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PUBLIC LIBRARY

Paula A. Kiely
Director

February 2, 2009

Alderman Robert Donovan
City Hall, Room 205
200 E. Wells St.
Milwaukee, WI 53202

Dear Alderman Donovan,

I am writing in response to the request of the Public Works Committee for additional information about the Library's green roof project. Capital funds in the amount of $950,000 have been included in the 2009 budget for this project. No additional City funding is being requested.

Enclosed are two studies we read before requesting funding for this project. Among the benefits mentioned are:

- A significant increase in the life span of underlying roofing material. Conventional roofs are expected to last 15 - 20 years as compared to 40 - 90 years for a green roof.
- Reduced costs. The University of Michigan study cited a savings of 25 – 29 percent less over a 40 year period with the investment breaking even after 20 years.
- Other benefits include reduction to stormwater runoff, improvement of thermal insulation, reduction of sound "pollution," and an increase in property value. Due to the Central Library's location on a heavily-trafficked portion of Wisconsin Avenue, the reduction in stormwater runoff has positive implications for our visitors using the sidewalks as well as for reducing the probability of localized street flooding.

Also enclosed is the cost benefit analysis prepared by the Budget Office last year in response to the Library's request for funding. The analysis shows:

- A total savings of $438,344.93 in energy costs over 40 years.
- A conservative estimate of overall savings of $294,232.39 in today's dollars over 40 years. If the experience of the Library reflects that of many other green roof projects, the savings that result from a longer useful life of the roof will be even greater.

I've provided several articles about green roofs that discuss the benefits of green roofs, including one from the University of Wisconsin Milwaukee's Great Lakes Water Institute.

And, as was recommended, I have contacted Jeff Mantes, Commissioner of the Public Works Department about this project. The Budget Office and I will be meeting with his staff to discuss the green roof project on the 809 Building and the Library's plan to install a similar roof.

I hope this information is helpful in answering your questions. If you'd like further information I will be happy to assist you.

Sincerely,

Paula A. Kiely

Paula A. Kiely
Director

C: Mark Nicolini, Budget and Management Director
Jake Miller, Budget and Management Analyst
Taj Schoening, Library Business Operations Manager
Kim Montgomery, Mayor's Office

Enclosures

LIFE CYCLE COSTS OF GREEN ROOFS
- A Comparison of Germany, USA, and Brazil -

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Abstract - Within the last decades, the trend to ever larger dwellings and the increases in industry and traffic have resulted in the continuous growth of cities. The settlement surface in Germany has doubled within the last 40 years and present growth amounts to 1.1% per year. In the USA, the built on surface extends by 3% per year; in Brazil this number may be much higher. Together with increasing emissions, especially caused by traffic, industry and domestic burning, this increase in settlement surface has led to a noticeable impairment of the urban climate. The climate of cities, in comparison to the climate of open land, in most cases has negative effects on urban inhabitants. For example, sleep disturbances and heart disease may be more prevalent. The limited available space in cities makes roof gardens an attractive possibility to improve the urban situation. In Europe, green roof technology has become increasingly important within the last 20 years. In the USA, green roof technology started two years ago and is now growing rapidly. Use of green roofs in Brazil is infrequent, but there, as in all countries, a substantial benefit of roof planting is the economic gain. This work presents these advantages by comparing green roofs with other kinds of roofs. The work presented here is preliminary, and is to be continued in the context of a thesis (diploma). Our first results should be useful for planners, architects, builders, and other experts involved in roof greening. The authors are looking forward to receive detailed information to calculate the benefits as well as possible.

Life Cycle Costs

The following benefits of green roofs can be judged by financial criteria. Although in most cases, one benefit alone is not enough to justify the installation of a green roof, we have to examine the benefits separately:

1. extension of the life span of the underlying waterproof system
2. reduction of the stormwater runoff
3. improvement of thermal insulation
4. reduction of sound reflection and transmission
5. increase in property value

Costs

Together with the underlying roof waterproofing, an extensive green roof Installation in Germany at present costs approximately 85 $ per square meter. The costs are roughly twice those of a conventional roof. In the USA the costs are similar. In Brazil the costs are 30% of these values. Compared to generally in all three countries low-priced pre-fabricated or welded roofs, green roofs cost about three times more. The low-priced roofs, however, require replacement or major repairs after approximately 15 years, whereas green roofs will survive thirty or more years (Table 1).

35 years of experience with green roofs in Germany demonstrate the value of the roof planting as protection of the waterproofing membrane. A roof which is covered with planting can be expected to outlast a comparable roof without greening by a factor of at least two. Although modern green roof planting systems are not more than 35 years old, many researchers expect that these installations will keep 50 years and more. The old green roofs in Berlin demonstrate a life span of more than 90 years before they require important repairs or replacement. In Germany 90 years is a typical lifespan so it is the time base for the following text.

Table 1: Life cycle costs during the lifespan of different types of roofs in Germany (construction and repair costs, disposal and recycling costs – not including maintenance). Data is based on a estimated 90-year building life cycle with a 100 m² roof. Costs are calculated per m². (own generalised calculation of projects and publication)

Type of Roof	**Construction costs in $/m²**	**Repairs (interval in years)**	**Renovation after... years (average)**	**Renovations costs during life span ($)**	**Reconstruction RC /Disposal and recycling – costs: RECY ***	**Sum ($/m²)**
Bitumen roof	40	Every ten years	After 15 years	6 x 40 = 240	20 RC, 20 RECY	320
Gravel roof	50	Every 15 years	After 15 – 20 years.	About 200	25 RC, 25 RECY	295
Extensive green roof without PVC-products	90	-	Temporally only occasional renovation work	40	40 RC, RE -.-	170
Extensive green roof with PVC products	85	-	Temporally only occasional renovation work	40	40 RC, 20 RECY	185
Intensive green roof without PVC-Products	380	-	Temporally only occasional renovation work	At last in maximum up to 380 (the same cost as the building costs during the whole lifespan)	100 RC, RECY -,-	860
Intensive green roof with PVC-products	340	-	Temporally only occasional renovation work	340	100 RC, 40 RECY	820

Depending on environmental regulations, the charges could rise in the next years! A waterproofing layer is necessary. But the PVC-layer causes problems in production and in terms of recycling.

Vegetation layer

When selecting plant material, the extreme living conditions must be considered. (Table 2):

Table 2: particular conditions on green roofs

strong winds	risk of breaking, drying up of plants (winter)
shallow soils	drying of substrate and wind erosion
intense sun radiation	higher evapotranspiration, leaf damage by heat, increased frost susceptibility during winter
limited volume of growing medium	restricted growing

Maintenance, Durability

Table 3: Annual and life span costs of the time of 90 Years of inspections and maintenance for the different roof types (related to the $100 m^2$ roof example), data per m^2.

Type of roof	**Annual requirements**	**Lifespan cost per m^2**	**Sum ($\$/m^2$)**
Bitumen roof	Optical inspection: only every five years, about 100 $ per roof inspection	0.2 (annual per m^2) x 90	18
Gravel roof	The same as a bitumen roof!	"	18
Extensive green roof	Annual optical inspection and removal of tree seedlings, 100 $ per visit	1 x 90	90
Intensive green roof	8 times in a year, about 100 $ per visit	8 x 90	720

All roof planting requires maintenance (Table 3). Extensive greening is low maintenance, i.e. after desired surface coverage, irrigation is no longer necessary. Temporary drying is desirable. Weeds, particularly tree seedlings, should be removed regularly (1-2 x/year). A higher proportion of mineral content in the substrate will reduce the development of weeds and therefore also reduce maintenance expenditure.

Extensive roof planting should not be fertilized. Fertilizing of intensive roof gardens depends on the composition of the substrate and on the selection of the plants. Regular maintenance and observation of the plants is very important. For extensive greening with Sedum, no pruning is necessary. The plants of an intensive green roof require the same pruning measures as on a ground location. Roof waterproofing as well as the drainage systems are to be inspected regularly (2 x/year) and cleaned if necessary. Inspection and maintenance costs are affected to a large extent by local wages (Table 4). The labour costs in the USA amount to approximately 50% of German labour costs. In Brazil they may be no more than 10%.

Table 4: Minimum hourly wages

GERMANY	USA	BRAZIL
10.36 $	5.25 $	< 1$ (240 R$ / month)

Well-being

If roof planting in the past was predominantly intended for architectural reasons, then today it is regarded as a compensation for displaced nature. Surveys of the inhabitants of large cities showed that 70-80% of the population feels itself underprovided with green in the neighbourhood. A study of 25 large German towns concluded that in nearly all cities 40% of the urban surfaces are covered and sealed and in some cities even 50%. It is interesting that the portion of sealed surface nearly doubled in the past 30 years even though the population shrank.

Table 5: Ecological and human benefits of green roofs (x means a benefit exists; xx = high value, - means no benefit existing)

Type of roof	**Visual quality**	**Health and recreational benefits**	**Bio-diversity**	**Stormwater retention (av. retention and financial savings)**	**Energy savings**
Bitumen Roof	-	-	-	-	-
Gravel roof	-	-	-	-	-
Extensive green roof	X	X	X	75%, (15 $\$/m^2$ for construction; 1,--/m^2 x a). 90.2 $/ /lifespan	X
Intensive green roof	XX	XX	X	100%, 90.2	X

One of the reasons for this is surely a rising requirement for each person's space. Nature moved to the periphery of the cities and a direct connection to nature for urban dwellers was made more difficult or completely lost. The greening of buildings in large towns and cities brings back a part of the lost nature to the citizens without requiring more space (Table 5).

Stormwater / Rainwater

Widespread impervious surfaces frequently result in an overloading of drainage networks and purification plants which in turn causes flooding and overspill of polluted wastewater into nearby bodies of water. To avoid these unpleasant and expensive consequences there are two possibilities: extension and enlargement of the sewer systems and purification plants, which is connected with high costs, or decrease and delay of the stormwater runoff. A suitable method to reduce the stormwater runoff is to plant green roofs (Table 6).

A green roof does have runoff. However it can be strongly reduced and delayed so that even in limited spaces, the infiltration of the surplus water on the property becomes possible. According to the FLL, the stormwater runoff of green roofs (10 cm soil) compared to non-green roofs is reduced by 50 %. Also in Germany these coefficients will be modified by new researches, but the administration actually uses in most cases the following old values.

Table 6: Stormwater runoff coefficient according to roof type

roofs without greening	**green roofs with a slope up to 5°**	**Green roofs with a slope over 5°**
roof surface > 3° slope: **1.0**	< 10 cm structure thickness: **0.5** 50 % less	Independent of structure thickness: **0.7**
roof surface < 3° slope: **0.8**	10-25 cm structure thickness: **0.3**	
gravel roofs : **0.5**	20-50 cm structure thickness: **0.2**	
	> 50 cm structure thickness: **0.1**	

Many German municipalities are currently charging annual fees for stormwater which accumulates on impervious surfaces. Obviously conventional roofs are considered to be impervious surface. For green roofs, the runoff coefficient is used to determine how much runoff will be introduced into the public sewer and how much annual fee must be paid. Therefore green roofs help to store precipitation .

Thermal insulation

The thermal insulation of a green roof is based on different layers which reduce the energy passage. This insulating effect is not constant but dependent on the weather and influenced by the water content of the layers, the water flow in the drainage layer and the wind velocity. Therefore the calculation of the insulating effect is difficult. The factors which can influence the thermal protection can be divided into the factors of heat transfer and convection. During heat transfer, the thermal protection is essentially based on cavities in plates or substrate and on air in spaces between substrate components. As well, the air within the vegetation works as thermal insulation.

During heat transfer, the absorption and reflection of the long-wave radiant heat from the building plays an important role in thermal protection. The nocturnal heating of the soil layers due to the root is likewise apparent. The surface roughness of the sod layer as opposed to a smooth tar roof causes a decrease in convection losses. The wind energy is converted in stems, stalks, leaves, etc. into warmth. The saving of energy, in particular at low temperatures, is also connected with the displacement of the freezing point from the roof surface into the soil layer.

The coordination of all factors has an effect, as though the vegetation layer would have the same heat conductivity of expanded clay. After Roofscapes(2002), a 10 cm green roof layer is equivalent to 5 cm of a normal technical insulation material but this is only a draft point of view. . Thus the insulation values are improved by about 25 % with extensive greening. This improvement serves not only the thermal insulation in the winter, but also decreases the temperature of underlying rooms in the summer. Substantially lower temperatures (on average 3-4 °C, Roofscapes, 2002) were measured in underlying rooms after roof greening. For buildings in the tropics, this is surely a factor which would favour greening. Especially in Brazil, with its constant energy requirement mostly due to the many air conditioning systems, this reduction in temperature would bring advantages. But until now there still exists a gap of climate measurements under tropic conditions.

Noise Insulation

Without increase of the mass of green roof construction materials, an improvement of the insulation of airborne sound can be achieved by roof planting, since the large cavities of a gravel layer in greening material are avoided. If the green roof thickness increases, the insulation of airborne sound continues to improve. A substrate depth of 20 cm can improve sound absorption up to about 46 dB (A). This is in particular interesting within the range of approach lanes from airports. On low buildings in the effective range of altitude acoustic sources, such as in trade and industrial areas, green roofs possess special importance. Conventional roofs reflect the sound whereas green roofs absorb it. The noise level can be reduced by 2 to 3 dB (A) compared to gravel roofs (Koch &.Seitz, 1998). A green roof can thus be considered as element or alternative in structural noise control – but also here are until now only a few measurements done.

Increase in property value

On the international estate markets, the consequences of economic weakness are generally visible. The demand for office space has clearly diminished, which is expressed in low rental rates (Table 7). Only in prime urban locations do the price level and occupancy rate remain stable. Generally the market is dominated by falling prices and decreasing occupancy.

Table 7: rental rates of the largest cities (DEKA Immobilien Global (31.03. 2003):Semi-annual report)

	GERMANY (Berlin)	USA (New York)	BRAZIL (Saõ Paulo)
Vacancy rate %	8	9	15
Top rents / m² / per year	300 $	550 $ (55 sq.ft.)	200 $

Table 8: Different roof types and their rental advantages (in $ /m²) (x = obligatory) (1): The calculation of rental rates in Germany is regulated; an additional 1/4 of the normal rent is allowable for terraces and roof gardens. For example, an average rent: 10,- ($ /m²)/4 x 12 Month x 90 Years. The rent of this roof garden is similar to an additional room in the flat of 25 m²!)

Type of roof	Waterproofing is required	Higher rent	Value in higher rent
Bitumen roof	X	-	-
Gravel roof	X	-	-
Extensive green roof	X	- (perhaps)	- reduction of stormwater fee
Intensive green roof	x	Yes	2.700,-- (1)

Ignoring the other benefits, green roofs are an architectural advantage. In new projects they can be considered as substantial elements of the entire landscape. Still more important, they can change traditional roofs into "roof landscapes" and this could lead to an economic advantage with the letting and the sales of buildings (Table 8). In many cases they can also be used in order to create passive recreation areas for employees and inhabitants. Often this value alone can justify the installation of a green roof.

Results

In the long-term, green roofs are more economical than non-greened roofs (Table 9, Figure 1). The same results are also found by another author (Haemmerle, 2002). The extensive green roof is inexpensive, with high visual quality ("beautiful"), and if all the additional advantages are calculated, the cost-benefit ratio will be rise further.

Roof gardens are not possible on all buildings, but if the construction allows a roof garden, a higher value of the flat is one consequence.

Many ecological benefits are still difficult or impossible to calculate, but the numbers provided here should help to make the decision for both types of green roofs easier.

What about in the US and Brazil?

In the US, roof gardens are becoming more and more fashionable. There is no regulation of the rental rates as in Germany, but the better quality of the flats also has a consequence on the price.

In Brazil, people prefer roof flats with green terraces because of the garden views. In tropical climates the life outside requires open green spaces. Many examples in Rio Sul demonstrate the same results!

Table 9: Total cost – benefit overview of the estimated lifespan of 90 years in $ per m²

Type of roof	**Construction, inspection and disposal/recycling costs (from Table 1, $)**	**Total maintenance (from Table 3, $)**	**Financial benefits / increased rental income (Table 5 + Table 2, $)**	**Total costs (-) or total profit (+) per m² (Column 2 + 3 –5, $)**
Bitumen roof	320	18	- -	338,00 -
Gravel roof	295	18	- -	313,00 -
Extensive green roof without PVC products	170	90	90,2	169,80 -
Extensive green roof with PVC products	185	90	90,2 –	184,80 -
Intensive green roof without PVC products	860	720	90,2 + 2.700,00	1.210,20 +
Intensive green roof with PVC-Products	820	720	90,2 + 2.700,00	1250,00 +

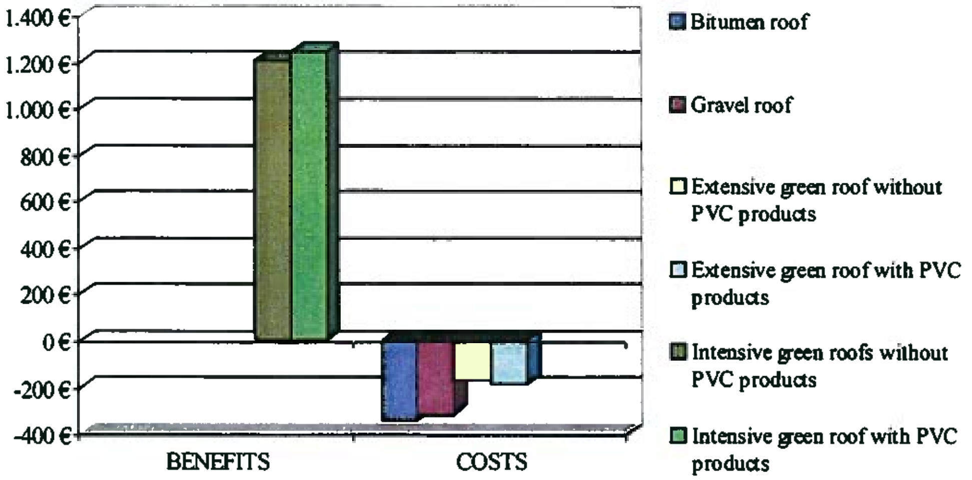

Figure 1: A first total cost – benefit overview of the estimated lifespan of 90 years in $ per m²

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Green Roof Valuation: A Probabilistic Economic Analysis of Environmental Benefits

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Green (vegetated) roofs have gained global acceptance as a technology that has the potential to help mitigate the multifaceted, complex environmental problems of urban centers. While policies that encourage green roofs exist at the local and regional level, installation costs remain at a premium and deter investment in this technology. The objective of this paper is to quantitatively integrate the range of stormwater, energy, and air pollution benefits of green roofs into an economic model that captures both the building-specific and city scale implementation. Currently, green roofs are mainly valued based on increasing the roof longevity and their ability to reduce stormwater runoff, with occasional consideration of reducing building energy consumption. Proper valuation of these benefits can reduce the present value of a green roof if investors look beyond the upfront capital costs. In this paper a net present value (NPV) analysis comparing a conventional roof system to a green roof system demonstrates that at the end of the

conventional roof. The mean difference between the cost of the green roof and the conventional roof is defined as the cost gap. The internal rate of return was then determined for each environmental benefit.

Stormwater Fees and Reductions Stormwater volume reduction by green roofs benefit municipalities; however, not all local water authorities pass the economic savings on to the owner of the green roof. Traditionally, the budget for stormwater management is provided through property taxes or potable water use fees. In recent years, municipalities have been moving toward stormwater fees based upon total impervious surface on a property, creating an opportunity to "credit" green roofs for stormwater reduction. For this study, data were collected from eleven municipalities with established stormwater management fees (Table 1, SI). It was assumed that the reduction in stormwater fees due to a green roof is normally-distributed at fifty percent of the stormwater fee for the building footprint. Impacts to stormwater infrastructure are only assessed at scale.

Energy Savings Determination and Valuation This study focuses on energy savings to mixed-use administrative/laboratory buildings at the University of Michigan campus in Ann Arbor, Michigan. Total expenditures for energy (natural gas and electricity) consumption (mean $225,000), total energy consumption (mean 4050 MWh), and energy consumption by fuel source (mean 2370 MWh from electricity and 1670 MWh from natural gas) were obtained for 130 university buildings for fiscal year 2003. National commercial building energy consumption

Central is $360,000

statistics provided additional data (e.g. average commercial conductance, system load factors) (24). To determine the roof's contribution to the HVAC energy requirement, the heat flux through the roof was determined according to the following 1-dimensional heat flux equation:

$$\dot{Q} = h \cdot A \cdot \Delta T \qquad \text{(Equation 1)}$$

where Q is the heat flux through the roof (W), A is the area of the roof (m^2), ΔT is the temperature difference between the building interior and the ambient temperatures (K), and h is the heat transfer coefficient ($W/m^2/K$).

$$h = \frac{k}{\Delta x} = \frac{1}{R} \qquad \text{(Equation 2)}$$

h is a function of the thermal conductivity of a material, k, and the material thickness, Δx. The inverse of h is the R-value, which represents a material's resistance to heat flow. The larger the R, the less heat flux Q. In the construction industry, R-value ($ft^2 * °F * h/Btu$) is commonly used to compare the effectiveness of insulation in building materials. An average R-value of 11.34 $ft^2 * °F * h/Btu$ (conductance of 0.50 $W/m^2/K$) was assumed for the conventional roof according to national commercial building data (24).

Now .10 kWh so 25% higher

Energy costs due to the heat flux were determined assuming natural gas for heating and electricity for cooling. With available energy expenditures per university building, prices were assumed to be \$0.08/kWh for electricity and \$0.02/kWh of natural gas. Energy savings through the use of a green roof were based on an assumption of an R-value of 1.2 $ft^2 * °F * h/Btu$ (conductance of 4.7 $W/m^2/K$) per centimeter depth for a 10.2-cm soil media. The total combined R-value for a conventional roof with a green roof is 23.4 $ft^2 * °F * h/Btu$ (total conductance of 0.24 $W/m^2/K$).

There are several factors that could explain the difference in plant uptake rates (green house vs. UFORE model). The UFORE-D model limited the uptake, which was determined from calculations of atmospheric pollutant flux, boundary resistance, and a hybrid of big-leaf and multilayer canopy model (45), to a mix of two types of plants. The minimum uptake rate for this study is the same order of magnitude (Figure 1, SI) as the value determined by the UFORE-D model (0.002 $kg_{NO2}/m^2/y$). The UFORE-D model is based upon hourly weather conditions and assumes that uptake occurs only via dry deposition of pollutants onto vegetation (45). While this assumption is valid when NO_2 is considered, fast reaction rates in the troposphere yield compounds that are more water soluble (e.g. HNO_3) (46). Periods of precipitation were assumed to result in no pollutant uptake; the reported values of NO_2 uptake using the UFORE-D model would be expected to be less than the values used in the current study.

Large-scale roof greening also indirectly benefits public health by reducing energy consumption. Green roofs can reduce peak energy demand resulting in fewer atmospheric emissions from power plants that run additional generators at peak times. Based upon emissions data for coal-fired utilities and natural gas combustion, estimates for avoided emissions for greening ten percent of Chicago are 2.21 million Mg_{NO2}/y and for Detroit are 1.83 million Mg_{NO2}/y (Table 4, SI) (47). Combining both direct (plant uptake) and indirect (fossil fuel reduction) methods of emission mitigation, greening ten percent of area roofs in Detroit would decrease public health costs by \$3.1 billion to \$11.8 billion per year, and in Chicago public health benefits would be \$3.8 billion to \$14.2 billion per year.

Net Present Value Analysis

The results were integrated into an economic model to determine the length of time required for a return on investment (ROI) in a green roof. Figure 1 shows the results of the analysis over the lifetime of the green roof system, and evaluates the green roof under a low air pollution benefit and a high air pollution benefit. The green roof is more expensive than the conventional roof at installation ($464,000 versus $335,000). Over the 40-year lifetime of the roof, the NPV of the green roof system is between 25% (low air pollution benefit estimate) and 29% (high air pollution benefit estimate) less than the NPV for a conventional system ($602,000).

Under the low estimate for health benefit valuation, the greatest potential economic contribution is due to energy savings. Annual benefits for the green roof system in this scenario are $2740 (2006$) per year. Energy savings account for nearly $1670 or 61% of the benefits. In this scenario, benefits due to mitigation of nitrogen oxides account for 33% of the annual benefits. Stormwater fee savings only account for 7% of the annual benefits.

$2,750
Gr Central's
rates.
X1.25 higher rates
,3,437

When a high estimate for valuation of public health benefits is used, air pollution mitigation becomes the dominant benefit economically. With total annual benefits of $5240, 65% of the benefits ($3390) are attributable to air pollution mitigation. Energy savings remain the same but account for only 32% of the total annual benefit. The stormwater benefit is further reduced to only three percent of the total. While the monetary value of the health benefits is uncertain, in both the high and low estimates, public health benefits contribute significantly to the total annual benefit of green roofs.

While currently green roof adoption is driven by stormwater benefits and energy savings (48), benefits due to direct air pollution uptake and energy savings control the ROI. Additional savings due to reduced onsite stormwater infrastructure are not included at the building scale as infrastructure savings at individual building sites could only be realized for new building construction or significant renovation projects. Similarly, while system loads to HVAC were taken into account to determine the total reduction in energy, infrastructure savings (from size reduction) were not included. This analysis focused on the opportunity for green roofs on existing buildings that could support an extensive vegetated roof with minimal impact on the building and roof. All other parameters remaining constant, varying degree days to evaluate other climate regions (the southeastern states or the western states) changed the total energy consumed resulting in the $2000 range for both the conventional and the green roof.

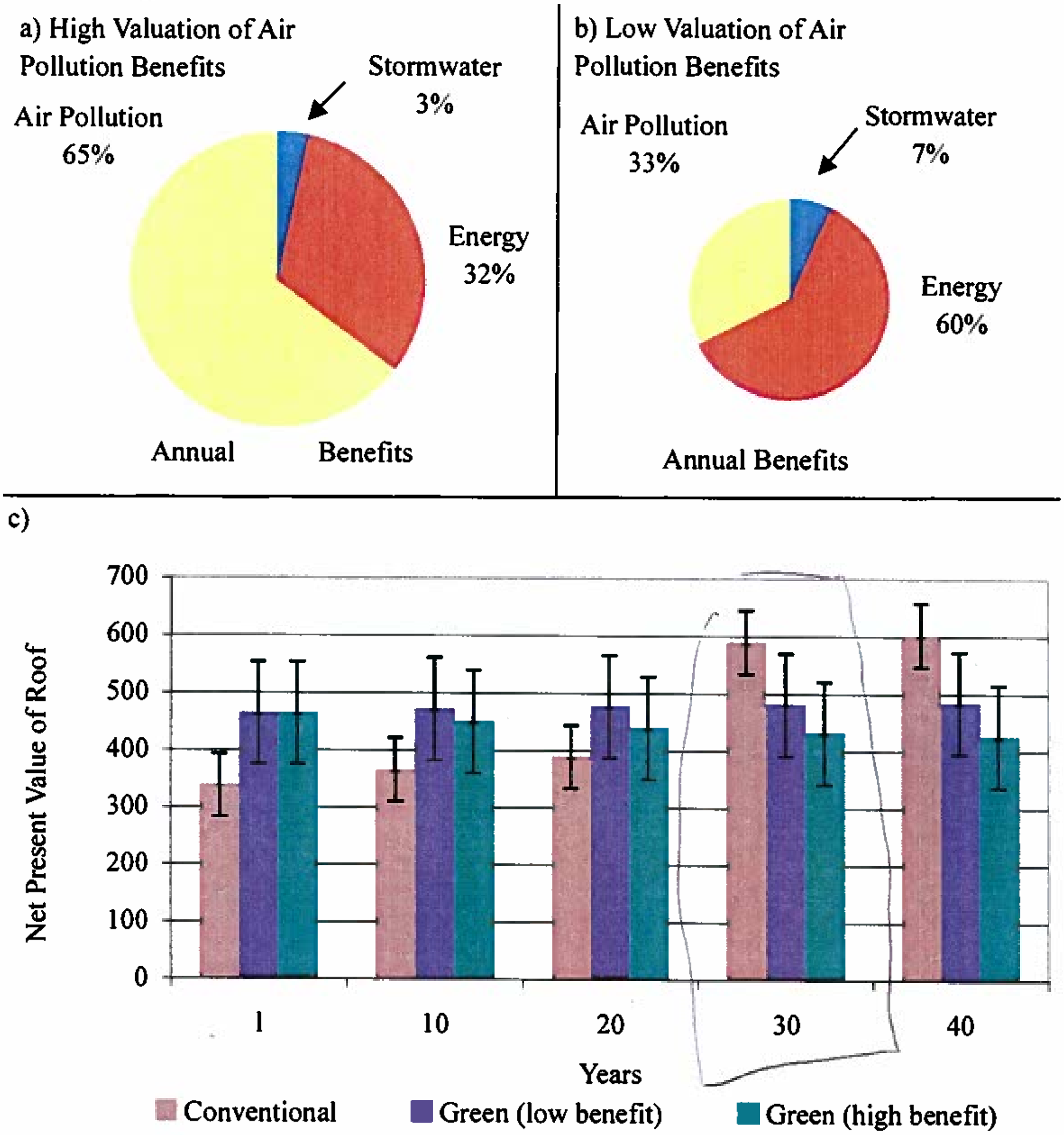
For large-scale urban greening projects, it should be noted that not all of these roofs may be conducive to green roof implementation due to restrictive architectural features (e.g. roof slope, HVAC system placement, structural limitations of building). The analysis contained here limits roof greening to twenty percent of existing roofs, similar to the analysis for Washington, DC by Deutsch et al. (15). For scaled stormwater benefits, the economic savings are over the long-term after greening projects began most likely occurring during normal maintenance and replacement of existing stormwater infrastructure.

Policy Implications

The mean green roof cost is 25 to 29 percent less over 40 years, with the investment breaking even after twenty years. Incorporation of air pollution benefits the greatest potential social cost factor into the economic analysis. Further work is required to incorporate HVAC size reductions, stormwater infrastructure size reductions, and multiple air pollutant reductions. Results from this analysis revealed that the benefit of improved air quality should not be ignored by policymakers as proper valuation of the benefit can greatly influence the NPV.

Proper valuation of environmental benefits requires changes to current policies that affect green roofs. Currently, the analysis performed here incorporated mean stormwater fees at \$ 0.17 per m^2 of land, yet projected long-term control plans are at \$3.36 per m^2 of land. Inclusion of these costs will impact the benefit analysis. Policies that make stormwater infrastructure expenses more transparent to the citizenry through stormwater fees or a market-based tradable permit scheme for contribution to impaired local waterways are two strategies that have potential to rectify the price discrepancy. Translating the air pollution mitigation ability of green roofs into an economic benefit to the technology would further reduce the NPV by 9%. This could be achieved through direct incentives reducing the upfront cost of a green roof or through the incorporation of green roofs into existing regional air pollution emission allowance markets. Further research into these policy alternatives will aid the design and development of strategies to translate the societal environmental and health benefits of green roofs to the building owners that ultimately construct green roofs.

To quantify the benefit of reducing NO_X emissions for building owners, green roofs could be integrated into the existing air emission allowance markets. If green roofs are considered an abatement technology, then incorporating sinks into a cap-and-trade program could allow the pollution taken up by a green roof to be traded on the open emissions allowance market. Such a program does not currently exist, in part due to the constraints placed on the demonstrations that a new technology fits abatement criteria. On-going research through professional organizations such as Green Roofs for Healthy Cities have emphasized the need for quantitative measurements of the green roof benefits (stormwater, energy, air) as a priority for influencing regional and national policy in this realm.


a) High Valuation of Air Pollution Benefits
Stormwater 3%
Air Pollution 65%
Energy 32%
Annual Benefits
b) Low Valuation of Air Pollution Benefits
Air Pollution 33%
Stormwater 7%
Energy 60%
Annual Benefits
c)
Net Present Value of Roof
700
600
500
400
300
200
100
0
1
10
20
30
40
Years
Conventional
Green (low benefit)
Green (high benefit)

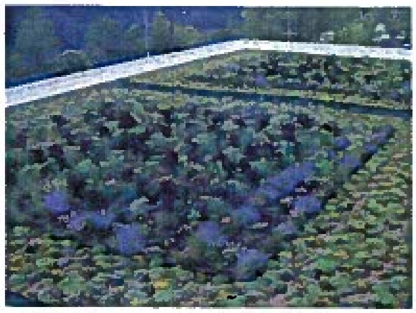
• the greenroof projects database • greenroofs.com

University of Wisconsin-Milwaukee Great Lakes Water Institute

GREENGRID
The Natural Choice for Your Roof

Project Name: University of Wisconsin-Milwaukee Great Lakes Water Institute
Year: 2003
Owner: University of Wisconsin-Milwaukee
Location: Milwaukee, WI, USA
Building Type: Educational
Greenroof Type: Extensive & Intensive, Test/Research
Greenroof System: Single Source Provider
Roof Size: 6480 sq.ft.
Roof Slope: 1.5%
Access: Accessible, Private
Submitted by: Sandra McCullough

Designers/Manufacturers of Record:
Modular Greenroof System: GreenGrid
Installation Contractor: GreenGrid™/Weston
Greenroof Design: GreenGrid™/Weston



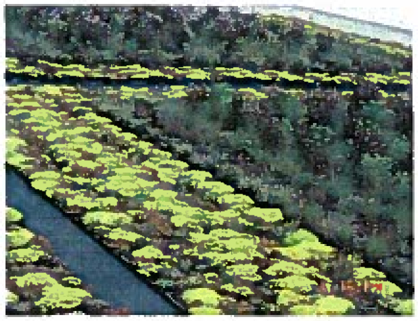
In September 2003, the University of Wisconsin Great Lakes Water Institute (GLWI), located in Milwaukee's inner harbor, installed a 6,480 sf GreenGrid™ green roof. The purpose of the green roof was to demonstrate an innovative and cost-effective stormwater Best Management Practice (BMP) that can be utilized in the Milwaukee metropolitan area and within The University of Wisconsin System. This green roof was planned to provide a working model strategy for stormwater management in urban areas. The goals for the GLWI green roof project are to research and document the benefits of green roofs including the following:

1) Reduce stormwater runoff volume and pollutants from the GLWI site. Having at least 8 inches of planting depth over the 2,500 ft2 green roof area could nearly absorb 75 gallons per minute of runoff. This added roof permeability could decrease future roof runoff to 30% of that from a traditional asphalt and gravel roof. The growth media in the green roof can also reduce peak velocity of runoff, which would facilitate the settling of particulates in the green roof, including fecal bacteria, before runoff reaches the harbor.

2) Document the environmental and economic benefits of green roofs, and establish a precedent for the use of green roof technology in the University of Wisconsin System. A group of Water Institute scientists will monitor the green roof and document its performance in terms of stormwater retention, energy savings, and enhanced roof structural integrity.

3) Provide professional experience in design and installation of green building technology and expose the public to the logistics of green roof implementation and management.

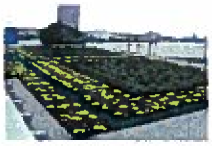
4) Provide an educational environment for the study and promotion of green roof benefits. The GLWI green roof will establish a venue to facilitate communication between civic officials and businesses regarding green building design and construction. This green roof project seeks to engage the Milwaukee community in the potential to develop sustainable cities. The Great Lakes Water Institute's mission combines education and outreach. With a green roof demonstration site, the GLWI can provide an important link between a functioning green roof and the educational efforts of green technology.



The GreenGrid™ green roof was designed using both the extensive and intensive modules, which accomplished the client's desire for greatest species diversity. The design incorporated the GreenGrid™ pavers to surround the plantings, extensive (4-inch) modules to outline the intensive (8-inch) modules, and two center areas of intensive plantings. Assembling the pavers and modules in this pattern gives the appearance of a "step" garden. Further, careful selection and placement of plant species in the modules, according to their mature height, color, bloom-time, and texture, was also undertaken to accommodate the transition. The first step of the design was composed of the GreenGrid™ pavers that are made from 100% recycled tires and stand about 1.5 inches in height. The second "step" consisted of extensive modules. These modules were randomly planted with 5 different species of sedum -- 10 plants per module – and included: Sedum acre, Sedum kamtschaticum, Sedum rupestre 'Forsteranum', Sedum spurium 'Bailey's Gold', and Sedum spurium 'Dragon's Blood'.

The third "step" was composed of intensive modules as a transition area between step 1 and 3. This step of modules covered the first four-feet of the intensive area and were planted with species that grow to a maximum height of 18 inches. Plantings included: Allium cemuum, Carex pensylvanica, Geum triflorum, Nepeta x faassenii, and Sedum 'Vera Jameson'. The remainder of the intensive modules comprised the fourth "step." These intensive modules were planted with species that can grow to approximately 32 inches and offer the most ornamental value to this green roof. Species that were planted include: Aster novae-angliae, 'Purple Dome', Monarda didyma 'Raspberry Wine', Penstemon digitalis 'Husker's Red', Perovskia atriplicifolia, Phlox paniculata David', Rudbeckia fulgida 'Goldstrum', Schizachyrium scoparium, Solidago speciosa, Sporobolus heterolepis, and Tradescantia ohiensis.

Additional thumbnail photos:



Further information on the GreenGrid™ green roof installation at The University of Wisconsin-Milwaukee – Great Lakes Water Institute can be obtained at their website, here. Please visit their live webcam here to see what is happening on the green roof. Learn more about GreenGrid in The Greenroof Directory here.

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S&E SCIENCE AND THE ENVIRONMENT BULLETIN
July / August 1999

Green skylines offer urban re-leaf

Vine-covered façades and lush rooftop gardens offer more than a green oasis in the concrete jungle. Studies show that they can help urban areas adapt to climate change and also decrease greenhouse gas emissions by reducing the energy spent on heating and cooling.

According to scientists, climate change will result in more frequent heat waves and several climate models indicate an increase in precipitation intensity, suggesting the possibility of more extreme rainfall events. These effects will be exacerbated in urban areas, where concrete and pavement reflect heat and prevent stormwater from being absorbed into the ground. In addition, urban areas must also cope with air quality problems, which may worsen in coming years.

Proven to greatly mitigate these impacts, vertical and rooftop gardening has seen a widespread renaissance in Europe in recent years, but is still little used in North America. To investigate its application in Canada, Environment Canada and several private sector partners recently completed a report on the benefits of rooftop and vertical gardens, titled *Greenbacks from Green Roofs: Forging a New Industry in Canada*, for the Canada Mortgage and Housing Corporation.

According to the report, one of the chief benefits of planting vegetation on buildings is to reduce energy usage and therefore greenhouse gas emissions. By protecting buildings from wind, plants can reduce heating in winter by 25 per cent and, through direct shading and evaporative cooling, air conditioning in summer can be reduced by 50 to 75 per cent. A 16-centimetre thick blanket of plants can increase the R-value of a wall by as much as 30 per cent.

Wall and rooftop gardens also regulate the "urban heat island," a phenomenon that causes cities to be up to 8° C warmer than the surrounding countryside due to re-radiated heat. Through evapotranspiration, a layer of vegetation can reduce the amount of re-radiated heat on a hot summer day by up to 90 per cent, thereby reducing the urban heat island by 3-4°.

One of the most tangible effects of green roofs is their ability to retain stormwater. In urban areas, most runoff flows into stormsewers, picking up contaminants such as oil, grease and heavy metals on the way, and depositing them into lakes, rivers or groundwater aquifers. According to European studies, rooftop gardens retain 70 to 100 per cent of precipitation that falls on them in summer and about half that in winter—storing it until it is taken up by the plants and returned to the atmosphere through evapotranspiration. Studies also show that plants act as a natural filter for runoff—removing up to 95 per cent of heavy metals such as cadmium, copper and lead.

Rooftop gardens also improve air quality, filtering out gaseous pollutants and particles. They protect building membranes from ultraviolet radiation and physical damage, and can be used to grow food, serve as habitat for wildlife, and even to foster well being.

Case studies show that the handful of major rooftop gardens in Canada—which run the gamut from a subsidized apartment in Toronto where tenants grow their own rooftop produce to a parking garage in Quebec City where a rooftop meadow has solved a rainwater leakage problem—are successful. However, the report suggests that demonstration projects, awareness campaigns and economic incentives are needed if green skylines are to become widespread in Canada.

With their data collection and review complete, EC scientists and partners from the

Green Roofs are a sustainable, environmental design approach that may help federal facilities meet LEED standards.

Green Roofs FOR HEALTHY LIVING

By Capt. Benjamin Morgan, USAF, and Lt. Col. Ellen England, Ph.D., MSA, CIH, CSP

Green, or vegetated, roofs have been used worldwide through the ages. Historic examples include the hanging gardens of Babylon, Roman roof gardens, English thatched roofs, the sod roofs of the Great Plains settlers and the 20th century's earth shelters. Contemporary green roofs are plentiful in Europe but few are found in North America. Prominent, profit-driven U.S. businesses such as The Gap and Ford Motor Corporation have built green roofs. Some cities, such as Chicago, Ill. and Portland, Ore., have installed vegetated roofs in some structures.

Green Roof Design

The design and appearance of today's green roofs have changed over time and reflect their intended use, building insulation requirements, building codes and the surrounding climate. Most green roofs feature several standard components, including a water proofing membrane, a drainage layer, growing medium and vegetation. The waterproofing membrane, which is affixed securely to the roof deck, typically consists of thermoplastic materials, such as polyvinyl chloride, and may be rolled out in a sheet or applied as a liquid coating. If the membrane lacks inherent root protection, a barrier is applied to prevent roots from penetrating the membrane and causing leaks.

Adding a layer of rigid insulation can improve energy efficiency. A drainage layer removes excess water when the plants and growing medium become saturated. Honeycombed plastic structures, expanded polystyrene beads, or lengths of perforated polystyrene tubing and other types of materials can be used in drainage systems. A filter fabric prevents soil particles from entering and clogging the drainage layer. If the roof pitch is greater than 20 degrees, a grid or lath can be installed atop the filter fabric to prevent erosion.

The growth medium, or substrate—typically lava rock, sand and humus—rests on the filter fabric. The vegetation, chosen to reflect climatic conditions, can be planted by hydro-seeding, inserted as plugs, or rolled onto the roof as pre-grown vegetated mats.

The depth of the substrate and type of vegetation determines whether a green roof is considered intensive or extensive. An intensive green roof resembles a roof garden; it has large and small plants. Intensive roofs are more complex and varied with aesthetically pleasing plants, walking paths, observation decks and park benches. Extensive green roofs typically have low growth height, succulent plants, called sedums, or native grasses. Extensive roofs require less growth substrate and maintenance than intensive green roofs and are rarely used for recreation.

Determining Its Effectiveness

To investigate the feasibility of adopting vegetated roof installation, the Air Force Institute of Technology conducted a literature search, case studies, site visits and a life cycle cost evaluation for an Air Force facility in Dallas, Texas.

To complete the life cycle cost evaluation, the initial and annual costs of a vegetated roof and asphalt built-up roof, both appropriately designed for the Dallas area, were compared over a 45-year life span. Building Logics in Virginia Beach, Va., provided the green roof design and installation cost information; Lockheed Martin furnished the asphalt

Chicago City Hall's intensive green roof is visually appealing and functional. Note the black, asphalt built-up roof on the county's portion of the building, back right.

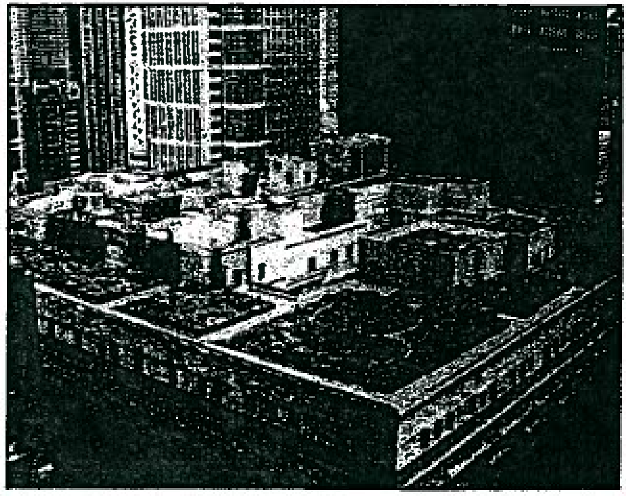


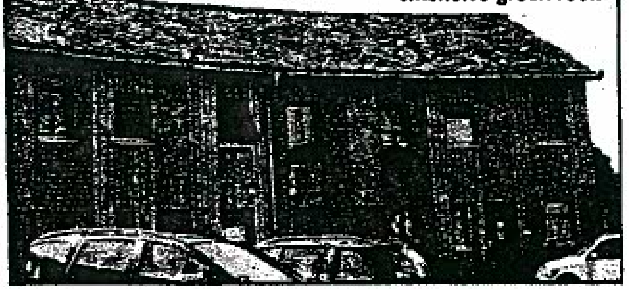
Photo courtesy Capt. Benjamin Morgan, USAF built-up roof design and installation cost information. The installation costs for both techniques were then compared. The cost model reflected annual energy use reductions and the associated savings that accrued through the use of green roof technology, along with annual maintenance expenditures for both roofing systems.

Focusing on the Positive

Published information and data from green roof owners indicate that vegetated roofs reduce the amount of storm water runoff that asphalt built-up roofs produce. Green roofs also last longer—typically for more than 45 years—because their vegetation protects the roof materials from wind, temperature fluctuations and UV exposure. Vegetated roofs also increase the level of thermal insulation and reduce roof temperatures—and thus air conditioning costs—along with the "urban heat island effect." They also decreased sound transmission, and improve aesthetics, wildlife habitat and microclimate.

The initial cost of installing the green roof was twice the cost of installing the asphalt built-up roof. But the maintenance costs of the asphalt built-up roof far exceeded those of the green roof. The life cycle cost, as a net present value, of the green roof proved to be 17 percent to 50 pecent of the asphalt built-up roof system, based on the initial installation costs of the built-up roof and estimated energy savings from green roof construction. (See Table 1.)

Low growth height of the sediums, as shown on this apartment building in Germany, is characteristic of an extensive green roof.



"Going Green" Governing Regulations

The rules and regulations the federal government and private industry are required to follow to conserve energy and practice good environmental stewardship are enshrined in The Clean Air Act, The Clean Water Act, and the National Environmental Policy Act.

Executive Orders (E.O.) 13148 "Greening the Government through Leadership in Environmental Management" and 13123 "Greening the Government through Efficient Energy Management," and military service-specific policy letters require sustainable design practices. E.O. 13148 addresses the areas of environmental accounting, life cycle assessment, environmental landscaping, pollution prevention and environmental leadership. E.O. 13123 mandates improved energy management to reduce energy consumption and associated air emissions. The policy letters issued by military services usually mandate the increased use of the Leadership in Energy and Environmental Design (LEED) standards or equivalents but federal facilities have been slow to implement them.

Green Lasts and Saves

In a direct comparison with asphalt built-up roofs, green roofs offer several significant benefits. They reduce storm water run-off and roof surface temperature and increase a roof's longevity. Although initial installation costs are relatively high, when total life cycle costs are considered, the green roof is cost effective and environmentally friendly.

Military engineers should consider installing green roofs to meet environmentally beneficial landscaping and life cycle assessment requirements set forth in E.O.13148, energy reduction requirements set forth in E.O. 13123 and policy mandates.

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Lt. Col.Ellen England, Ph.D., MSA, CIH, CSP, is a Professor in the Department of Systems and Engineering Management, Air Force Institute of Technology, Wright-Patterson AFB, Ohio; ellen.england@afit.edu, or 937-255-3636, ext 4711.

Table 1. Cost in dollars ($) for three iterations of the life cycle cost model.

Life Cycle Cost Model	Iteration 1	Iteration 2	Iteration 3
Green roof installation	$1,072,083	$1,072,083	$1,072,083
Asphalt BUR installation	523,363	613,652	770,868
Green roof annual energy savings	2,500	7,500	12,500
Green roof annual maintenance	500	500	500
Asphalt BUR annual maintenance	a	a	a
Green roof life span	45 years	45 years	45 years
Asphalt BUR life span	15 years	15 years	15 years
Green roof NPV	982,083	757,083	532,083
Asphalt BUR NPV	2,246,647	2,517,549	2,989,198

a: Increases exponentially from 0-$50,000 depending on years of use.

COST-BENEFIT ANALYSIS OF INSTALLING GREEN ROOF VS. CONVENTIONAL ROOF AT CENTRAL LIBRARY

Year	Increased work on grants/ RFPs/ site assessments	Increased debt service above regular roof replacement*	Increased maintenance costs for green roof	Total extra costs due to green roof	Energy savings due to green roof**	Debt service saved due to longer roof life***	Total benefits	Net benefit (cost)	NPV benefit (cost)	Overall NPV benefit/cost
2009	$4,500.00	$0.00	$0.00	$4,500.00	$0.00	$0.00	$0.00	($4,500.00)	($4,500.00)	($4,500.00)
2010	$0.00	$11,666.67	$2,000.00	$13,666.67	$3,628.68	$0.00	$3,628.69	($10,037.98)	($9,651.90)	($14,151.90)
2011	$0.00	$23,333.33	$2,080.00	$25,413.33	$3,810.12	$0.00	$3,810.12	($21,603.21)	($19,973.38)	($34,125.28)
2012	$0.00	$23,333.33	$2,163.20	$25,496.53	$4,000.63	$0.00	$4,000.63	($21,496.90)	($19,109.78)	($53,236.06)
2013	$0.00	$23,333.33	$2,249.73	$25,583.06	$4,200.66	$0.00	$4,200.66	($21,382.40)	($18,277.76)	($71,512.82)
2014	$0.00	$23,333.33	$2,339.72	$25,673.06	$4,410.70	$0.00	$4,410.70	($21,262.36)	($17,476.10)	($88,988.92)
2015	$0.00	$23,333.33	$2,433.31	$25,766.64	$4,631.23	$0.00	$4,631.23	($21,135.41)	($16,703.62)	($106,692.54)
2016	$0.00	$23,333.33	$2,530.64	$25,863.97	$4,862.79	$0.00	$4,862.79	($21,001.18)	($15,959.17)	($121,651.71)
2017	$0.00	$23,333.33	$2,631.86	$25,965.19	$5,105.93	$0.00	$5,105.93	($20,859.26)	($15,241.66)	($136,893.37)
2019	$0.00	$23,333.33	$2,960.49	$26,293.82	$5,361.23	$0.00	$5,361.23	($20,932.69)	($14,706.96)	($151,600.33)
2019	$0.00	$23,333.33	$2,846.62	$26,179.95	$5,629.29	$0.00	$5,529.29	($20,550.66)	($13,883.29)	($165,483.62)
2020	$0.00	$23,333.33	$2,860.49	$26,293.82	$5,910.75	$0.00	$5,910.75	($20,383.06)	($13,240.45)	($178,724.07)
2021	$0.00	$23,333.33	$3,078.91	$26,412.24	$6,206.29	$0.00	$6,206.29	($20,205.95)	($12,620.67)	($191,344.66)
2022	$0.00	$23,333.33	$3,202.06	$26,535.39	$6,516.61	$0.00	$6,516.61	($20,018.78)	($12,022.77)	($203,367.41)
2023	$0.00	$23,333.33	$3,362.17	$26,695.50	$6,642.44	$0.00	$6,842.44	($19,653.06)	($11,464.65)	($214,832.06)
2024	$0.00	$23,333.33	$3,530.28	$26,863.61	$7,184.58	$0.00	$7,184.56	($18,679.05)	($10,927.08)	($225,759.14)
2025	$0.00	$11,666.67	$3,706.79	$15,373.46	$7,543.78	$0.00	$7,543.79	($7,829.67)	($4,180.33)	($229,939.46)
2026	$0.00	$0.00	$3,892.13	$3,892.13	$7,920.88	$0.00	$7,920.98	$4,028.85	$2,068.30	($227,871.16)
2027	$0.00	$0.00	$4,086.74	$4,086.74	$8,317.02	$0.00	$8,317.02	$4,230.29	$2,088.19	($226,782.97)
2028	$0.00	$0.00	$4,291.07	$4,291.07	$8,732.86	$0.00	$8,732.88	$4,441.80	$2,108.27	($223,674.70)
2029	$0.00	$0.00	$4,505.63	$4,505.63	$9,169.52	$0.00	$9,169.52	$4,663.89	$2,128.54	($221,546.16)
2030	$0.00	$0.00	$4,730.91	$4,730.91	$9,627.89	$46,666.67	$56,294.68	$51,563.76	$22,627.91	($198,918.26)
2031	$0.00	$0.00	$4,967.45	$4,967.45	$10,109.39	$93,333.33	$103,442.72	$98,475.27	$41,552.17	($157,366.08)
2032	$0.00	$0.00	$5,215.83	$5,215.83	$10,614.86	$93,333.33	$103,948.19	$98,732.37	$40,058.32	($117,307.76)
2033	$0.00	$0.00	$5,476.62	$5,476.62	$11,145.61	$93,333.33	$104,478.94	$99,002.32	$38,622.93	($78,684.83)
2034	$0.00	$0.00	$5,750.45	$5,750.45	$11,702.89	$93,333.33	$105,036.22	$99,285.77	$37,243.76	($41,441.07)
2035	$0.00	$0.00	$6,037.97	$6,037.97	$12,288.03	$93,333.33	$105,621.36	$99,583.39	$35,918.66	($6,522.41)
2036	$0.00	$0.00	$6,339.87	$6,339.87	$12,902.43	$93,333.33	$106,235.76	$99,895.90	$34,645.55	$29,123.14
2037	$0.00	$0.00	$6,656.86	$6,656.86	$13,547.56	$93,333.33	$106,880.89	$100,224.02	$33,422.45	$62,545.59
2038	$0.00	$0.00	$6,988.71	$6,989.71	$14,224.83	$93,333.33	$107,558.26	$100,568.56	$32,247.45	$94,793.04
2039	$0.00	$0.00	$7,338.18	$7,339.19	$14,936.16	$93,333.33	$108,269.51	$100,930.32	$31,118.70	$125,911.75
2040	$0.00	$0.00	$7,706.15	$7,706.15	$15,682.99	$93,333.33	$109,016.32	$101,310.17	$30,034.44	$155,946.18
2041	$0.00	$0.00	$8,091.46	$8,091.46	$16,467.14	$93,333.33	$109,800.47	$101,709.01	$28,992.96	$184,939.15
2042	$0.00	$0.00	$8,496.03	$8,496.03	$17,290.50	$93,333.33	$110,623.83	$102,127.80	$27,992.63	$212,931.78
2043	$0.00	$0.00	$8,920.63	$8,920.83	$18,155.02	$93,333.33	$111,488.35	$102,567.52	$27,031.88	$239,963.66
2044	$0.00	$0.00	$9,366.67	$9,366.87	$19,062.77	$93,333.33	$112,396.10	$103,029.23	$27,153.57	$267,117.23
2045	$0.00	$0.00	$9,835.22	$9,835.22	$20,015.91	$46,666.67	$66,682.58	$56,847.36	$14,982.24	$282,099.47
2046	$0.00	$0.00	$10,326.98	$10,326.98	$21,016.71	$0.00	$21,016.71	$10,689.73	$2,817.30	$284,916.77
2047	$0.00	$0.00	$10,843.33	$10,843.33	$22,067.54	$0.00	$22,067.54	$11,224.21	$2,958.17	$287,874.94
2048	$0.00	$0.00	$11,385.49	$11,385.49	$23,170.82	$0.00	$23,170.92	$11,785.42	$3,106.07	$290,981.01
2049	$0.00	$0.00	$11,954.77	$11,954.77	$24,329.46	$0.00	$24,329.46	$12,374.70	$3,261.38	$294,242.39
TOTALS	$4,500.00	$349,999.96	$217,283.79	$571,783.75	$438,344.93	$1,399,999.96	$1,838,344.89	$1,266,561.14	$294,242.39	$294,242.39

Assumption Is 4% inflation cost unless otherwise noted.

*Assumption is green roof results in City borrowing of $950,000 vs. $700,000 conventional roof.
** Based on 5% inflation for energy costs.
*** Assumption is that conventional roof is replaced for $1,000,000 after 20 years ($700,000 with 2% annual inflation).