover roofing system. The existing roof covering and roof deck assembly should be thoroughly evaluated to verify it can be a good substrate for SPF. For more information, see the 1996 Factory Mutual 4470 test, *Spray Polyurethane Foam Roof Insulation with Protective Coatings for Use in Recover Roof Construction and New Construction over Structural Concrete Roof Decks.*

[2] See the ORNL Envelope Research Center's 1996 *Building Thermal Envelope Systems and Materials—Update.*

[3] Additional information can be found in Dupuis' "A Field and Laboratory Assessment of Sprayed Polyurethane Foam-based Roof Systems," report.

[4] For more on the results, see the 2005 Factory Mutual research report, "Spray Polyurethane Foam Roofing with Protective Coating Systems in Class I Roof Deck Assemblies."

[5] See the *Proceeds of the Low-slope Workshop Oak Ridge National Laboratories, 1996-2000.*

[6] See note 3.

[7] See Kashiwagi's 1996 report, "Roofing Contractors/ Systems Performance Information."

ADDITIONAL **INFORMATION**

Authors

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Abstract

Much of the sprayed polyurethane foam (SPF) roofing market has focused on property owners or institutions that pay their own energy bills. However, what about a leased or rented property, where these costs are transferred to the renter? Can SPF roofing systems be a cost effective alternative to membrane roofing systems over time without taking energy costs into consideration?

MasterFormat No.
07 57 13-Sprayed Polyurethane Foam Roofing

UniFormat No.
B1020-Roof Construction Vapor Retarders, Air Barriers, and Insulation

Key Words

Division 07	Roofing
Lifecycle costs	Sprayed polyurethane foam

Figure 4 SPF Roofing Compared to Membrane Over 30 Years Adjusted to 2009 Costs (Other Factors Added)

1860-m (20,000-sf) roof in Southern	Cost of roof system over 30 years	Initial cost per sf	Coating cost per sf	Tear-off cost per sf	Maintenance per year	Tapered insulation to provide slope
50-mm (2-in.) SPF w/10-year re-coat	$148,500	$3.85	$1.52 (x2)	N/A	$350/yr	
50-mm (2-in.) SPF w/15-year re-coat (R-12 to 14)	$117,900	$3.85	$1.52	N/A	$350/yr	
Three-ply BUR, 10-year system (R-12 to 14 polyiso)	$335,250	$3.23 (x3)	N/A	$1.32 (x2)	$975/yr	$3.00/ft (x2)
Four-ply BUR, 15-year system (R-12 to 14 polyiso)	$269,250	$3.86 (x2)	N/A	$1.32	$975/yr	$3.00/ft

[8] The costs listed in the *Estimator* do not include profit, overhead, local permits, bid bonds, flashing costs, etc. Therefore, the actual installed price would typically be higher. Depending on the building, other factors—such as size, project complexity, number and type of penetrations, and debris removal—can add to the roof's cost. Installers' prices can vary substantially depending on overhead, travel expenses, productivity, compliance with safety and health regulations, and various warranties fees.

'The *Estimator* contains modifiers for different cities to reflect differences in material and labor costs. For example, within California, San Diego pays on average 18 percent more for labor than the Bakersfield, which is right at the national average. San Francisco pays a premium of over 60 percent more for labor than the national average. It should also be noted projects that require union labor or wages typically are higher than non-union jobs. Labor rate differences become more important when using systems that require extensive number of persons for installation, such as BUR. For example, a typical 1900 m² (20,000-sf) BUR project would require a roof crew of 12 to 15, while an SPF installation of the same size normally needs three to five people.

[10] See note 3.

" See note 5.

'The survey was published in the March 2000 *Professional Roofing*.

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