
**Applying Life Cycle Costing (LCC) to Roofing
Investments: A Guide to Using Green Roofs for Healthy
Cities *GreenSave Calculator***

Prepared for:

Green Roofs for Healthy Cities



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1 Introduction

Green Roofs for Healthy Cities (GRHC) is a non-profit, membership based industry association dedicated to the development of the green roof industry throughout North America. In addition to practical tools such as the *GreenSave Calculator*, GRHC is developing a professional accreditation for green roof designers and installers which will be introduced in 2009. There are a number of courses available about green roof design and installation provided across North America throughout the year, as well as specialized workshops dedicated to policy making and design for habitat restoration.

Green roofs have a wide range of possible public and private benefits, many of which are not factored into a financial analysis of proposed projects. The purpose of this guide is to help users of the *GreenSave Calculator* tool start using it effectively to evaluate various roofing related investment scenarios. The Tool focuses on long timeframes, real monetary costs and savings, and financial returns attributed to employing conventional and green (vegetative) roofs. It also provides some guidance to the users about how to factor in financial information from benefits that may be overlooked in the analysis.

This guide explains the various input data requirements and results generated by the Tool. An example case study is available at the end of the guide. For more case study examples completed using this tool, see GRHC's website. The *GreenSave Calculator* is a web-enabled set of tab related worksheets, similar to a spreadsheet environment. In fact, the offline template is an Excel based spreadsheet (with limited calculation abilities) which once uploaded to the GRHC website, is read by the Tool and the results are calculated. It is at this point the Tool user may choose to share their results with other Tool users on the site. In this way we all learn and create a body of knowledge that all of us can pull on when preparing life cycle cost and benefit assessments of green (vegetative) and other more traditional roofing membrane systems.

The Tool really has two components: (1) an embedded Life Cycle Costing "Calculator" capable of assessing 3 investment scenarios side-by-side over a period of up to 60 years; and (2) a set of linked worksheet "Benefit Modules" to help the user to derive the necessary cost and benefit information about the proposed projects to generate a more robust Life-Cycle Cost Benefit result.

2 Getting Started

2.1 Overview

There are many different methods for evaluating investment decisions, and many different measures that can be used. The GRHC Tool deals with the life cycle costing (LCC) method and the underlying metric information necessary to support a fair and reasonable investment analysis of various roofing options.

LCC is an economic method for evaluating project investment alternatives over a selected period of time. It is particularly suited to determining whether the higher initial cost of an investment is justified by reductions in future costs (e.g., operating, maintenance, repair or replacement costs). It can also be used to compare investment alternatives with different initial and future costs.

The alternatives can be compared in various ways. The *GreenSave Calculator* uses three methods:

1. the Present Value (PV) of the entire stream of cash flows;
2. the Internal Rate of Return (IRR) on the investment; and
3. the simple payback period.

All of these measures are described in more detail later in this Guide.

The procedure for calculating an LCC can be summarized in the following steps.

1. Identify the alternative investment scenarios and any operational limitations.
2. Establish basic financial assumptions for the analysis.
3. Compile all relevant cost and savings (benefits) data for each of the scenarios to be considered.
4. Compare the LCCs for each alternative to determine the one with the lowest LCC.
5. Make a final decision, based on the LCC result as well as any risk, uncertainty or unquantifiable benefits/effects that may have a bearing on the decision.

The LCC result is expressed in present value¹ terms for a selected timeframe and discount rate. Typically, an LCC evaluation considers the following investment data and assumptions²:

- Study period — investor's project holding period during which time benefits or savings will be realised, or the expected life of the green roofing system.
- Discount/'hurdle' rate — investor's time preference for money which determines the degree to which future costs and savings, such as replacement costs or improved energy efficiency, will be factored into the analysis. The higher the rate, the less significant are the future costs and savings.
- Uncertainty vs. risk – Uncertainty in the analysis usual pertains to the quality of the initial cost and savings data and the length of study period – the longer the study period the less certain we can be about the future. Risk relates to assumed investment risk, which may not be the same for all roofing alternatives.
- Inflation rate — general plus energy price inflation (in the case of an energy cost sensitive investments)
- Investment cost data — initial cash investment and total installed capital cost (including any grants or subsidies)
- Residual roof value at the end of the study period. For example, assume the study period is set to the expected life of a green roof, say 40 years, and the alternative

¹ The value in today's dollars of money to be spent or received in the future, recognizing that a dollar in the future may not be considered as valuable as a dollar today, even if there is no inflation. This is often called the "time value of money" or "time preference".

² The GRHC Tool is designed to provide before tax results and excludes financing cost considerations – hence it does not include depreciation nor financing costs.

roofing system lasts 15 years, then over the course of 40 years the alternative roof is going to be replaced twice – at years 15 and 30. But at the end of the study period (40 years) the alternative roof still has 5 years of useful life, so one-third of its value (5/15) is its residual value at the end of the study period and needs to be factored into the analysis. Similarly, at the end of 40 years the green roof may also have a residual value in terms of reusing the plant materials, soil, insulation, etc. – these two should be factored into the analysis.

- Recurring annual operation and maintenance costs
- Periodic replacement cost (if applicable)

Because this Tool has been designed specifically to consider (green) roof investments there are a number of additional costs and savings (benefits) modules that are built into the Tool that consider such aspects as:

- Storm water mitigation, including cost savings associated with government grants or feebates on operations;
- Heat island effect mitigation, through the use of government grants;
- Development fees and related costs, which may include savings associated with density bonusing, tax increment financing, or fast tracking development approvals;
- Marketability and rent-ability of the roof area, which may translate into reduced costs for marketing and management as well as free media about the project; and,
- Tenant Health and Productivity considerations, which may translate into less worker absenteeism.

These modules are designed to assist you in determining, what, if any, benefits may be determined that would effect the life-cycle cost and benefits of the project. The Life-Cycle Cost-Benefit Calculator portion of the Tool utilizes a set of four linked worksheets. The first worksheet, “**LCC Assumptions and Results**”, is where the user enters the required information and gets back the results of the life cycle cost calculation. In this worksheet you can see the present value, simple payback period and internal rate of return results for up to three investment scenarios.

Each of the three “**Results Calculator**” sheets show the annual cash flows by cost/savings element, the resultant total cash flow for individual years on both a nominal (unadjusted) and discounted basis, and the calculated life cycle cost results for the investment over the expected life – up to 60 years. Each “Result Calculator” sheet corresponds to one of the three Investment Scenarios indicated on the first “LCC Assumptions and Results” sheet. These “Results Calculator” sheets provide a level of transparency so the user can verify inputs used in the calculation of the various financial measures. A user of the Tool can complete one, two or three scenarios and compare the results side-by-side.

2.2 Input Requirements

This section describes each of the major data element fields used in the process of completing an LCC assessment using the *GreenSave Calculator*. It is recommended that users have the Tool open while reviewing this section.

The “LCC Assumptions and Results” sheet is divided into three sections:

- Description + Common Assumptions,
- Investment Data, and
- Financial Results Summary.

The calculator is capable of analysing three roof investment scenarios side-by-side – Scenario 1, Scenario 2, and Scenario 3.

The next two sub-heading sections describe the user input requirements for the Calculator on a line-by-line basis (in relation to the worksheet modules where applicable). The final section discusses the financial measures and their interpretation.

2.2.1 Description + Common Assumptions

Project Name – optional text field for description of the scenario to be evaluated

Date and Time – preset to current date and time

Completed by – optional text field to enter user/evaluator’s name

Company - optional text field to enter company name

Contact phone number - optional text field to enter phone number

Contact email - optional text field to enter user/evaluator’s email address

Study period in years [Enter a whole number, e.g., for 10 years, enter ‘10’]

The study period indicates the number of years over which the investment scenario is to be assessed (minimum = 1 year; maximum = 60 years). The study period may either reflect the investor’s time horizon³ or the expected life of the longest lasting roof scenario being assessed (e.g., a green roof with an expected life of 30 to 40 years).

The Study period is an important component of the analysis because it will determine how many years the benefits of the project will be incorporated into the analysis. For example, on large infrastructure projects, the timeline may be 50, 75 or even a hundred years. If 10 years is chosen, then the benefits of extended life expectancy from a green roof will not be factored into the analysis, because the 10 years is too short a study period. Ten years, however, may be the right amount of time for the project investor if they will be transferring ownership of the building at that time.

Applicable discount (hurdle) rate (%) [Enter a number, e.g., for 9%, enter ‘9’]

The discount/hurdle rate is the rate of interest that makes an investor willing to invest a dollar today to get more than a dollar some time in the future. The discount/hurdle rate from a potential homeowner’s perspective could be the cost of capital (e.g., mortgage rate) or what he or she might receive from another investment vehicle of similar risk (e.g., US/Canada savings bonds for a low risk investment vs. the stock market for a higher risk investment). A building developer would typically use his or her company’s average weighted cost of capital (debt and equity) adjusted for the perceived risk of the investment; alternatively, the company might already have a hurdle rate (required rate of

³ The expected length of time a sum of money is to be invested.

return) policy used to assess prospective investments (e.g., 15%). The entered discount rate is used to discount all future annual cash flows in order to calculate the present value of the investment.

General price inflation factor (%) [Enter a number, e.g., for 3.5%, enter ‘3.5’]

The user enters the annual inflation rate over the life of the project. North American general consumer price inflation (excluding energy) has averaged between 2 and 3% for the last 10 years. Between Jan/97 and Jan/07, US general price inflation has averaged 2.72% (Source: www.inflationdata.com) Since 1997, Canadian general price inflation has average 2.04% per year. (Source: www.bankofcanada.ca.) The *GreenSave Calculator* includes a preset default general price inflation of 2.72% and 2.04% for the US and Canada. The default value is invoked when the Tool user completes the configuration page and indicates the currency they want to work in. The default value is only a suggested rate and may be changed by the user.

Thermal fuel energy price inflation factor (%) [Enter a number, e.g., for 3%, enter ‘3’]

This is the annual energy price inflator to be used to escalate the cost of thermal fuels (oil, natural gas, coal) over the study period. Since 1992, N. American natural gas prices have increased by 9% annually on average. (Source: Natural Resources Canada, Office of Energy Efficiency). The *GreenSave Calculator* includes a preset default value of 9% for thermal fuel energy annual price inflation for both the US and Canada; however, the default value is only a suggested rate and may also be changed by the user.

Electricity price inflation factor (%) [Enter a number, e.g., for 3%, enter ‘3’]

This is the annual energy price inflator to be used to escalate the cost of electricity over the study period. Since 1992, electricity prices have increased by 3% annually in Canada (Source: Natural Resources Canada, Office of Energy Efficiency) and 2.5% annually in the US (Source: US Department of Energy). The default values for annual electricity price inflation has therefore been set at 3% and 2.5% for Canada and the US, respectively, but again these can be changed by the Tool user to reflect local rate conditions or the purchase of “green” power.

2.2.2 Investment Data

Investment Name (description) – text field descriptor for each investment scenario to be evaluated. This descriptor is linked to the various scenarios under each of the worksheet Modules. It is highly recommended that Tool users complete this field.

Total installed capital cost [Enter a dollar value, e.g., for \$10,000, enter ‘10000’]

This value represents the total investment necessary to install the particular roof system. The cost entered should be before any capital subsidy or rebate is applied (these grants and subsidies will be calculated and applied later once the applicable worksheet Modules are completed – e.g., see Storm Water and Heat Island Modules). The embedded calculator assumes the installed capital cost occurs at the beginning of year 1.

Annual electricity energy cost [This value is copied from the Energy Use Module for each of the scenarios being considered]

This is a cost calculated by the Tool user for each roofing scenario in the Energy Use Module. This value is escalated by the electricity inflation factor in future years.

Annual thermal fuel energy cost [This value is copied from the Energy Use Module for each of the scenarios being considered]

This is a cost calculated by the Tool user for each roofing scenario in the Energy Use Module. This field value is escalated by the thermal fuel inflation factor in future years.

HVAC Downsizing Capital Savings [This value is copied from the Energy Use Module for each of the scenarios being considered]

This value reflects the HVAC capital cost savings achieved through the use of a cool or green (vegetative) roof designs as they may reduce peak load reductions. If peak load pricing is not applicable to your geographic location this value will not be calculated. The embedded Calculator treats this capital cost savings as a reduction in the installed cost of the roof system scenario.

Storm Water Control (mitigation grant or annual feebate) [This value is copied from the Storm Water Module for each of the scenarios being considered]

This value is only included in the analysis if the user has completed the Storm Water Module. The calculated value is treated as a one-time grant and is deducted from the Installed Capital Cost. Recurring annual benefit, such as a feebate, should be calculated and entered separately as an “Other annual savings” (see other annual (costs) or savings heading below)

Annual maintenance cost [This value is the sum of annual maintenance costs as calculated in the Roof Durability and Storm Water Modules for each of the scenarios being considered]

The user enters the maintenance cost applicable to each of the investment scenarios considered. The annual maintenance costs entry is subject to general price inflation in future years.

Roofing replacement interval (in years) [This value is copied from the Roof Durability Module for each of the scenarios considered.] The replacement interval indicates the timing of periodic roof replacement costs and any salvage (residual) value related to the replaced materials (e.g., the reuse of ballast or insulation). For example, for a 25-year study period where a roof is replaced every 12 years, the replacement interval value is ‘12’; this scenario would result in two replacements (at years 12 and 24) with an adjustment for the extended life beyond the study period (see residual value below).

Periodic replacement cost [This value is copied from the Roof Durability Module for each of the scenarios considered.]

The user enters the periodic replacement cost in dollars. A periodic replacement cost represents a recurrent cost (negative cash flow) incurred at regular intervals (i.e., at the replacement interval) to maintain the roof function over the designated study period. This cost should reflect replacement of the roof including related tear-off and landfill

costs, if applicable (see Roof Durability Module). Periodic replacement costs are subject to the general price inflation escalator. For example, a roof replacement with a twelve-year expected life has a replacement cost of \$35,000 in today's dollars; the Calculator computes that at year 12, the periodic replacement interval, the roof will cost $(\$35,000 \times 1.025^{12})$ at an annual inflation rate of 2.5%.

Periodic salvage value (at roof replacement) [This value is copied from the Roof Durability Module for each of the scenarios considered.]

The user enters the periodic salvage value in dollars in the Roof Durability Module. A salvage value represents a positive cash flow recurring at regular intervals (i.e., at replacement intervals) due to the salvage of non-replaced materials (e.g., the reuse of ballast or insulation materials). All salvage values are subject to the general price inflation escalator. For example, 80% of the ballast material for a roof with a twelve-year expected life has a salvage value of \$5,000. The Calculator computes that, in year 12, the replacement interval, the salvage value of the ballast will be $(\$5,000 \times 1.025^{12})$. Note: if the **periodic replacement cost** calculated above already considers material salvage or reuse do not enter a value for periodic salvage value.

End of Life Residual Value [This value is copied from the Roof Durability Module for each of the scenarios considered.]

This is the residual number of years remaining in a roof system at the end of the study period in today's \$. - e.g., study period is 25yrs, the roof is replaced at year 17 at a cost of \$40,000, therefore, roof will last 8yrs beyond study period (25-17) and has a residual value of $(8/17 \times \$40,000) = \$18,824$. This value is projected into the future at the rate of general inflation.

Urban Heat Island Effect Mitigation (capital cost savings) [This value is copied from the Urban Heat Island Module for each of the scenarios considered.]

This value is treated as a one-time capital cost offset. If this is annual cost savings value enter it under "other annual (costs) or savings" as a positive value.

Development Fee Reduction (capital cost savings) [This value is copied from the Development Fees Module for each of the scenarios considered.]

This value is treated as a one-time capital cost offset. If this is annual cost savings value enter it under "other annual (costs) or savings" as a positive value.

Annual Increase in Revenue due to Roof System [This value is copied from the Saleability-Rentability Module for each of the scenarios considered.]

This value is treated as an annual revenue (positive cash flow) which is escalated at the general rate of inflation.

Annual Increase in Revenue due to Productivity and Health [This value is copied from the Tenant Health and Productivity Module for each of the scenarios considered.]

This value is treated as an annual revenue (positive cash flow) which is escalated at the general rate of inflation.

Net Capital Cost (year 0) – a Tool calculated result adjusting the total installed capital considered by the model net of all capital offsets. That is, Total Installed Capital Cost minus all capital cost offsets (e.g., less HVAC downsizing, Stormwater and UHI mitigation grants, and all one-time development fee savings).

Other annual (costs) or savings [Enter a dollar value, e.g., for an annual savings of \$1,000, enter '1000'; for an annual cost of \$1,000, enter '-1000']

The user enters any other costs or savings applicable to the investment scenario. All cost information is entered as a negative cash flow, while a savings is entered as a positive cash flow. The annual other costs or savings entry is escalated by the general price inflation value.

2.2.3 Financial Results Summary

NPV for study period (yrs), at one-third of study period, at two-thirds of study period – dollar value computed by the Calculator. These three rows calculate the cumulative net present value (NPV) of an investment scenario at three distinct intervals over the study period (at the end of the study period, at one-third of the study period and at two-thirds of the study period). Using three periods shows when an investment begins to pay off, if ever. NPV is the net result of all future cash inflows minus the present value investment and any associated cash outflows. It considers the time value of money (discount rate) by taking into consideration such things as the cost of capital, interest rates and investment opportunity costs. *The NPV is particularly sensitive to the discount rate.* It recognizes that money has a cost (interest) and that an investor might prefer to have a dollar today versus having a dollar a year from now. If an investor is only willing to accept a 10% or better return on his or her investment, then he or she would be willing to invest a dollar today to receive \$1.10 a year from now; this investor's time value of money (discount rate) is 10%. In other words, the "present value" of \$1.10 a year from now is one dollar today in the mind of the investor. The larger the NPV – other things being equal – the more attractive the investment. ***In the case of a roof investment analysis it is unlikely that the roof will generate a positive NPV and hence, the roof with the least negative NPV is the better investment outcome.***

Simple payback period on total project investment (yrs) – the number of years required to pay back the *total project* investment, computed by the Calculator. This payback measure is calculated assuming the total project cost was funded out of cash-on-hand – i.e., it assumes that no annual financing costs are involved. Essentially, the simple payback period measure helps identify projects that will be unusually profitable or unprofitable early in their life. However, since the method ignores benefits and costs over the remaining service life of a project beyond the payback year, it imposes a bias against long-term projects with relatively long payback periods in favour of short-lived projects with quick paybacks. While the simple payback period should not be used as the primary indicator to evaluate a project, it is useful as a secondary measure to indicate the level of risk of an investment – a quicker payback period is usually an indicator of less risk.

Internal Rate of Return (IRR) on investment (%) – determines the discount (hurdle) rate achieved by the investment, and is calculated by the model. IRR is the flipside of the net present value (NPV) calculation and is based on the same principles and the same mathematics. NPV shows the value of a stream of future cash flows discounted back to the present by some percentage that represents the minimum desired rate of return or the cost of capital. The IRR, on the other hand, computes a break-even rate of return. The IRR is the rate at which the value of cash outflows equals the value of cash inflows. IRR should be compared to the investor’s cost of capital or desired hurdle rate; i.e., the investor should avoid an investment in a project if its IRR is less than the cost of capital or minimum desired hurdle rate. The Calculator reports IRRs between –20% and +50%. If the calculated IRR is less than –20%, the Calculator will provide a message – “IRR not available-very negative”.

3 Brief Case Study

This section presents a brief, generic case study to demonstrate data requirements and use of the GRHC *GreenSave Calculator*. This particular case study was developed for a new 4 story multi-unit residential building (20 rental dwellings) located in Toronto with a concrete roof deck. The building owner is considering three roofing solutions – a conventional modified bitumen roof, a PVC single ply “cool roof” design and an inaccessible extensive green vegetative roof. To follow this case study in the Tool – open file “*generic user guide case study*” file from the shared case study file menu.

3.1 Case Study Description

Objective: determine the financial viability of these three roofing alternatives using the GRHC *GreenSave Calculator* over a study period of 25 years – the expected life of the green roof system. That is, determine whether the higher initial cost of a green roof system, relative to the two less capital-intensive alternatives is warranted given the extended durability of the green roof and future lower annual costs.

Building and system requirements information: The 4 story MURB has twenty rental dwelling units of various sizes with a concrete roof deck area of 385m² (4144 ft²) and a perimeter of 85m (1260ft). The heat for the building will be met by a natural gas boiler and the cooling load will be handled by a series of electricity powered air conditioning roof top units. The builder’s mechanical engineer estimates that the annual typical heating and cooling fuel requirements for the building would be 9474 m³ of natural gas and 2778 kWh of electricity for a typical roofing scenario (i.e, conventional modified bitumen). Further, the mechanical engineer estimates that a single ply cool roof design would reduce the cooling electricity demand by 7% on an annual basis, while the extensive green roof would achieve the same cooling load reduction as well as reduce the heating fuel demand by an additional 2% per annum. The owner will charge rent with heating and cooling included in the rent, so all energy use savings would accrue to the building owner.

The city of Toronto offers a one-time \$10/m² (\$0.93/ft²) storm water mitigation grant for the installation of green roofs capable of attaining a 50% reduction in run-off, which the green roof is designed to retain. The building owner has also been advised that the city is

also “fast tracking” green buildings through the permitting process and the general contractor believes this fast tracking will save the owner \$2,500 in development fees. Lastly, the building owner believes that employing a green roof will reduce rental unit turnover and improve the marketability of the building, thus reducing rental management costs by \$3,000 per year.

Financial Information: The building owner has received installed roofing quotes and other information as described in the Table below:

	Conventional Modified Bitumen	PVC Single Ply – Cool roof	Extensive Green Roof
Initial installed cost ¹	\$49,728	\$41,440	\$103,600
Cost per ft ²	\$12	\$10	\$25
Roof Durability (yrs) ²	16	12	25
Annual Maintenance Cost ³	\$761	\$557	\$1200
Annual Energy Cost ⁴			
Electricity for cooling (@\$0.09/kWh)	\$250	\$233	\$233
N. Gas heating (@ \$0.28/m ³)	\$2,653	\$2,653	\$2,600
Estimated Replacement Cost ⁵	\$58,016	\$49,728	\$0
Periodic Replacement Salvage Value ⁶	\$0	\$0	\$23,200
Landfill Cost at Replacement ⁷	\$1,473	\$982	\$0
End of Life Residual Value ⁸	\$27,972	\$37,987	\$0
Storm Water Mitigation ⁹	\$0	\$0	\$3,850
Development Fees ¹⁰	\$0	\$0	\$2,500
Building Marketability ¹¹	\$0	\$0	\$3,000

¹ initial installed capital cost includes labour and materials (e.g., membrane, vapour barrier, insulation, flashing + additional materials for the green roof system – drainage plane, root barrier, filter fabric, 6” of soil and plant materials) – entered directly in LCC Assumptions and Results Module

² roof expected life entered in Roof Durability Module

³ Annual maintenance cost for Mod Bit and PVC roof estimated at 2% of initial capital cost, green roof annual maintenance estimated at \$0.30/ft² – entered directly in Roof Durability Module

⁴ annual energy prices and cost by fuel type entered in Energy Use Module

⁵ Estimated Replacement cost = initial installed cost + tear-off cost (if applicable). Tear-off cost estimated at \$21.50/m² (\$2/ft²) – values entered in Roof Durability Module

⁶ Neither the conventional modified bitumen or PVC roof have any salvage value at the end of their designated replacement periods. The extensive green roof will salvage a portion (e.g., 80%) of its insulation, soil and plant materials when it is replaced – at 80% recovery the estimated salvage value of these materials is \$23,206 (80% of their original cost) - values entered in Roof Durability Module

⁷ Landfill cost is based on landfill rates (\$85/ m ton) in Toronto and mass of roof materials going to landfill. Landfill costs are added to replacement cost in the Tool – see Roof Durability Module

⁸ End of Life Residual Value estimated as follows: [(roofing life span years remaining after study period)/life span] * initial installed cost - Conventional Mod. Bit. – (9/16 x \$49,728 = \$27,972; PVC roof – (11/12 x \$41,440 = \$37,986; green roof has no residual value as a roof - see Roof Durability Module

⁹ Storm water mitigation – applicable to the green roof only, treated as a one-time initial capital cost offset – see Storm Water Mitigation Module

¹⁰ Development Fees – permit “fast tracking” benefit that is applicable to the green roof only, treated as a one-time initial capital cost offset – see Development Fees Module

¹¹ Saleability–Rentability – combined effect of increased building marketability and reduced rental administration cost – applicable to the green roof only- See Saleability–Rentability Module

The discount rate to be used will be equal to the current cost of capital (8%) faced by the owner-developer. The prevailing price of natural gas and electricity is \$0.44/m³ and \$0.09/kWh, respectively. General inflation is expected to average 2.2% per year.

3.2 Case Study Results

The results below indicate that all of the roof system investments considered do not yield a positive return on investment or payback their respective costs. Typically roofs are a necessary and ongoing cost and do not generate positive cash flows; hence the poor IRR and the inability to payback the initial investment cost are not surprising. The NPV too, for all the projects, is negative at a discount rate of 8%. Given that a roof is an unavoidable building cost we wish to minimize this cost over the investment-holding period. The green roof is the least cost roofing option over the 25-year holding (study) period. However, if the building owner were possibly only going to keep the building for only 8 years, the owner would be better off employing the lower cost PVC roofing system, everything else being equal. This result underscores why building developers who plan to turn the building over quickly typically emphasize lower initial costs when contemplating roof systems. After 16 years (two-thirds of the study period) the extensive green roof is cost competitive with both alternative roofing systems, but it is not until the last third of the study period where the longer durability of the green roof system actually starts to pay-off relative to the other two roofing alternatives.

	At yr.	Conventional Modified Bitumen	PVC Single Ply – Cool roof	Extensive Green Roof
NPV for study period (yrs)	25	\$(158,068)	\$(156,380)	\$(145,579)
NPV at year (one-third of study period)	8	\$(78,236)	\$(68,561)	\$(109,463)
NPV at year (two-thirds of study period)	16	\$(130,175)	\$(121,285)	\$(126,866)
Simple Payback Period on total project investment (yrs)		Payback period longer than study period	Payback period longer than study period	Payback period longer than study period
Internal Rate of Return (IRR) on Investment (%)		IRR not available-very negative	IRR not available-very negative	IRR not available-very negative