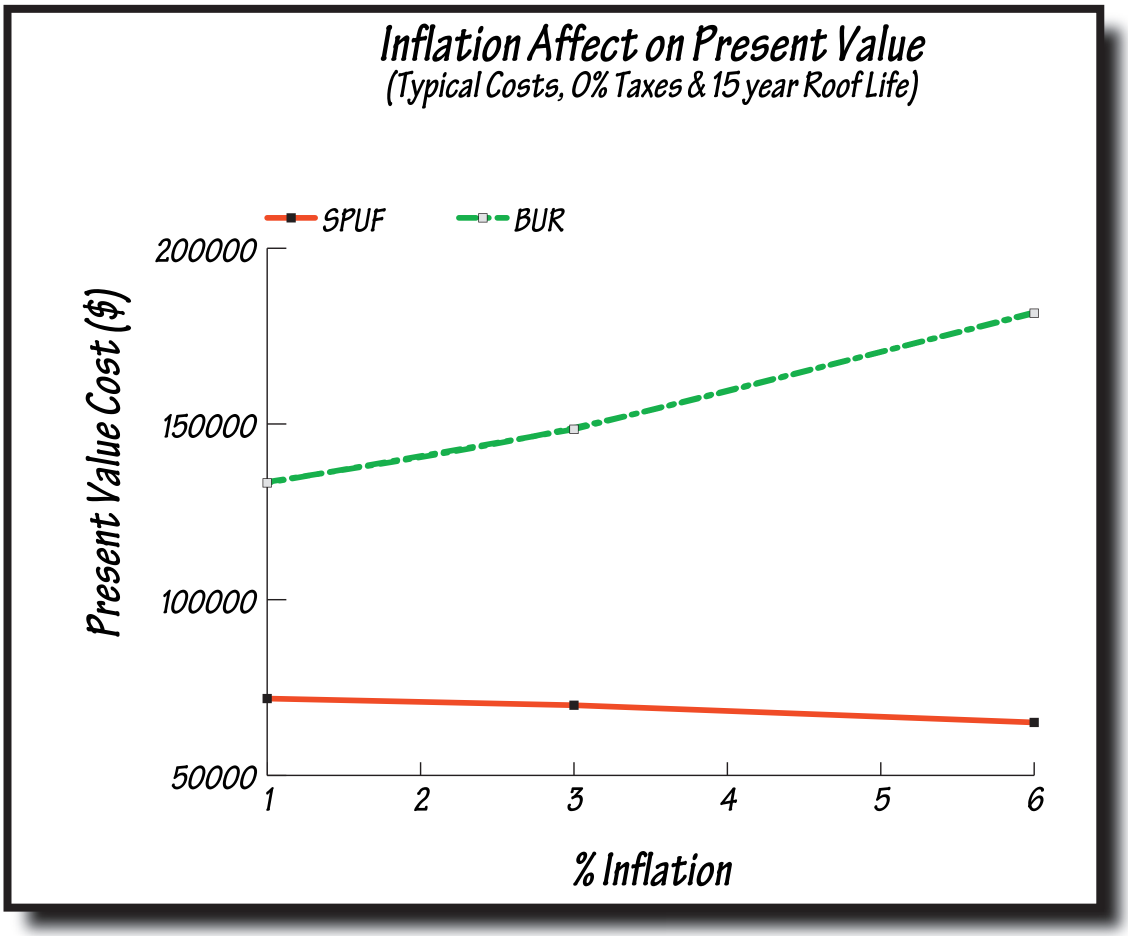
Spray Polyurethane Foam Alliance Life Cycle Cost Study



This report has been prepared for the exclusive use of the Spray Polyurethane Foam Alliance and their members or agents by Michelsen Technologies, LLC

Acknowledgement

I want to acknowledge the assistance from the members of the Spray Polyurethane Foam Alliance who graciously provided cost and performance data, without which this study could not be done. They shall remain nameless to protect the information they provided from their competitors.

Mason Knowles and Bob Elliott also need to be recognized for the time and efforts they extended to make this project possible.

T.W. Michelsen

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The Spray Polyurethane Foam Alliance (SPFA) was interested in developing a Life Cycle Cost (LCC) study over 30 years comparing spray polyurethane foam roofs against membrane roofs. This study was needed to answer questions from long-term building owners about the long-term Life Cycle Costs of Spray Polyurethane Foam (SPUF) verses other roofing options. SPFA hired Michelsen Technologies, LLC to do the study. The principle of Michelsen Technologies, LLC, Dr. Theodore Michelsen has been the Executive Director of the Roofing Industry Educational Institute (RIEI), in which capacity he taught classes on Roof Asset Management and Life Cycle Costs.

Michelsen Technologies, LLC conducted the study according to ASTM E 917 - 02 “Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems”. The steps in this standard are:

1. Identify the objectives, alternates and constraints (See page 5, Discussion: Model Assumptions)
2. Establish data assumptions for the analysis (See pages 5&6, Discussion: Model Assumptions)
3. Compile cost data (Members of SPFA supplied confidential data on the costs of Spray Polyurethane Foam from 6 regions of the United States, each with different climatic conditions. Michelsen Technologies, LLC supplied typical cost for membrane roofing.)
4. Compute the LCC for each alternative. (See Table 1, this section).
5. Compare LCC’s of each alternative to determine the one with the minimum LCC. (See pages 12 - 18 Discussion section).
6. Make final decision based on LCC. (This is left to the building owner.)

The 30 year study period, 7% discount rate and 3% inflation chosen for the study shows Spray Polyurethane Foam having a cost advantage over membrane roofs of a low of 13% up to 56% based on the national numbers (see Table XX). Within a region the best cost benefits comes from the 15 year re-coating and the lowest from the 6 year re-coating, as might be expected (see Table 1).

The reason for Spray Polyurethane Foam’s advantage is due to several factors:

1. No tear-off was needed during a re-coating, thus reducing costs for the tear-off it self and the need to add new insulation to the roof.
2. Re-coating costs are lower than membrane costs.
3. The reflectivity of the coatings reduced cooling energy costs and in all cases gave an annual net energy savings.
4. Consequential damages due to leaks were zero, since Spray Polyurethane Foam roofs generally do not leak.

Table 1. Summary of Life Cycle Cost Study

Location	Present Value	Full Cost After Inflation	Coating Cost /sq. ft.	Foaming Cost /sq. ft.	Mainten-ance	% of BUR Costs
Southern CA						
6 Yr. Recoat	$105,441	$206,108	$1.52	$1.63	$500	71%
10 Yr. Recoat	$77,756	$125,906				52%
15 Yr. Recoat	$75,640	$104,848				51%
Phoenix, AZ						
6 Yr. Recoat	$101,507	$207,977	$1.40	$1.77	$1,667	68%
10 Yr. Recoat	$76,122	$137,021				51%
15 Yr. Recoat	$69,966	$109,743				47%
Fort Worth, TX						
6 Yr. Recoat	$117,738	$227,061	$1.59	$1.62	Covered	79%
10 Yr. Recoat	$85,089	$132,461				57%
15 Yr. Recoat	$72,431	$90,602				49%
Florida						
6 Yr. Recoat	$125,102	$248,265	$1.51	$2.10	$1,067	84%
10 Yr. Recoat	$94,442	$159,149				64%
15 Yr. Recoat	$81,788	$118,249				55%
Louisville, KY						
6 Yr. Recoat	$105,167	$204,376	$1.40	$1.57	$275	71%
10 Yr. Recoat	$77,530	$124,301				52%
15 Yr. Recoat	$65,189	$86,010				44%
Upstate New York						
6 Yr. Recoat	$115,190	$229,995	$1.47	$1.48	$267	78%
10 Yr. Recoat	$83,181	$137,693				56%
15 Yr. Recoat	$64,624	$86,605				44%
BUR						
$1.00	$55,877	$146,476				
$2.50	$102,184	$224,617				
$4.00	$148,491	$302,759				
$6.00	$210,234	$406,947				

A. Study Details:

1. Life Cycle Cost Methodology:

Life Cycle Cost is a concept where one tries to estimate the full costs of an object or activity over the expected life of that object or activity. By comparing two or more Life Cycle Costs of competing objects or activities the lower cost option can be determined, even if it had a higher initial cost. To do so correctly, all the expected costs and influences on that objects or activities must be estimated and the study period or time frame for the Life Cycle Cost study must end on the end of the expected life (or multiple lives in needed) for each object or activity considered. In addition the same conditions must be applied to all objects or activities equally. For buildings, typical costs are:

- Initial cost
- Maintenance costs
- Inflation rate
- Tax affects, such as writing off of capital costs for tax paying entities.
- Energy costs
- Component replacements over the study period (i.e. a roof on building who's study period is longer than the expected life of the roof).

For this study we used the methodology in ASTM E 917 - 02 "Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems". It recommends the consideration of all the items listed above. Before discussing the methodology, we need to define a few terms. The definitions below are taken from ASTM E 833-02a "Standard Terminology of Building Economics" and the United States Internal Revenue Service documents.

a. Terms from ASTM E 833-02a "Standard Terminology of Building Economics"

Life-cycle Cost (LCC) Method, *n* - a technique of economic evaluation that sums over a given study period the costs of initial investment (less resale value), replacements, operations (including energy use), and maintenance and repair of an investment decision (expressed in present or annual value terms).

Study Period, n - the length of time over which an investment is analyzed (Synonym: life-cycle, time horizon).

Inflation, n- a rise in the general price level, usually expressed as a percentage.

Discount Rate, n - The rate of interest reflecting the investor's time value of money, used to determine discount factors for converting benefits and costs occurring at different time to a base time.

Discounting, n – a technique for converting cash flows that occur over time to equivalent amounts at a common time.

Present Value, n – the value of a benefit or cost found by discounting future cash flows to the basic time (Synonym: future worth).

Maintenance and Repair Costs, n – the total of labor, materials and other related costs incurred in conducting corrective and preventative maintenance and repair on a building, or on its systems and components or both (Synonym: expensed cost, current costs).

b. Terms from Internal Revenue Service (www.irs.gov)

Capital Asset, n – a piece of equipment or machinery, a building or portion thereof, a vehicle, etc. that must be *Depreciated* and meets all the following requirements:

- must be used in business or held to produce income
- most be expected to last more than one year
- must be something that wears out, decays, gets used up, becomes obsolete, or loses its value from natural causes.

Depreciation, n – a decrease in the value of a capital asset over the time that the asset is being used in a Class Life as determined by the IRS

- begins when a capital asset is placed in service for use in a business
- ends when the capital Class Life schedule OR
- when the capital asset is retired from service (which ever comes first).

Class Life of Nonresidential Real Property is 39 years.

Note: When taxes are considered in the Life Cycle Cost study, the remaining un-depreciated capital costs of the roof are captured (added to the depreciation) the year the roof is replaced.

2. The basic procedure for ASTM E917-02:

1. Identify the objectives, alternates and constraints (See page 5, Discussion: Model Assumptions)
2. Establish data assumptions for the analysis (See pages 5 & 6, Discussion: Model Assumptions)
3. Compile cost data (Members of SPFA supplied confidential data on the costs of Spray Polyurethane Foam from 6 regions of the United States, each with different climatic conditions. Michelsen Technologies, LLC supplied typical cost for membrane roofing.)
4. Compute the LCC for each alternative. (See Table 1, Introduction & Background section).
5. Compare LCC's of each alternative to determine the one with the minimum LCC. (See pages 12 - 18 Discussion section).
6. Make final decision based on LCC. (This is left to the building owner.)

The major step is the computing the LCC for each alternative. This step involves taking all the costs and bringing them back to today's (the base time used in this study) costs after adding corrections for inflation and then doing a present value calculation. The present value is the value of a benefit or cost found by discounting future cash flows to the current time. To do the present value calculation we "discount" the estimated full cost for each year by the discount rate. This basically makes the owner or investor neutral to making an investment today or some time in the future. A simple way to think about this calculation is if you planned to invest all the money needed over the study period at the discount rate, how much money would you need. You would need the full amount for expenses in the first year but future costs would be less due to the “interest” earned on the invested money. The longer out the expenses the less of today’s dollars you would need. More simply put, we use the concept of the time value of money in determining the full Life Cycle Cost of an option.

Using the formulas from ASTM E 917 and the model assumptions, a Microsoft Excel spreadsheet was developed. The spreadsheet was then populated with data for each of the cases. We looked at a range of membrane costs ($1 to $6 per square foot) and a range of costs of 50% to 200% of the average cost for Spray Polyurethane Foam Roofs as supplied by several SPFA members in each region studied. The resultant data is given below in graphical form. Table 1 (page 2) gives the data for the average Spray Polyurethane Foam costs and membrane cost range. The results are discussed in detail below, in the section on each region.

B. Model Assumptions:

In this Life Cycle Cost Study (LCC) we looked at six (6) regions of the United States; Upstate New York State (a cold climate), Louisville, KY (a moderate humid climate), South Central Florida (a hot humid climate), Dallas-Fort Worth Texas (a hot moderately humid climate), Phoenix, AZ (a hot dry climate) and Southern California (a moderate climate). For each of these climates we modeled the Life Cycle Costs over a 30 year study period for both a membrane roof system and a Spray Polyurethane Foam Roof System installed over a 15 year old gravel surfaced Built-up Roof (BUR) or other membrane roof system. The existing membrane roof system contained R-10 polyisocyanurate roof insulation. This would have been a typical roof construction during the late 80’s and 90’s until the advent of energy codes. The existing membrane roof system was de-graveled or otherwise prepared for the new roof system and then covered with either a layer of one (1) inch Spray Polyurethane Foam and a coating or a R-5 divorcing layer of roof insulation and a membrane roof with a reflectivity of 20%. The 20% reflectivity would represent typical values for aggregate surfaced (BUR or ballasted single plies) or granule surfaced (BUR or modified bitumen capsheet) membrane roofs.

The use of one (1) inch of Spray Polyurethane Foam or R-5 divorcing insulation under the membrane roof is based on the ASHRAE 90.1-2002 version that suggests an R-15 for most of the United States. These constructions would meet most building codes requirements that the roof be brought up to current energy code requirements during reroofing. Local energy codes are generally based on ASHRAE 90.1. One model region, southern California is an exception to the R-15, requiring just R-10. However, many existing roofs in this area have little or no roof insulation, so if here we assumed that the existing roof had only R-5, then the model would continue to be reasonable.

Acrylic, silicone and urethane coating costs were used for each Spray Polyurethane Foam roofs. Re-coating times of 6, 10 and 15 years were used, as these reflect potential coating lives and are evenly divisible into the 30-year study period, as required for a meaningful LCC study. The lowest cost coating was used for the 6 and 10 year re-coating costs, while the more expensive coating costs were used for the 15 year re-coating cycle. We recognize that all three coating types are claimed to be 15 year coating, but it makes more intuitive sense to do the study this way. We obtained new and 3 year exposure coating reflectivity data from several coating manufacturers and averaged the results for each type of coating. Our aging assumptions on the reflectivity was that two thirds (⅔) of the reflectivity change between the new and 3 year exposure data took place between the first and second year with the remaining one third (⅓) taking place between the second and third year. Additionally, we assumed no change took place after the third year. These assumptions generally fit the reported experience of Lawrence Berkeley National Laboratory and Oak Ridge National Laboratory reflective roofs studies. The major cause of reflectivity loss is dirt buildup on the roof surface, which comes to an equilibrium level in about 3 years. The reflectivity data was then entered into the OAK RIDGE NATIONAL LABORATORY'S ROOF CALCULATOR, available at http://www.ornl.gov/roofs+walls/facts/ CoolCalcEnergy.htm. The energy savings data from this website was then placed into the LCC model to calculate the energy saving for the coated Spray Polyurethane Foam Roof Systems after subtracting the membrane roof system energy saving. For Southern California, we assumed only an R-10 for the model. The energy costs were inflated at the rate of 4% per year (1% higher than the base inflation rate), to reflect the expected continual increase in energy costs.

While the Spray Polyurethane Foam roof system was considered to be sustainable, the membrane roof system was not. We assumed the life to be 15 years, after which, the roof was replaced. Unlike the Spray Polyurethane Foam roof, where the worn roof was "rejuvenated" by re-coating, the membrane roof needed to be torn off and replace, as it was the second roof on the building. To the square foot cost used for the initial recover, we added $0.97 for tear off and disposal costs and $0.25 for the new insulation as the per square foot cost already includes R-5 and installation costs.

Repair and maintenance costs estimated were also included in the model as those customers that would be interested in Life Cycle Costs would already have a roof maintenance program. For the Spray Polyurethane Foam roof, annual inspection and repair costs as supplied by the contractors were used. Polyurethane foam is watertight in and of it self, so we did not include any consequential damage repairs. For the membrane roof system a moderate inspection and maintenance program was used. It consisted of a visual inspection every other year (initial inspection $1,500, subsequent inspections $350). We assumed that each inspection created $500 worth of repair work. Leaks were assumed to occur at the rate of one (1) per year for years five (5) through 10 (10) and twice a year for the remaining five (5) years. The total leak repair cost was $250 per occurrence.

The LCC model is capable of including tax saving due to amortizing the roof capital expenses as well as the inflation rate and time value of money. For this study all the examples were conducted with the federal and state tax rates at 0. This was done for several reasons. First, many potential roofing customers who would be interested in this study are schools and government agencies which do not pay taxes and therefore do not get to write off the cost of the capital expense against their taxes. Second, it would be impossible to know a private companies actual tax rates, which generally are lower than the published tax rates. To help those customers in the private sector understand the benefits of being able to write off the roof costs against their taxes, we have included a graph for Phoenix, AZ giving the LCC for different tax rates and directions on doing a calculation to estimate the Life Cycle Cost when taxes are considered (see page 7).

The LCC model used in this study used an inflation factor of 3%, which is a historical rate. The discount rate (the return that makes an owner not care about dollars spent to day or in the future) was set at 7%, a low historical value. Both the inflation rate and discount rate have graphs showing the effects of varying rates on the study for Phoenix, AZ and directions on doing calculations to estimate the affects of other inflation and / or discount rates on the Life Cycle Costs (see pages 7&8).

C. Using the Information:

Our goal in putting this study together was to provide SPFA members a tool with which to sell the long term benefits of their roof systems. This is the reason that we offer a range of costs, as this allows a SPFA member to develop a semi-customized example to meet their customer's needs. This section will explain how to develop a semi-customized study.

1. Adjusting Spray Polyurethane Foam Costs:

a. Other Areas of the Country:

For areas of the country other than modeled, the SPFA member should choose the area modeled that closest resembles the climate in their area. If the costs are different, they can adjusted as described below.

b. Coating Costs:

The coating costs are the easiest to adjust, as one only has to take the information off of the graph of the "Spray Foam Present Value Costs" for the selected region.

c. Foaming Costs:

Adjusting the foaming cost (which include surface preparation) requires a little more work. From Table 1 (page 2) in the Introduction & Background section, look up the square foot "Foaming Costs" and subtract this value from your square foot foaming costs. Then multiply this value by 20,000 (the size of the model job). The resultant value should then be added to the "Present Value" found from the "Coating Cost" adjustment above. Preparation costs or other costs differences in the first year can be directly added to the present value costs, as there is no "discount" for first year costs.

d. Maintenance Cost Adjustment:

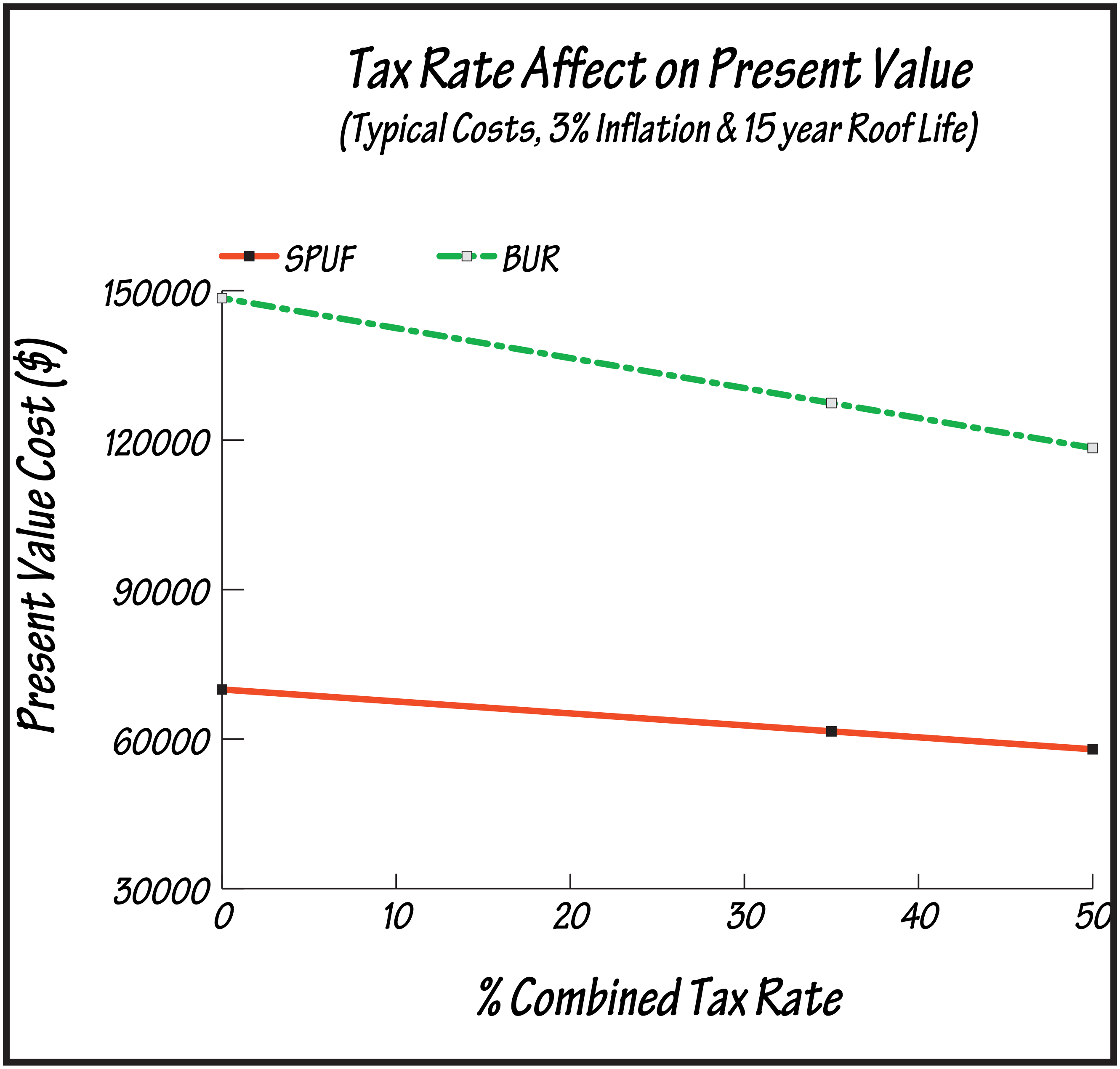
To adjust the maintenance cost factor, subtract your estimated annual maintenance cost from the value given in the "Data Summary" Table in the introduction section. Multiply this value by 30 then 0.4136. The resultant value is then added to the Present Value calculated above (if your maintenance cost is less, you will be adding a negative number, effectively reducing the Present value).

e. Job Size Adjustment:

To adjust the Present Value for different job square footage, just multiply the Present Value by the ratio of the actual job size to 20,000 square feet.

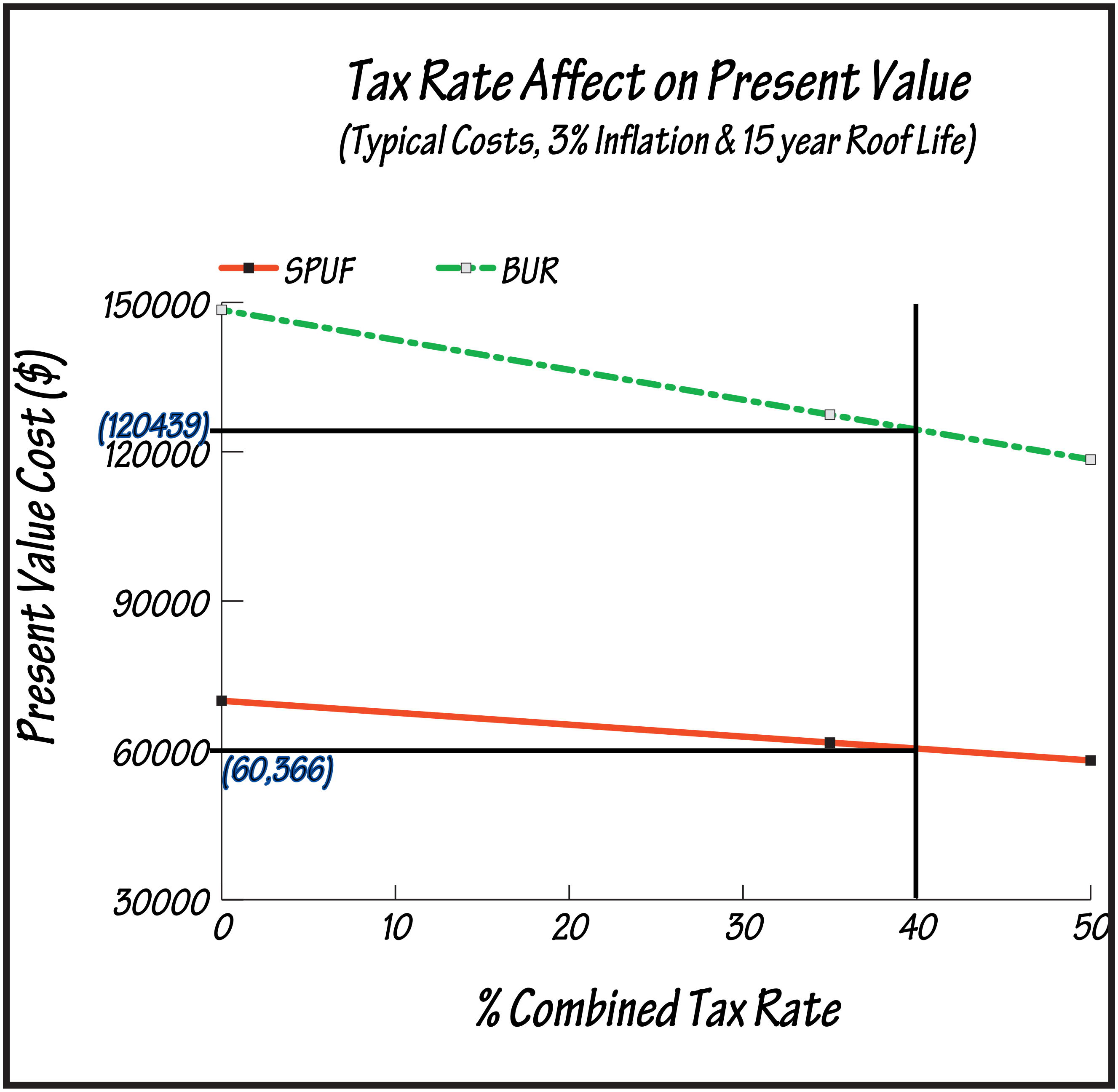
f. Tax Rate Adjustment:

While the basic study did not include the tax benefit for the reasons noted above, private owners who pay taxes would be interested in the affect taxes would have on the Life Cycle Cost, as in general the



Graph 1. Tax Rate Affect on Present Value

higher the tax rate the lower the present value. To assist in this we have provide a graph of tax rate vs. present value for both SPFA and membrane roofs (Graph 1, page 8). While limited to the 15 year re-coat for the Phoenix area, the trend could be applied to other areas by using simple ratios from this graph. For example a customer in Fort Worth, TX pays a combined tax rate (federal and state tax rates adjusted for deduction of state taxes on the federal rate, Federal Rate x (1-State Rate) +State Rate) of 40%. The zero tax present value for Spray Polyurethane Foam = $72,431 and membrane roofing = $148,491. From Graph 2 page 9, with the example demonstrated, at 40% combined tax rate = $60,366, vs. $69,966 at zero tax rate. The ratio is 60366 / 69966 = 0.863. Multiply the ratio by the area present value, or 0.863 times $72,431 or $62,493. Since the membrane rate was the same we can just read it off the graph, as $120,439. If a different membrane square foot cost was needed we would have to have done the ratio calculation as well. The tax rate will reduce the present value, but will not

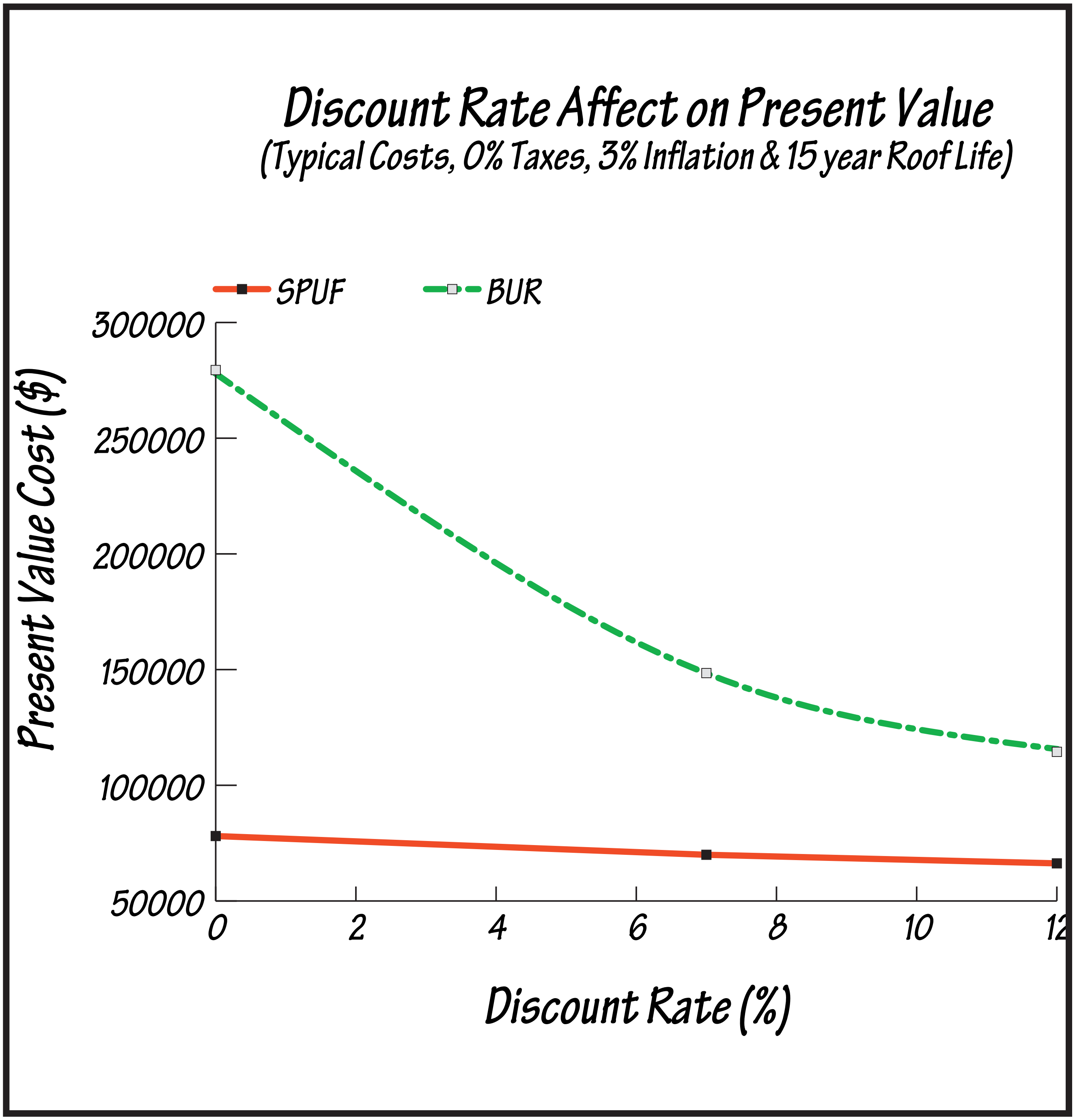


Graph 2: Tax Rate Affect on Present Value, Example

change the relationship between the lower cost and higher cost option, only change the magnitude of the difference.

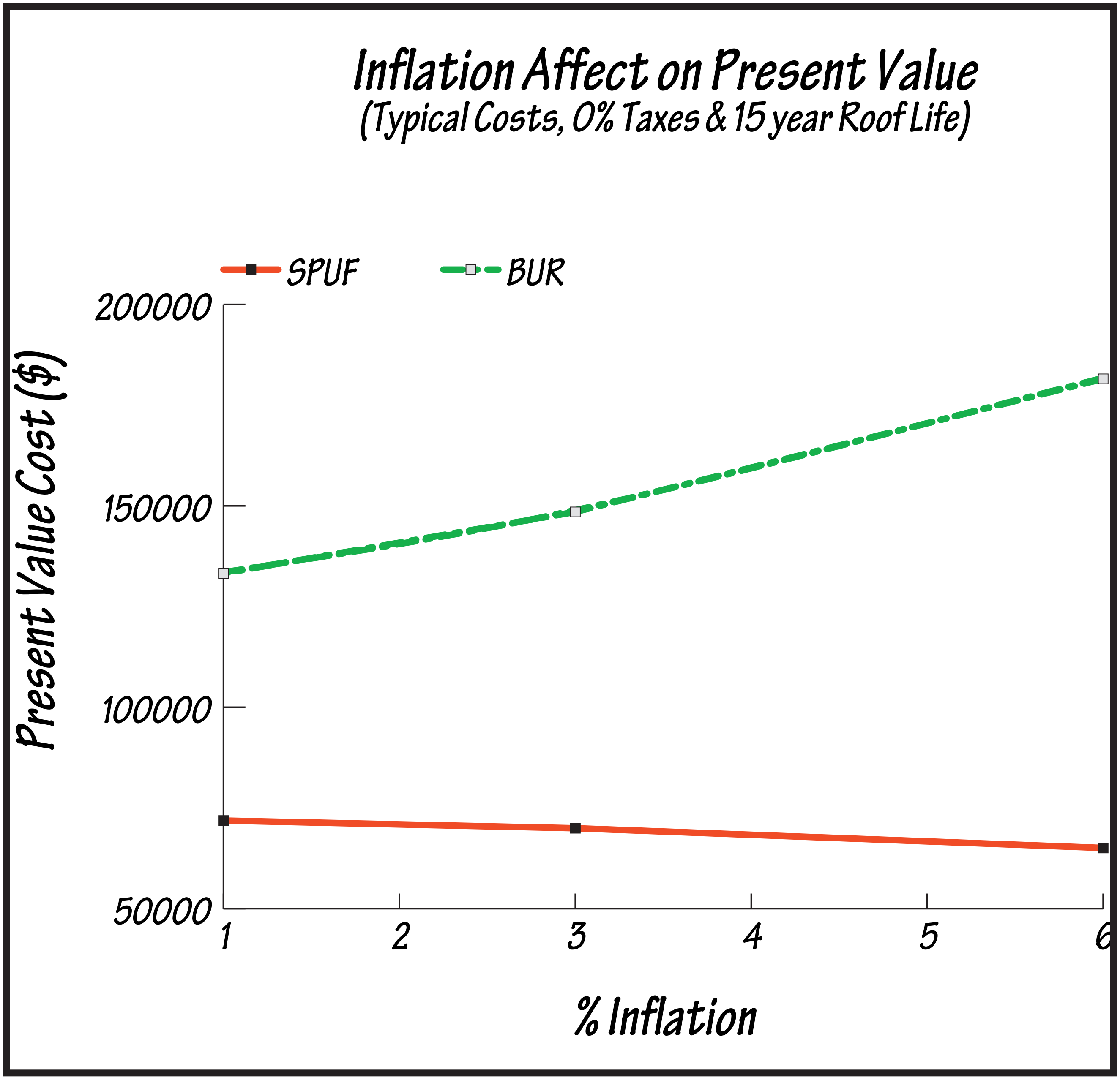
<u>g. Discount Rate or Inflation Rate Adjustment:</u>

Using the appropriate graph (Graph 3 {page 10} or 4 {page 11}), follow the procedure outlined above for the Tax Rate Adjustment. The higher the discount rate the lower the present value will be, you are getting a higher return on your money. In general the higher the inflation rate the higher the present value. However, if the energy savings are large, then it can over power the general inflation affect.



Graph 3: Discount Rate Affect on Present Value

As is the case for Phoenix, AZ. With the energy inflation rate being one (1) point higher than the general inflation rate, the energy saving, which is subtracted from the present value, grows faster than the other costs and causes a slight decrease in the present value. For example the percentage that energy saving represents on the present value before subtracting the energy saving is 24% for 1% inflation and 39% for 6% inflation.



Graph 4: Inflation Affect on Present Value

While we have provided the data needed for customizing the Life Cycle Costs, most customers will be happy with the models as they exist and just seeing how the variable will affect the final numbers. As none of the variable will switch the lower cost option with the higher cost option, just change the relative difference between them.

D. Upstate New York:

The Upstate New York area was chosen to represent a cold climate region. A summary of the data used for this region is shown below in Table 2.

Table 2: Upstate New York Data Summary

Upstate New York	Present Value	Full Cost After Inflation	Coating Cost/sq. ft.	Foaming Cost/sq. ft.	Mainten-ance	% of BUR Costs
6 Yr. Re-coat	$115,190	$229,995	$1.47	$1.48	$267	78%
10 Yr. Re-coat	$83,181	$137,693				56%
15 Yr. Re-coat	$64,624	$86,605				44%

Table 3 gives the square foot installed cost a membrane system would have to have to equal the Life Cycle Cost of the Spray Polyurethane Foam Roof System for each of the studied re-coating times. Stated another way, unless the membrane costs are less than the values given, the Spray Polyurethane Foam Roof will have the lowest Life Cycle Cost.

Table 3: Upstate New York Equal Membrane Cost per Square Foot

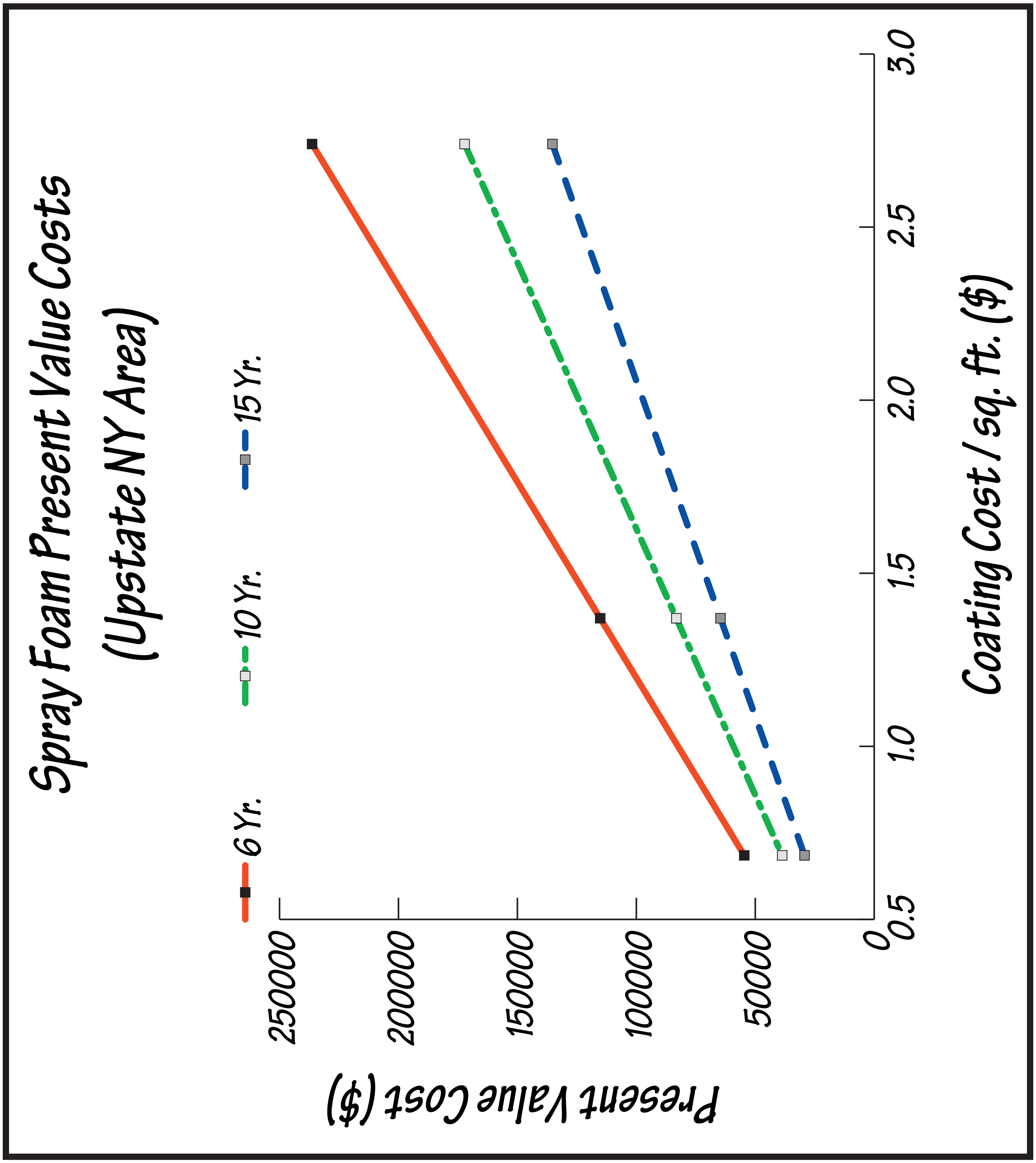
Upstate New York	Present Value	Membrane Cost / sq. ft. to Equal SPUF
6 Year Re-coat	$115,190	$2.92
10 Year Re-coat	$83,181	$1.88
15 Year Re-coat	$64,624	$1.28

Table 4 contains information on the size of the impact the energy savings from the reflectivity of the Spray Polyurethane Foam Roof has on the present value for this region. To prevent over stating the energy savings affect on the present value, we have added the energy saving present value back into the total present value before determining the percentage. Because the energy savings is subtracted from the other costs in the present value and can be a sizable percentage, adding it back in first prevents an over statement of relative size of the energy savings. If a reflective membrane system with a reflectivity of 90% is the competition, then adding in 110% of the energy saving present value to the listed Spray Polyurethane Foam Roof present value, will compensate for the slightly lower reflectivity of the Spray Polyurethane Foam Roof. Compare the Spray Polyurethane Foam Roof present value obtained per above to the value obtained from the Present Value vs. BUR Cost per Square Foot graph in the Appendix on page 26, for the cost per square foot of the reflective membrane system. The reason for the decrease in the energy saving present value is that as the coating time goes up, the more years of reduced reflectivity there are. The higher cost coating has a slightly higher aged reflectivity, which explains the increase in the 15 year re-coating over the 10 year re-coating.

Table 4. Energy Saving Present Values for Upstate New York

Re-coat Time	Energy Saving Present Value	% of Total Present Value
6 Years	$,9258	7%
10 Years	$8,898	10%
15 Years	$9,099	12%

Graph 5 gives the Spray Foam Present Value Costs for a range of coating costs. As would be expected, the lowest Life Cycle Cost option is the 15-year re-coating, which represents the least number of applications of coating.



Graph 5: Spray Foam Present Value Costs, Upstate New York

E. Louisville, KY Region:

The Louisville, KY area was chosen to represent a moderate but humid climate region. A summary of the data used for this region is shown below in Table 5.

Table 5: Louisville, KY Data Summary

Louisville, KY	Present Value	Full Cost After Inflation	Coating Cost/sq. ft.	Foaming Cost/sq. ft.	Mainte-nance	% of BUR Costs
6 Yr. Re-coat	$105,167	$204,376	$1.40	$1.57	$275	71%
10 Yr. Re-coat	$77,530	$124,301				52%
15 Yr. Re-coat	$65,189	$86,010				44%

Table 6 gives the square foot installed cost a membrane system would have to have to equal the Life Cycle Cost of the Spray Polyurethane Foam Roof System for each of the studied re-coating times. Stated another way, unless the membrane costs are less than the values given, the Spray Polyurethane Foam Roof will have the lowest Life Cycle Cost.

Table 6: Louisville, KY Equal Membrane Cost per Square Foot

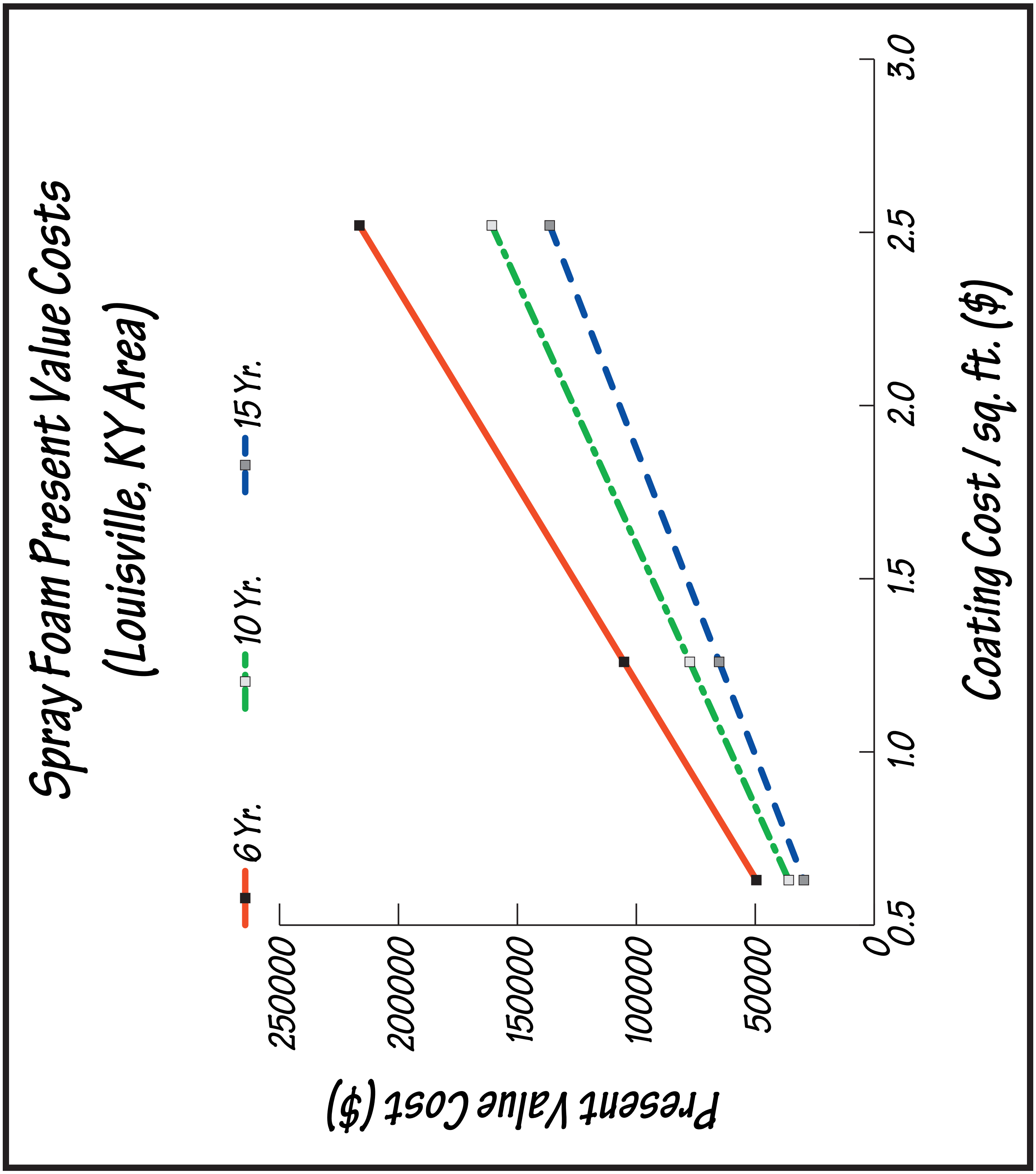
Louisville, KY	Present Value	Membrane Cost / sq. ft. to Equal SPUF
6 Year Re-coat	$105,167	$2.60
10 Year Re-coat	$77,530	$1.70
15 Year Re-coat	$65,189	$1.30

Table 7 contains information on the size of the impact the energy savings from the reflectivity of the Spray Polyurethane Foam Roof has on the present value for this region. To prevent over stating the energy savings affect on the present value, we have added the energy saving present value back into the total present value before determining the percentage. Because the energy savings is subtracted from the other costs in the present value and can be a sizable percentage, adding it back in first prevents an over statement of relative size of the energy savings. If a reflective membrane system with a reflectivity of 90% is the competition, then adding in 110% of the energy saving present value to the listed Spray Polyurethane Foam Roof present value, will compensate for the slightly lower reflectivity of the Spray Polyurethane Foam Roof. Compare the Spray Polyurethane Foam Roof present value obtained per above to the value obtained from the Present Value vs. BUR Cost per Square Foot graph in the Appendix on page 26, for the cost per square foot of the reflective membrane system. The reason for the decrease in the energy saving present value is that as the coating time goes up, the more years of reduced reflectivity there are. The higher cost coating has a slightly higher aged reflectivity, which explains the increase in the 15 year re-coating over the 10 year re-coating.

Table 7. Energy Saving Present Values for Louisville, KY

Re-coat Time	Energy Saving Present Value	% of Total Present Value
6 Years	$,9,495	8%
10 Years	$9,113	11%
15 Years	$9,447	13%

Graph 6 gives the Spray Foam Present Value Costs for a range of coating costs. As would be expected, the lowest Life Cycle Cost option is the 15-year re-coating, which represents the least number of applications of coating.



Graph 6: Spray Foam Present Value Costs, Louisville, KY

F. South Central Florida Region:

The South Central Florida area was chosen to represent a hot and humid climate region. A summary of the data used for this region is shown below in Table 8.

Table 8: South Central Florida Data Summary

Florida	Present Value	Full Cost After Inflation	Coating Cost/sq. ft.	Foaming Cost/sq. ft.	Mainte-nance	% of BUR Costs
6 Yr. Re-coat	$125,102	$248,265	$1.51	$2.10	$1,067	84%
10 Yr. Re-coat	$94,442	$159,149				64%
15 Yr. Re-coat	$81,788	$118,249				55%

Table 9 gives the square foot installed cost a membrane system would have to have to equal the Life Cycle Cost of the Spray Polyurethane Foam Roof System for each of the studied re-coating times. Stated another way, unless the membrane costs are less than the values given, the Spray Polyurethane Foam Roof will have the lowest Life Cycle Cost.

Table 9: South Central Florida Equal Membrane Cost per Square Foot

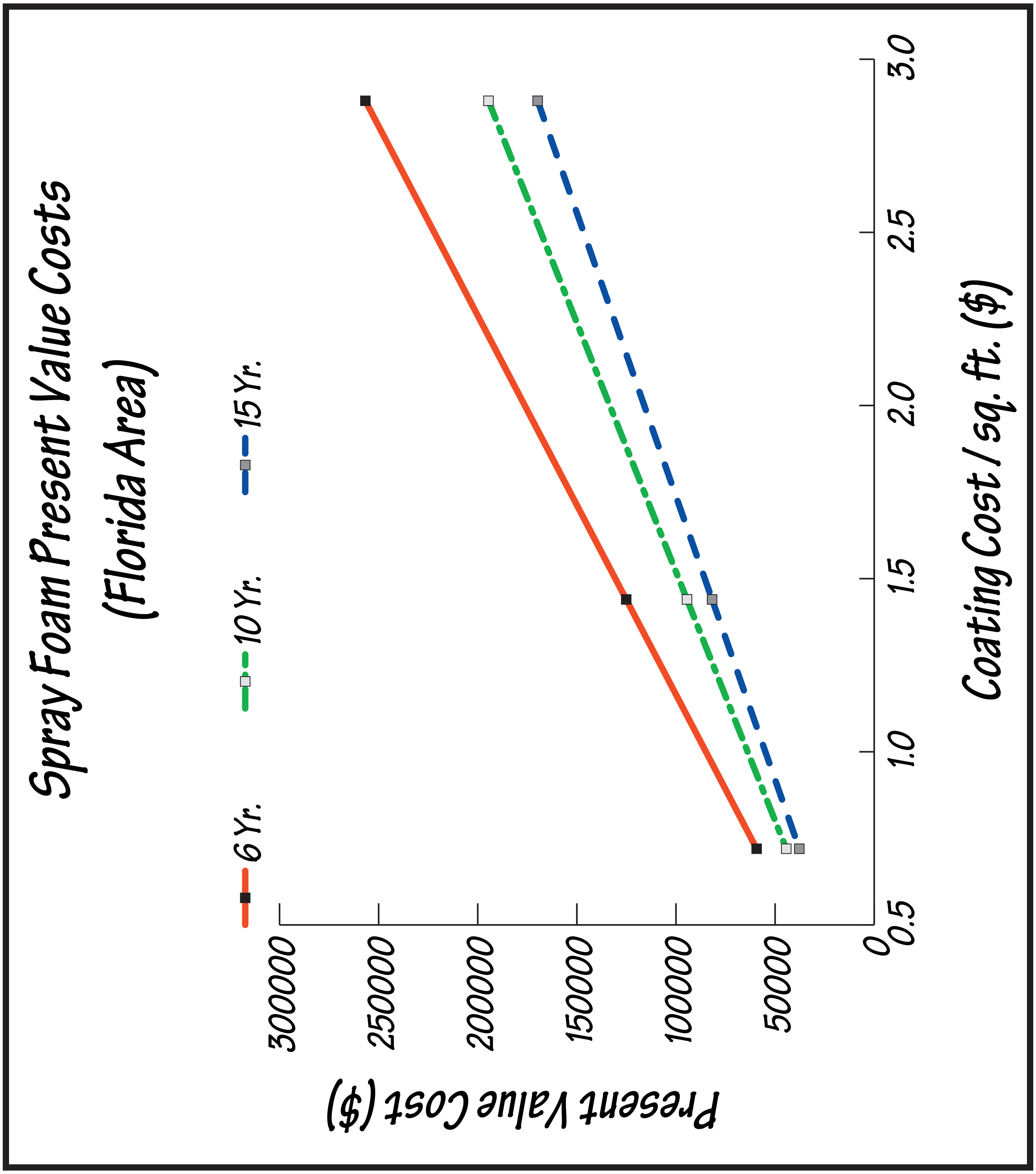
South Central Florida	Present Value	Membrane Cost / sq. ft. to Equal SPUF
6 Year Re-coat	$125,102	$3.24
10 Year Re-coat	$94,442	$2.25
15 Year Re-coat	$81,788	$1.84

Table 10 contains information on the size of the impact the energy savings from the reflectivity of the Spray Polyurethane Foam Roof has on the present value for this region. To prevent over stating the energy savings affect on the present value, we have added the energy saving present value back into the total present value before determining the percentage. Because the energy savings is subtracted from the other costs in the present value and can be a sizable percentage, adding it back in first prevents an over statement of relative size of the energy savings. If a reflective membrane system with a reflectivity of 90% is the competition, then adding in 110% of the energy saving present value to the listed Spray Polyurethane Foam Roof present value, will compensate for the slightly lower reflectivity of the Spray Polyurethane Foam Roof. Compare the Spray Polyurethane Foam Roof present value obtained per above to the value obtained from the Present Value vs. BUR Cost per Square Foot graph in the Appendix on page 26, for the cost per square foot of the reflective membrane system. The reason for the decrease in the energy saving present value is that as the coating time goes up, the more years of reduced reflectivity there are. The higher cost coating has a slightly higher aged reflectivity, which explains the increase in the 15 year re-coating over the 10 year re-coating.

Table 10. Energy Saving Present Values for South Central Florida

Re-coat Time	Energy Saving Present Value	% of Total Present Value
6 Years	$,19,726	14%
10 Years	$18,949	17%
15 Years	$19,451	19%

Graph 7 gives the Spray Foam Present Value Costs for a range of coating costs. As would be expected, the lowest Life Cycle Cost option is the 15-year re-coating, which represents the least number of applications of coating.



Graph 7: Spray Foam Present Value Costs for South Central Florida

G. Fort Worth, TX Region:

The Fort Worth Texas area was chosen to represent a hot and moderately humid climate region. A summary of the data used for this region is shown below in Table 11.

Table 11: Fort Worth, TX Area Data Summary

Fort Worth, TX	Present Value	Full Cost After Inflation	Coating Cost/sq. ft.	Foaming Cost/sq. ft.	Mainte-nance	% of BUR Costs
6yr. Re-coat	$117,738	$227,061	$1.59	$1.62	Covered	79%
10 Yr. Re-coat	$85,089	$132,461				57%
15 Yr. Re-coat	$72,431	$90,601				49%

Table 12 gives the square foot installed cost a membrane system would have to have to equal the Life Cycle Cost of the Spray Polyurethane Foam Roof System for each of the studied re-coating times. Stated another way, unless the membrane costs are less than the values given, the Spray Polyurethane Foam Roof will have the lowest Life Cycle Cost.

Table 12: Fort Worth, TX Equal Membrane Cost per Square Foot

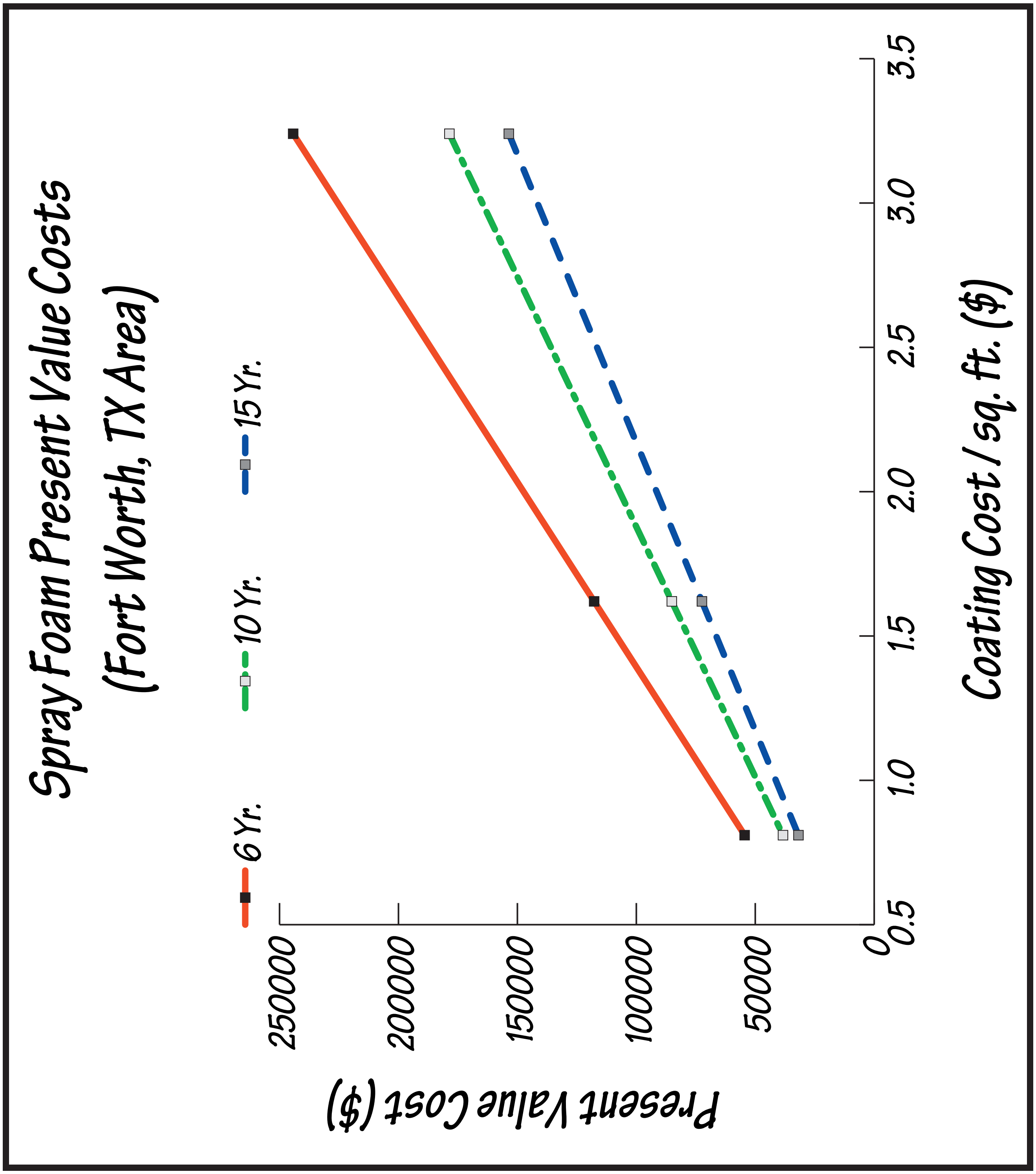
Fort Worth, TX	Present Value	Membrane Cost / sq. ft. to Equal SPUF
6 Year Re-coat	$117,738	$3.00
10 Year Re-coat	$85,089	$1.95
15 Year Re-coat	$72,431	$1.54

Table 13 contains information on the size of the impact the energy savings from the reflectivity of the Spray Polyurethane Foam Roof has on the present value for this region. To prevent over stating the energy savings affect on the present value, we have added the energy saving present value back into the total present value before determining the percentage. Because the energy savings is subtracted from the other costs in the present value and can be a sizable percentage, adding it back in first prevents an over statement of relative size of the energy savings. If a reflective membrane system with a reflectivity of 90% is the competition, then adding in 110% of the energy saving present value to the listed Spray Polyurethane Foam Roof present value, will compensate for the slightly lower reflectivity of the Spray Polyurethane Foam Roof. Compare the Spray Polyurethane Foam Roof present value obtained per above to the value obtained from the Present Value vs. BUR Cost per Square Foot graph in the Appendix on page 26, for the cost per square foot of the reflective membrane system. The reason for the decrease in the energy saving present value is that as the coating time goes up, the more years of reduced reflectivity there are. The higher cost coating has a slightly higher aged reflectivity, which explains the increase in the 15 year re-coating over the 10 year re-coating.

Table 13. Energy Saving Present Values for Fort Worth, TX

Re-coat Time	Energy Saving Present Value	% of Total Present Value
6 Years	$,8,794	7%
10 Years	$8,412	9%
15 Years	$8,746	11%

Graph 8 gives the Spray Foam Present Value Costs for a range of coating costs. As would be expected, the lowest Life Cycle Cost option is the 15-year re-coating, which represents the least number of applications of coating.



Graph 8: Spray Foam Present Value Costs, Fort Worth, TX Area

H. Phoenix, AZ Region:

The Phoenix, AZ area was chosen to represent a hot and dry climate region. A summary of the data used for this region is shown below in Table 14.

Table 14: Phoenix, AZ Area Data Summary

Phoenix, AZ	Present Value	Full Cost After Inflation	Coating Cost/sq. ft.	Foaming Cost/sq. ft.	Maintenance	% of BUR Costs
6 Yr. Re-coat	$101,507	$207,977	$1.40	$1.77	$1,667	68%
10 Yr. Re-coat	$76,122	$137,021				51%
15 Yr. Re-coat	$69,966	$109,743				47%

Table 15 gives the square foot installed cost a membrane system would have to have to equal the Life Cycle Cost of the Spray Polyurethane Foam Roof System for each of the studied re-coating times. Stated another way, unless the membrane costs are less than the values given, the Spray Polyurethane Foam Roof will have the lowest Life Cycle Cost.

Table 15: Phoenix, AZ Equal Membrane Cost per Square Foot

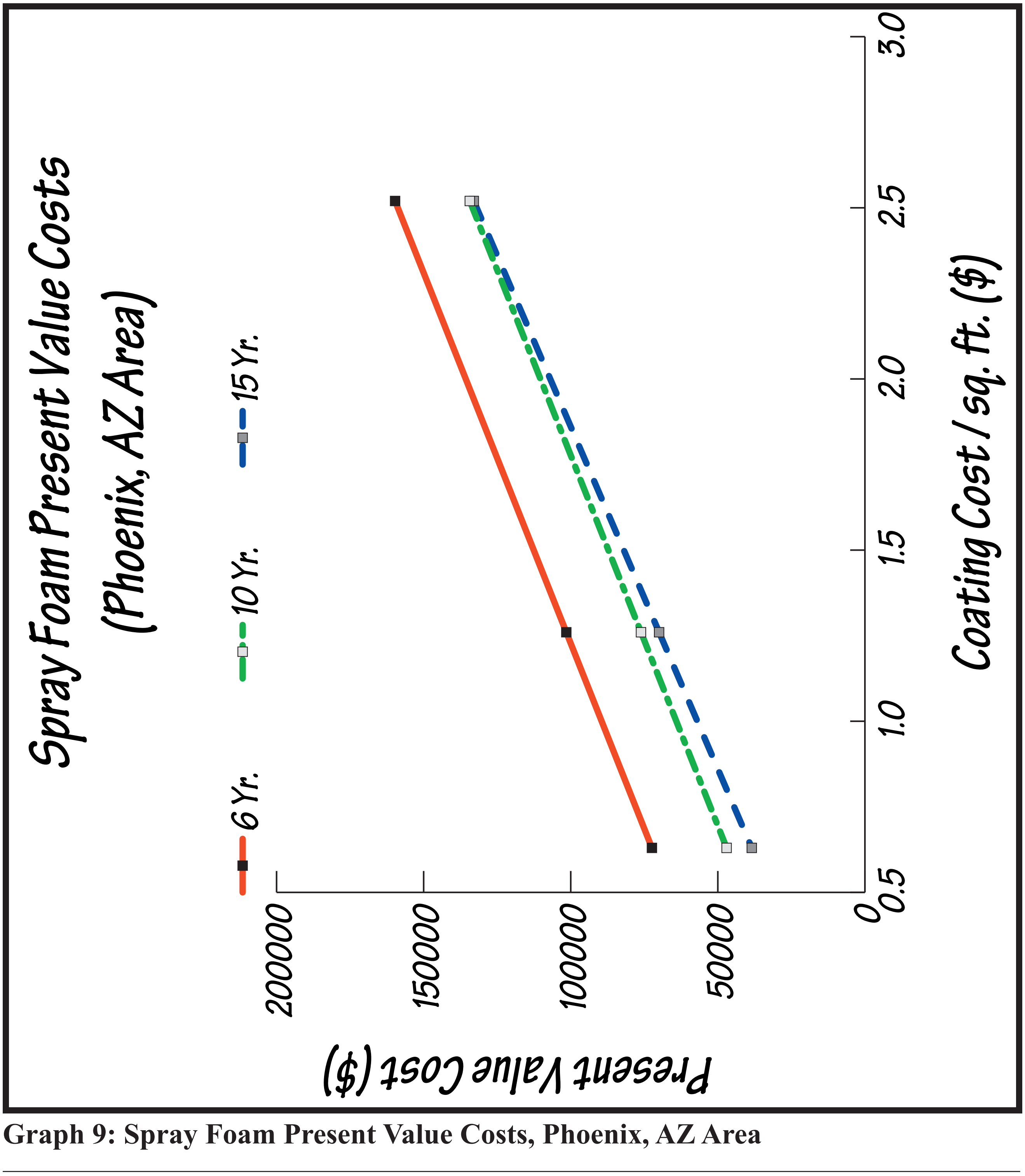
Phoenix, AZ	Present Value	Membrane Cost / sq. ft. to Equal SPUF
6 Year Re-coat	$101,507	$2.48
10 Year Re-coat	$76,122	$1.66
15 Year Re-coat	$69,966	$1.46

Table 16 contains information on the size of the impact the energy savings from the reflectivity of the Spray Polyurethane Foam Roof has on the present value for this region. To prevent over stating the energy savings affect on the present value, we have added the energy saving present value back into the total present value before determining the percentage. Because the energy savings is subtracted from the other costs in the present value and can be a sizable percentage, adding it back in first prevents an over statement of relative size of the energy savings. If a reflective membrane system with a reflectivity of 90% is the competition, then adding in 110% of the energy saving present value to the listed Spray Polyurethane Foam Roof present value, will compensate for the slightly lower reflectivity of the Spray Polyurethane Foam Roof. Compare the Spray Polyurethane Foam Roof present value obtained per above to the value obtained from the Present Value vs. BUR Cost per Square Foot graph in the Appendix on page 26, for the cost per square foot of the reflective membrane system. The reason for the decrease in the energy saving present value is that as the coating time goes up, the more years of reduced reflectivity there are. The higher cost coating has a slightly higher aged reflectivity, which explains the increase in the 15 year re-coating over the 10 year re-coating.

Table 16. Energy Saving Present Values for Phoenix, AZ

Re-coat Time	Energy Saving Present Value	% of Total Present Value
6 Years	$,29,126	22%
10 Years	$28,001	27%
15 Years	$28,723	29%

Graph 9 gives the Spray Foam Present Value Costs for a range of coating costs. As would be expected, the lowest Life Cycle Cost option is the 15-year re-coating, which represents the least number of applications of coating. The reason that the 10-year re-coating costs and 15 year re-coating costs are so close is that in this region the lower cost coating cost was low relative to the higher cost coating costs. Also, the maintenance costs were the highest. The net result of these conditions is a 15-year re-coating cost that is close to the 10-year re-coating cost. As the coating cost increases it "over powers" the other costs shrinking the benefit of the longer re-coating time.



Graph 9: Spray Foam Present Value Costs, Phoenix, AZ Area

I. Southern California Region:

The Southern California area was chosen to represent a moderate climate with small seasonal changes region. A summary of the data used for this region is shown below in Table 17.

Table 17: Southern California Area Data Summary

Southern CA	Present Value	Full Cost After Inflation	Coating Cost /sq. ft.	Foaming Cost /sq. ft.	Maintenance	% of BUR Costs
6 Yr. Re-coat	$105,441	$206,108	$1.52	$1.63	$500	71%
10 Yr. Re-coat	$77,756	$125,906				52%
15 Yr. Re-coat	$75,640	$104,848				51%

Table 18 gives the square foot installed cost a membrane system would have to have to equal the Life Cycle Cost of the Spray Polyurethane Foam Roof System for each of the studied re-coating times. Stated another way, unless the membrane costs are less than the values given, the Spray Polyurethane Foam Roof will have the lowest Life Cycle Cost.

Table 18: Southern California Equal Membrane Cost per Square Foot

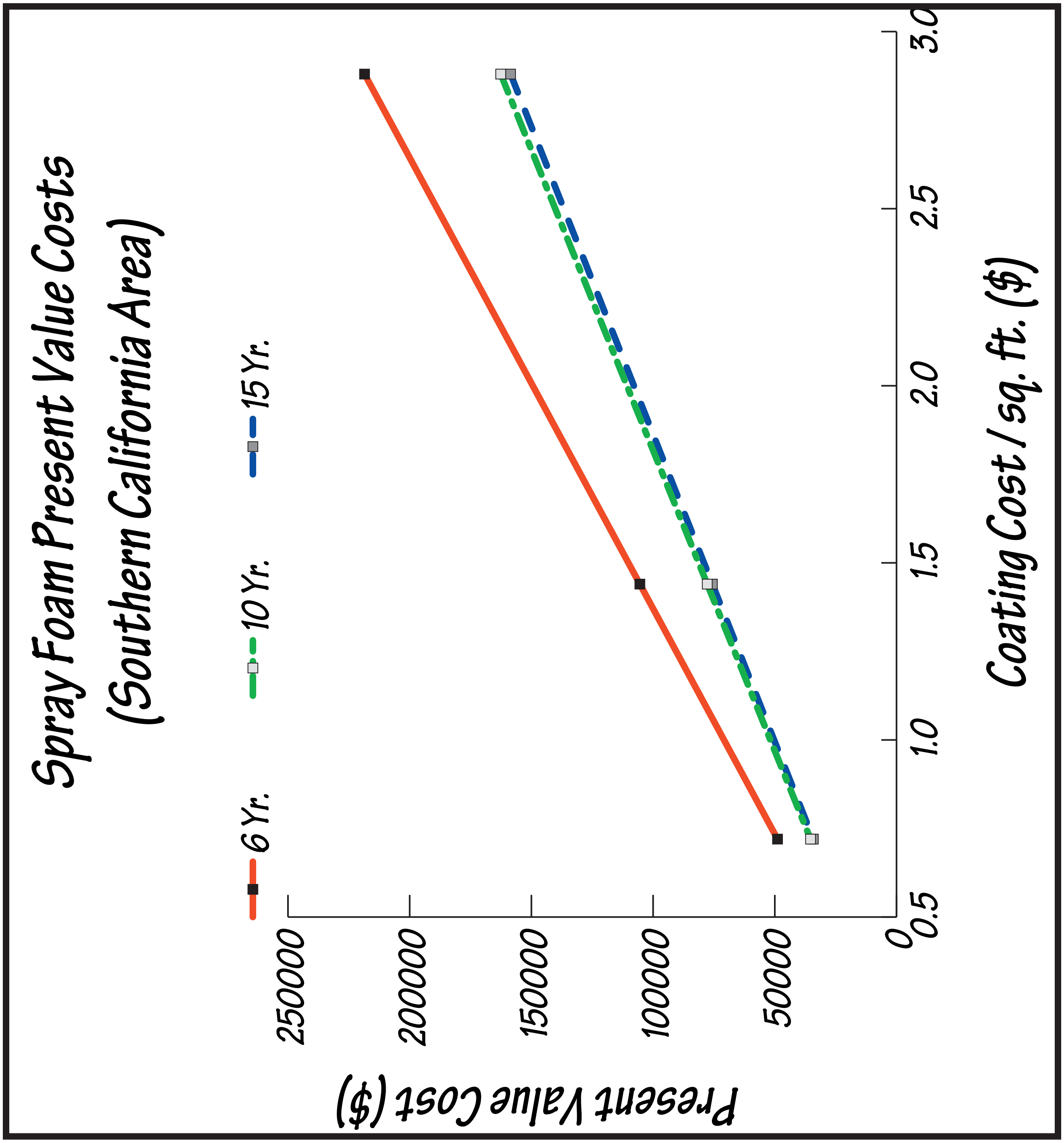
Southern California	Present Value	Membrane Cost / sq. ft. to Equal SPUF
6 Year Re-coat	$105,441	$2.61
10 Year Re-coat	$77,756	$1.71
15 Year Re-coat	$75,640	$1.64

Table 19 contains information on the size of the impact the energy savings from the reflectivity of the Spray Polyurethane Foam Roof has on the present value for this region. To prevent over stating the energy savings affect on the present value, we have added the energy saving present value back into the total present value before determining the percentage. Because the energy savings is subtracted from the other costs in the present value and can be a sizable percentage, adding it back in first prevents an over statement of relative size of the energy savings. If a reflective membrane system with a reflectivity of 90% is the competition, then adding in 110% of the energy saving present value to the listed Spray Polyurethane Foam Roof present value, will compensate for the slightly lower reflectivity of the Spray Polyurethane Foam Roof. Compare the Spray Polyurethane Foam Roof present value obtained per above to the value obtained from the Present Value vs. BUR Cost per Square Foot graph in the Appendix on page 26, for the cost per square foot of the reflective membrane system. The reason for the decrease in the energy saving present value is that as the coating time goes up, the more years of reduced reflectivity there are. The higher cost coating has a slightly higher aged reflectivity, which explains the increase in the 15 year re-coating over the 10 year re-coating.

Table 16. Energy Saving Present Values for Southern California

Re-coat Time	Energy Saving Present Value	% of Total Present Value
6 Years	$,13,863	12%
10 Years	$13,300	15%
15 Years	$13,484	15%

Graph 10 gives the Spray Foam Present Value Costs for a range of coating costs. As would be expected, the lowest Life Cycle Cost option is the 15-year re-coating, which represents the least number of applications of coating. The reason that the 10-year re-coating costs and 15 year re-coating costs are so close is that in this region the lower cost coating cost was low relative to the higher cost coating costs. The net result of these conditions is a 15-year re-coating cost that is close to the 10-year re-coating cost. As the coating cost increases it “over powers” the other costs shrinking the benefit of the longer re-coating time.



Graph 10: Spray Foam Present Value Costs, Southern California Area

J. General Discussion:

As would be expected the longer the roof system lasts the lower its cost per year. The lowest Life Cycle Cost will always be the system that has the lowest cost over the study period. Since the installed cost of a roof is generally much larger than the maintenance costs, the cost of maintenance to extend a roof will cost far less than an early roof replacement. Also, when there is only a small difference between the installed cost of the shorter life roof system and the longer life roof system then the Life Cycle Costs heavily favor the longer life roof system. Thus when we consider a 15-year re-coating time for a Spray Polyurethane Foam Roof System, it is a very competitive roof system. The most expensive 15 year re-coat example our study was Southern Florida with a Life Cycle Cost of $81,788 or $2,726 per year. This corresponds to an installed cost of $1.84 per square foot cost for a membrane roof system. For a membrane roof system installed over insulation the cost per square foot will be higher.

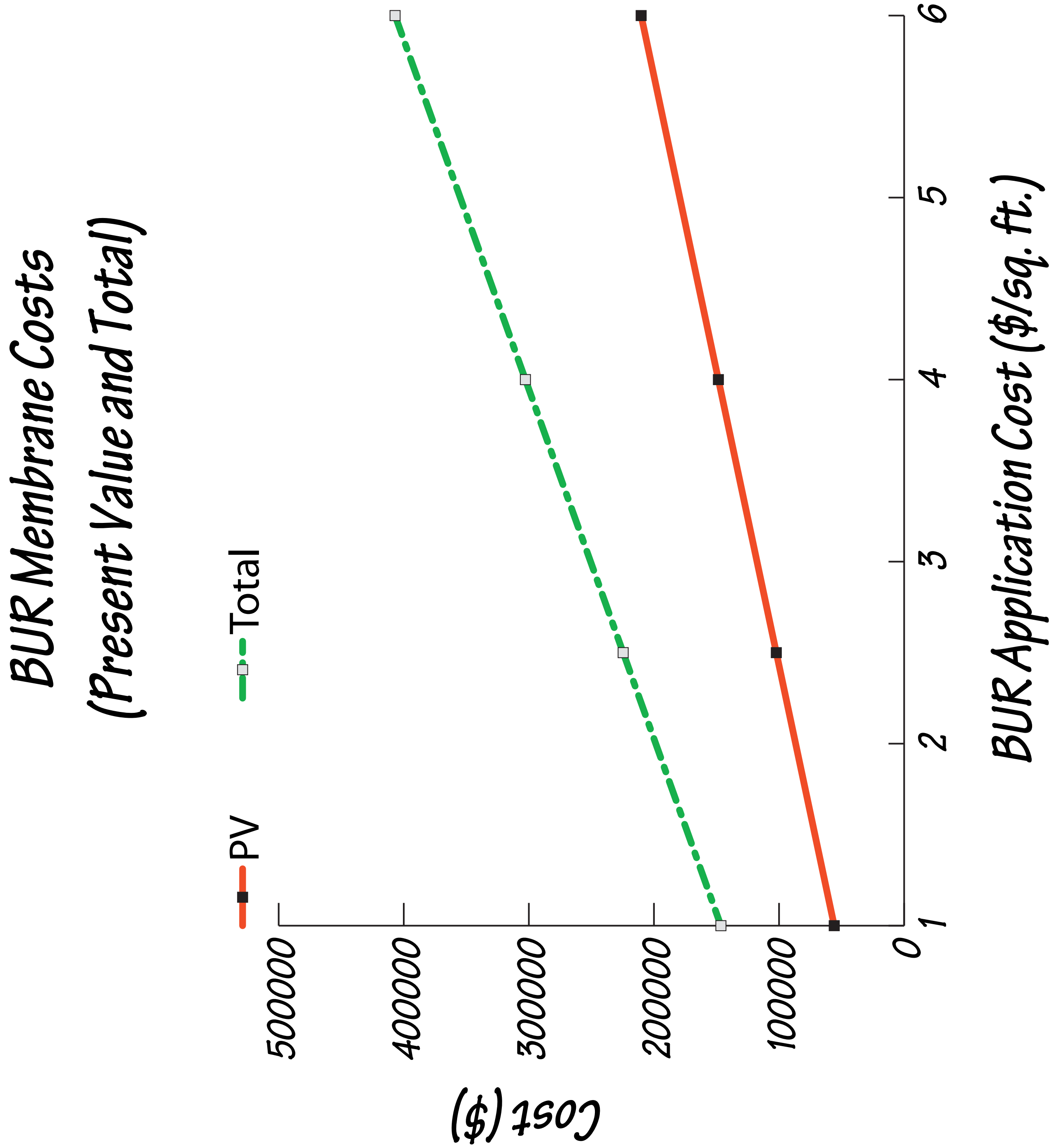
In the Southern California and Phoenix, AZ region, the common membrane roofing practice is to install a nailed 3 ply BUR roof directly to the wood (plywood or OSB) deck and insulate with fiber glass batts under the deck. These costs can be as low as $1.00 per square foot, excluding the insulation. But, batt insulation is one of the least expensive insulations on a dollar per R-value basis, making these systems under $1.25 per square foot installed. However, these roofs are often only a ten (10) year roof system. Using ten (10) years roof life we obtain present values, as shown in Table 14 below. For all but the 6 year re-coat situation, Spray Polyurethane Foam Roofs will have a lower Life Cycle Cost than the 3 ply nailed BUR for both Southern California and Phoenix, AZ. Thus on wood decks, Spray Polyurethane Foam may not always have the lowest Life Cycle Costs, but on all other decks that are insulated it is the lowest Life Cycle Cost compared to membrane roof system. A general Life Cycle Cost study like this one, cannot fully quantify the other benefits of Spray Polyurethane Foam Roof Systems such as: no leaks and its ease of sustainability, even though costs for these issues were incorporated to a degree. For many businesses the costs of lost operations due to water leaking into the building are so large that they overshadow everything else. For these special cases which are specific to those businesses, the leak related costs used in this study do not come close, as we only considered simple repair of damaged ceiling tile or drywall. When everything is taken into account Spray Polyurethane Foam Roof Systems have many advantages, not the least of which is a measurable lower Life Cycle Cost.

3 Ply BUR $/ft^2	Present Value
1.05	81,151
1.15	85,416
1.25	89,681

Table 14. 3 ply BUR Costs vs. Present Value for 10 Year Roof Life

Spray Polyurethane Foam Roofs have a very favorable 30-year Life Cycle Cost compared to membrane roof systems in most situations. In many situations they will have competitive or lower initial cost as well. The lower Life Cycle Cost comes from saving from not having to tear the existing roof off when the life the second roof on the building is reached and that re-coating is less expensive than replacing the membrane roof, as well as the energy saving from the reflective coatings used. The only case where membrane roofs might have a lower Life Cycle Cost would be for a nailed 3-ply BUR directly to a wood deck on large open buildings compared to a 6 yer re-coating cycle. But even in these situations Spray Polyurethane Foam can be competitive when other benefits to the long-term owner are considered, such as the sustainability of the roof for more than 30 years.

When reflective or cool roofing is considered, even over wood decks Spray Polyurethane Foam should win, as reflective roof systems will cost over $2.50 per square foot installed. Today, there is a strong push toward reflective or cool roofing, which is a positive situation for Spray Polyurethane Foam Roof Systems.



Graph 11: BUR (Membrane) Square Foot Costs vs. Present Value