GREEN ROOF
DEVELOPER'S GUIDE

GROUNDWORK SHEFFIELD

Life

the green roof centre

Green Roof Developor’s Guide

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Cold deck roof
The insulation is located on the interior side of the deck. The deck is not warmed by the building interior and ventilation is required above the insulating layer to reduce condensation. In the relatively humid climate of the UK the cold deck roof is generally not a preferred option.

Covenant
In tenant terms it's the quality of the business and how likely they are to be able to pay the rent for the full lease term.

Inverted warm deck roof
The insulation is located on the exterior of the roof waterproof layer. The waterproof layer now becomes the vapour control layer preventing condensation between itself and the deck. The thermal insulation protects the waterproof layer from extremes of temperature. The thermal insulation is commonly retained in place by ballast consisting of paving slabs or gravel.

Evapotranspiration
The combined action of evaporation (of water from the soil) and transpiration (water loss from plants).

Substrate
Growing medium for the plants and can be made up of various materials including soil, and reclaimed building materials mixed with nutrient material (compost). The key factors are substrate depth and whether it is nutrient rich or poor.

Transpiration
To give off (water) vapour through the skin (of plants).

Warm deck roof
Insulation is placed between the exterior waterproof layer and the roof deck (the deck being the surface that supports the waterproof layer and transfers roof surface loads to structural members). A vapour control layer is placed between the insulation and waterproof layer to reduce condensation. No internal ventilation of the roof interior is required.

Whole Life Costs
The analysis usually using Net Present Value of future inflows and outflows of cash due to a particular asset or change.

Life Cycle Assessment
Life Cycle Assessment (lCA, life cycle analysis or ecobalance) is used to assess the environmental performance of a product from cradle to grave.

Net present Value
The discounting of future cashflows to present day values.

Urban Heat Island Effect (UHIE)
The Urban Heat Island Effect is where an urban area has a higher temperature than the surrounding land. It is caused by the reduction in green space through urbanisation and the large amount of hard surfaces that provide high thermal mass and can result in the area of the 'heat island' having its own micro-climate. The Environmental Protection Agency state that on hot summer days, urban air can be 2-10°F (2-6°C) hotter than the surrounding countryside.

1. Report Objectives

This report aims to demonstrate the economic advantages of integrating Green Roofs into a development and will relate existing data to a UK setting. The recognised methodologies of Net Present Value and Discount Rate are used to demonstrate both the short-term and long-term financial gains to be had from investment in Green Roof technology.

Although this report looks primarily at commercial and office developments, the same financial and non financial benefits can be derived for residential apartment blocks and public buildings, in fact any low pitch “flat roof”.

The current thinking on Green Roofs, in relation to key benefits will be reviewed, including:

- Increasing energy efficiency - cooling in summer, insulation in winter
- Filtering and cleaning toxins from both air and storm water
- Retaining rainwater before it evaporates,
- Delaying storm surges and reducing the likelihood of flooding
- Reducing urban temperatures and associated smog and low atmosphere ozone
- Insulating against sound and noise
- Preserving and enhancing biodiversity
- Providing aesthetic appeal and ‘green space’ recreational opportunities
- Using recycled materials including aggregates and plastics improves sustainability

The final section of the report will show how these “general” benefits can be translated into the following income for developers and building owners:

- Increased rent
- Attract better covenant tenants
- Decrease letting voids
- Increase the value of a building.

2. Introduction

It is generally accepted that climate change is happening. The widespread flooding across England in July 2007 served to heighten public awareness of the potential effects and has focused attention on the need to plan and adapt for changing future climates. This approach is termed sustainable development with guidance to achieve it set down in PPS1 of the National Planning Policy 2004.

Developers have to balance their responsibility to ensure that they reduce their impact on the environment and society whilst still making money. Sustainable development is common-place in rhetoric but difficult to achieve in a cost effective reality.

This report demonstrates how we can improve development economics for new and refurbished buildings and at the same time bring environmental and social benefits.

The problem usually raised with environmental improvements is that they are prohibitively costly. This report shows how to combine the capital costs and the 'cost in use' to ensure the right decisions are taken with regard to developments.

There is an environmental "technology" that saves money, improves the value of the development, reduces the environmental impact, and provides real benefits to staff. In other words a win/win/win option.

Green roofs are that "technology" and this report demonstrates how installing green roofs on a new or refurbished building will:

- Increase the value of a development
- Increase rent
- Increase yield
- Reduce the void periods
- Increase letability
- Reduce energy consumption
- Reduce CO2 emissions
- Remove pollutants from the air
- Reduce the occupation costs of a building

The report also looks at how to value a green roof, what design options are available, how to install them and how to maximise the benefits.

Developers need to consider 'climate proofing' their buildings to cope with wetter winters and warmer summers. Our cities will be up to 6 degrees hotter as high density developments lead to the Urban Heat Island effect. The developers able to respond to these challenges and changing customer preferences for greener buildings will maintain a competitive advantage in the marketplace.

3. Green Roof: Fast Facts

Things you should know about Green Roofs before reading this report:

- A typical single storey building with a Green Roof and 100mm (3.9 inches) of growing medium would result in a 25% reduction in summer cooling needs and 15% reduction in heating in winter.
- 1m^2 (10.76 ft^2) of grass roof can remove between 0.2 kg of airborne particulates from the air every year.
- 1 m^2 (10.76 ft^2) of foliage can evaporate over 0.5 litres of water on a hot day and on an annual basis the same 1m^2 can evaporate up to 700 litres of water.
- A Green Roof with a 120mm (4.7 inches) substrate layer can reduce sound by 40 decibels; a 200mm (7.9 inches) substrate layer can reduce sound by 46 - 50 decibels.
- On a summer day, the temperature of a gravel roof can increase by as much as 25°C (77°F), to 60 - 80°C (140 - 176°F). Covered with a Green Roof, the temperature of that roof will stay at 25°C (77°F), saving energy costs.
- 200 mm (7.9 inches) of substrate with a 20cm to 40cm (7.9 - 15.7 inches) layer of thick grass has the combined insulation value of 150mm (5.9 inches) of mineral wool.
- Rooms under a Green Roof are at least 3 - 4°C (5.4 - 7.2°F) cooler than the air outside, when outdoor temperatures range between 25 - 30°C (77 - 86°F).
- The Possman Cider Cooling and Storage Facility in Frankfurt, Germany yielded a 2-3 year payback for their Green Roof system through savings in heating and cooling costs, as well as in equipment costs, since additional cooling towers had become unnecessary.
- Green Roofs retain between 50 and 70% of the rain that falls on them; in winter they retain between 25 and 40%. A Green Roof with a 40 to 200mm (1.6 - 7.9 inches) layer of growing medium can hold 100 to 150mm (3.9 - 5.9 inches) of water

This report will show how these "general" benefits can be translated into specific income for developers and building owners:

- Increased rent
- Attract better covenant tenants
- Decrease letting voids
- Increase the value of a building.

We will first look at what an economical analysis can tell us about the inclusion or otherwise of a Green Roof on a development.

4. Economic Analysis

This report looks primarily at commercial and office developments however, the same financial and non financial benefits can be derived for residential apartment blocks and public buildings, in fact any low pitch “flat roof”.

In every development appraisal an economic analysis takes place, which can be fairly rudimentary or extremely detailed and it can be based on known data or estimates. The analysis will always include the capital cost of the development and an appraisal of the value when complete. Recently developers have been using Net Present Value, (NPV), to assess the value of the project.

NPV has a number of advantages as it uses capital cost and the cost of using the building to assess value. This provides a better analysis of the economic benefits of how a development is designed. It makes possible the estimation of the positive or negative impact on the project’s profit of any decision the design team or the developer makes.

The ultimate value of the project is primarily derived from hard facts, such as the rent and the net lettable area, but it is also influenced by subjective considerations such as the covenant of the tenant and the likelihood of future rental voids. Increasingly values are being influenced by the concept of for how long the building will be satisfactory to tenants.

This is logical because the value is going to be based on the number of years that the investor can reasonably expect rental income less any costs incurred along the way.

This is the very calculation that NPV does to determine value and can be applied equally to the whole building or a single component.

In this section we will look at the various methods of analysis including:

- Whole life cost
- Life cycle analysis
- Net Present Value

and what benefits they provide to a developer.

5. Whole Life Cost & Life Cycle Analysis

We need to look at what Whole Life Cost (WLC), and Life Cycle Analysis (LCA), mean and the difference between. Unfortunately the two terms Whole Life Cost and Life Cycle Analysis are often used interchangeably and, incorrectly, to describe whatever it is that the user wants it to mean.

There is also another term in common usage - Life Cycle Costing, which has no universally accepted meaning and can refer to WLC or LCA, or a bit of both, depending on who is using it and the context. We do not use the term Life Cycle Costing in this report however, when used in a development scenario the meaning should always be defined by the user.

Both WLC and LCA have well accepted definitions and they describe very different processes that have different uses.

5.1 Whole Life Cost

Whole Life Cost is the analysis of all relevant and identifiable cashflows regarding the acquisition and use of an asset.
Definition of Whole Life Costs, The Whole Life Cost Forum

Where:

- Cost - may be financial only or may include non financial elements (LCA)
- Analysis – the presentation of the data in a way that is understandable to the reader
- Relevant - means those costs directly attributed to the asset under review
- Identifiable - means we have to be able to quantify it in some way
- Cashflows - are the annual incomes and expenditures for the life of the asset
- Assets - can be whole buildings or a single small component
- Acquisition - can mean the construction of a building or the purchase of a component
- Use - is all costs involved in the use of the asset

5.2 Life Cycle Analysis (or Assessment)

Life Cycle Assessment is a process to evaluate the environmental burdens associated with a product, process, or activity by identifying and quantifying energy and materials used and wastes released to the environment; to assess the impact of those energy and materials used and releases to the environment; and to identify and evaluate opportunities to affect environmental improvements. The assessment includes the entire life cycle of the product, process or activity, encompassing, extracting and processing raw materials; manufacturing, transportation and distribution; use, re-use, maintenance; recycling, and final disposal.
- Guidelines for Life-Cycle Assessment: A ‘Code of Practice’, SETAC, Brussels

You will note the difference in language and construction of these two definitions.

5.3 The difference between WLC and LCA

WLC is essentially an economic analysis with defined meanings and a methodology that provides repeatable results. The definition is tight and precise and not open to much “interpretation” or influence by the operator.

LCA , on the other hand, is wide ranging and allows a lot of interpretation by the operator. In fact most LCA methodologies provide for weighting of the results to highlight aspects that the user considers more important. This weighting means that the results are rarely repeatable as different people have widely different perceptions of each element’s importance which will vary the weightings and the result.

The author took part in a LCA comparison of land based aggregates versus sea dredged for a project at Heathrow Airport. The analysis team considered the land miles that the aggregates would have to travel, land derived 20 to 40 miles and sea dredged Norfolk coast to West London 140 miles, was similar and had identical weightings. The team also decided that the general impact of a quarry was 5 times greater than the impact of sea dredging on the environment even though it was shown that the sea dredged required more energy to extract and process. This “interpretation” element of assigning weightings allows the results to be skewed to achieve a pre-determined outcome in this case using sea based aggregates.

In summary the results from LCA need to used with care and the results from WLC need to be used with knowledge.

This report is focused on demonstrating the financial value of developers incorporating Green Roofs which means LCA is less appropriate than WLC here. WLC uses Net Present Value (NPV) to calculate the outcome of a decision and to understand the results correctly we need look at the process of NPV more closely.

6. Net Present Value

Net Present Value (NPV) can tell us, very clearly and decisively, if it's more profitable to spend more capital today and lower the cost in use or select a lower capital cost option and accept the cost in use impact.

However, typically there are a number of names used which mean slightly different things but are in common use.

When users talk about looking at the overall value of a project they usually refer to a Net Present Value (NPV) which is a way of describing the method of Discounted Cash Flows (DCF). When using DCF the answer can be positive, a net present value (NPV) or negative, a net present cost (NPC) which, to confuse things further, can also be expressed as a positive number.

DCF is a comparison technique and is used to compare the results of a decision. Therefore the logical spread of results are positive numbers show an income and negative show a cost. We are used to this concept, because we understand that higher positive numbers and lower negative number are the better results.

DCF is undeniably considered a “black art” by many in the property industry but it is a very useful step forward. Before about 1990 the most common way of selecting between capital projects was a simple payback calculation - how many years of profit would it take to pay back the original investment - which unfortunately did not always lead to the best decisions being taken.

6.1 How do NPV and DCF Work?

DCF was invented to answer a simple question

“If I have 2 competing investment opportunities and can only afford to invest in 1, which one should it be?”

If you were offered these 2 similar capital investments of say £100 each with payback periods of
- 2 years,
- 4 years.

under the payback method of assessment you should accept the first, but this assumes the different lives of the investments have no impact on the profitability.

So let us now add a little more information and see if that changes the decision:
- investment 1 provides £50 surplus per year but its life is 3 years,
- investment 2 provides only £33 surplus per year but has a life of 6 years.

To understand the relative benefits, and make the decision now, we need to analyse the future cashflows which look like this:

Investment opportunity	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total income
1	£50	£50	£50	nil	nil	nil	£150
2	£33	£33	£33	£33	£33	£33	£198

Now the logical decision is to go for Investment 2 as it provides a higher surplus for the same investment. Which is why payback often gave the wrong guidance.

Discounting the forward value of the inflows adds to the validity of the result by compensating for the time it takes to earn the surpluses.

The easiest way to explain Net Present Value is in terms of the well understood principle:

- the return required by an investor.

Let's suppose you have some money to invest, and you have been offered a government bond as an investment (bonds give fixed returns so are sold at a lower amount than the face value). When the bond matures, exactly one year from now, you will be able to exchange it for £100 in cash.

The bank issuing the bond is 100% reliable and risk-free so no risk premium needs to be applied.

So the question is: how much would you be willing to pay now in order to obtain this bond?
Given the choice between receiving £100 today or £100 next year, almost everybody would choose to have the money now.

In other words, money today is more valuable than the same amount of money tomorrow. This principle is called the 'time value of money'.

The difference in value is not only due to inflation - even if inflation were zero, people would virtually always prefer to receive money now than in a year's time. The main reasons for this are:

- most people have an expectation that their wealth will be greater in the future, so the relative value to them of a particular sum of money will be correspondingly less in the future
- money received now can be 'put to work' to earn a return so that, in a years time it will have accumulated in value
- the benefit of money received now is certain whereas, because there is no guarantee that you will be alive next year, the benefit of money received next year is uncertain. This is the element of risk.

Suppose you want to earn 10% annual interest on your investment. You will therefore be willing to pay around £91 for the bond.

The present value (PV) is calculated using the formula:

$$\textit{Present value} = \textit{the value of the bond} \times \frac{100}{100 + \textit{the required return}}$$

Which for our example is:

$$\textit{Present value} = £100 \times \frac{100}{100 + 10} = £91.09$$

So, at a 10% rate of return, the bond is worth £90.91 today. Another way of saying the same thing is:

- at a discount rate of 10%, the bond has a present value of £90.91.

This means that, to you today, the value of £100 in 12 months time is £90.91. So, it can be seen how the future value of money is discounted by a rate that is time-related.

Now, consider another investment. This time it is a £1,000 bond maturing in 2 years.
But this time you only require an 8% rate of return on your investment. You would therefore be willing to pay the present value today £857.34 for the bond (£857.34 x 1.08 x 1.08 = £1,000).

The present value of a future sum of money therefore depends on three factors:

- how big the cashflows are
- how far into the future the sum of money will be paid or received
- the rate of return that is expected or required.

To summarise

- In present value terms, any future set of cashflows, including inflows and outflows, will have a current value depending on the time-period and discount rate applied.

- For any given discount rate, the present value of a future sum of money is the amount you would need to invest today, at an interest rate equal to the discount rate, in order to obtain that sum of money.

In a DCF analysis of a project, each component of the project cash flow is treated as if it were equivalent to a bond - in other words, it is the promise of a particular sum of money at some specific time in the future and therefore carries risk which is included in the Discount Rate.

Once you have chosen what discount rate you wish to use, you can calculate the present values of the different parts of the cash flow. If you sum together the annual present values of all the different components of the project cash-flow, the result is called the Net Present Value.

On the following page we add more data to our previous example to see if the results change.

So let's now add some more data to our earlier example with a 10% discount rate:

	Capital Cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
Investment 1	**-£100**	£50	£50	£50	£0	£0	£0	£50.00
Discount	£1.00	£0.91	£0.83	£0.77	£0.71	£0.67	£0.63	
Discounted Cashflow	**-£100.00**	£45.45	£41.67	£38.46	£0.00	£0.00	£0.00	£25.58

	Capital Cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
Investment 2	**-£100**	£33	£33	£33	£33	£33	£33	£98.00
Discount	£1.00	£0.91	£0.83	£0.77	£0.71	£0.67	£0.63	
Discounted Cashflow	**-£100.00**	£30.00	£27.50	£25.38	£23.57	£22.00	£20.63	£49.08

The Net Present Value of the 2 investments are:

Investment 1	£26	**Investment 2**	£49

As investment 2 generates a higher return that is the one that should be chosen.

The problem with development projects is that the initial cashflows are usually costs generating net outflows and that the benefits, or inflows, do not start to accumulate until a later date. The longer that time-period or the lower the inflows the less value they will have today. Also the inflows may not be directly to the benefit of the original developer.

So having seen what NPV is, what can it do for developers?
NPV can tell us clearly if it's better to spend more capital today and make a greater return during the future.

Using Green Roofs as an example at a basic analysis level the capital costs are balanced against savings made in the drainage and in reduced energy costs throughout the life of the project.

The analysis can add in as many other incomes and costs as the user sees fit. Later in this report we will look at the impact a Green Roof makes on the value of a development and what financial benefits can, and should, be included.

Net Present Value function is available in all good spreadsheets and is not difficult to operate once the methodology is understood.

We now move onto the variable in a NPV calculation, the Discount Rate, and how to use it.

6.2 Discount rate

Selection of Discount Rate is very important as 5% and 10% Discount Rates for the same conditions give very different results see table 1 below. While Net Present Value is a very robust approach to analysis with very few areas open to manipulation, it should be acknowledged, however, that a skilled practitioner in NPV can influence the result by selecting an inappropriate Discount Rate.

Unfortunately this is the area in which decision makers are less likely to have sufficient knowledge to make their own assessments. The discount rate used to evaluate a project should reflect:-

- The weighted average cost of the capital WACC, (which is unique to the business concerned) – this is the average cost of borrowing to the business and includes bank borrowing and shareholder returns.
- The risk of the project to the business - the benefit of money received now is certain whereas, because there is no guarantee that you will be alive next year, the benefit of money received next year is uncertain there is, therefore, a risk with any investment and that risk tends to grow with time.
- The opportunity cost of that capital - money received now can be 'put to work' to earn a return so that, in a year's time it will have accumulated in value.

***Table 1** Effect comparison of different Discount Rates*

Discount Rate	**NPV**
5%	24,188
7%	19,307
8%	17,350
10%	14,154

Table 1 uses identical cashflows over 15 years and only the discount rate is changed. The variance between the 5% and 15% discount rate demonstrates the importance of selecting the right rate.

In recent studies various rates have been used. Acks (2003) used a private real discount rate of 8% for New York City buildings, while the Treasury Board of Canada (1998) suggested a general rate of 10%.

Wong et al. (2004), in a life cycle analysis of the private costs of Green Roofs in Singapore, used a rate equal to the average prime rate (bank interest rate) over the last 10 years which was 5.15%. However, using the average interest rate is not an acceptable method for deciding the discount rate as it has no reference to the cost base of the business making the decision.

In the absence of reliable data to assess the Discount Rate the author has found that a rate of 7% provides the right level of comparability and provides sufficient cover for the risk involved.

The choice of Discount Rate impacts Green Roof projects as they typically involve significant costs of construction in the present day (ie 100% non discounted costs) and benefits that accrue over the life of the roof, higher discount rates make these projects look less attractive than cases with identical costs and benefits but lower discount rates.
For more information on Discount Rates see **http://www.wlcf.org.uk/ChoiceOfDiscountRates.htm.**

6.3 Problems with a WLC approach

The majority of the construction industry, including major clients such as the Government, focus just on the initial capital cost with no understanding of the links between Capital Costs, Cost in Use and project value.

How many times do development teams fight to keep costs to budget and how many times do excellent project requirements get cut out to reduce the overall budget?

The project Quantity Surveyor must be instructed to consider cost in use and to complete a Net Present Value analysis for each option selection and decision points. Without this instruction from the client they will have no other option but to be capital focused.

The other misnomer to be wary of is “value engineering” where the normal process is to strip out capital costs without considering either the impact on the cost of use or how that element will affect the costs of other components.

However, speculative developers and long term property investors are beginning to understand and to exploit the concept of how “green” technologies, and particularly Green Roofs, add value to their developments. We look at this in more depth now.

This concludes the theory behind financial appraisals and we now need to consider the non-financial aspects of asset selection and decision making.

7. Why Green Roofs influence a building's sustainability

It is a simple concept that roofs absorb heat; stand on any roof in the summer and the reflected light levels are high and the surface is hot. Similarly go into the loft of any home in the UK and the solar gain and heat transmission is evident by the stiflingly hot atmosphere.

By making roofs cooler, designers can reduce the amount of absorbed solar energy, and consequently reduce the amount of heat conduction into buildings. This reduces daytime net energy inputs (Akbari and Konopacki, 20041; Akbari et al, 2001) and the demand for air conditioning.

Eumorfopoulu (1998) carried out detailed calculations to examine the thermal behaviour of a planted roof and concluded that Green Roofs can contribute to the thermal performance of buildings.

This study further showed that of the total solar radiation absorbed by the planted roof, 27% is reflected, while the plants and the soil absorb 60%, and 13% is transmitted into the soils.

Evidently, with a Green Roof the insulation value is in both the plants and the layer of substrates (Eumorfopoulu, 1998). Patterson (1998) also showed that Green Roofs prevented temperature extremes and the insulation value of the soil on the structure lowered the cooling energy costs.

Onmura et al. (2001) measured surface temperatures of white roofs and Green Roofs and found that a typical Japanese roof was at 60°C whereas a Green Roof was around 28 to 30°C. Similar studies have been carried out in Germany with a similar 60°C but with a reduction to 25°C. This 35°C reduction is now considered to be the European average.

Sonne (2006) used a roof with 50% Green Roof and 50% exposed to compare surface temperatures. They found that there was an average range of;

Table 2 *Temperature comparisons of Exposed and Green Roofs*

Roof Type	Lowest temp	Highest temp	Range	Time of peak
Exposed	8°C	36°C	28°C	14:00
Green	16.6°C	17.8°C	1.2°C	23:00

Sonne also measured the daily minimum and maximum variations. The results are also fairly consistent over the summer and winter months.

Figure 1 *Summer roof diurnal temperature range*

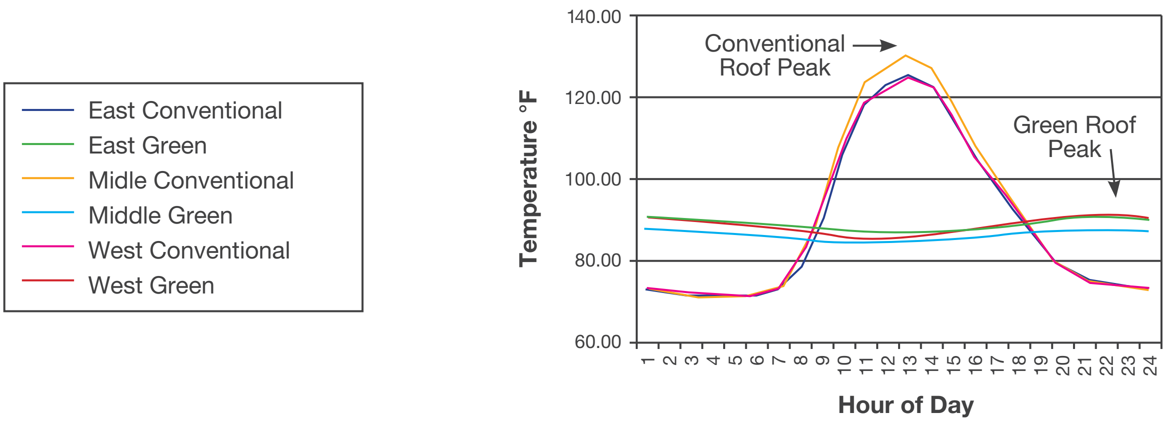
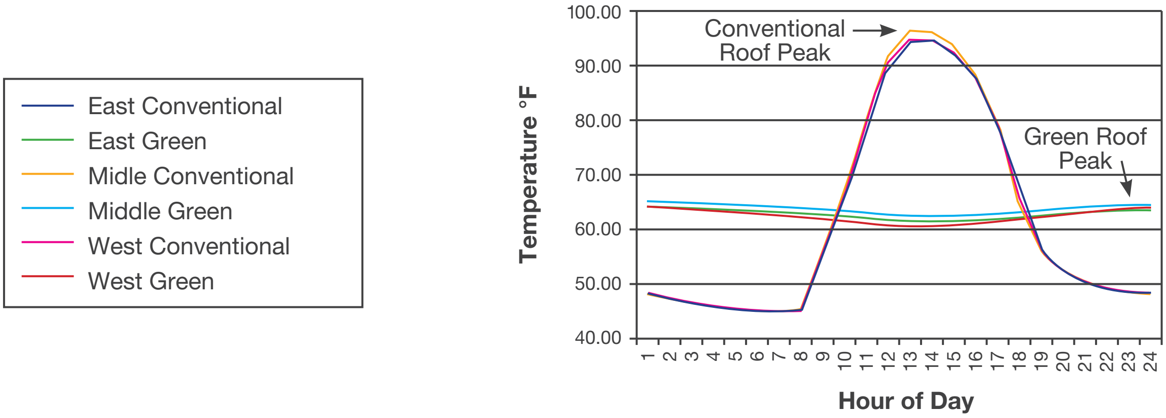


Figure 2 Winter roof diurnal range



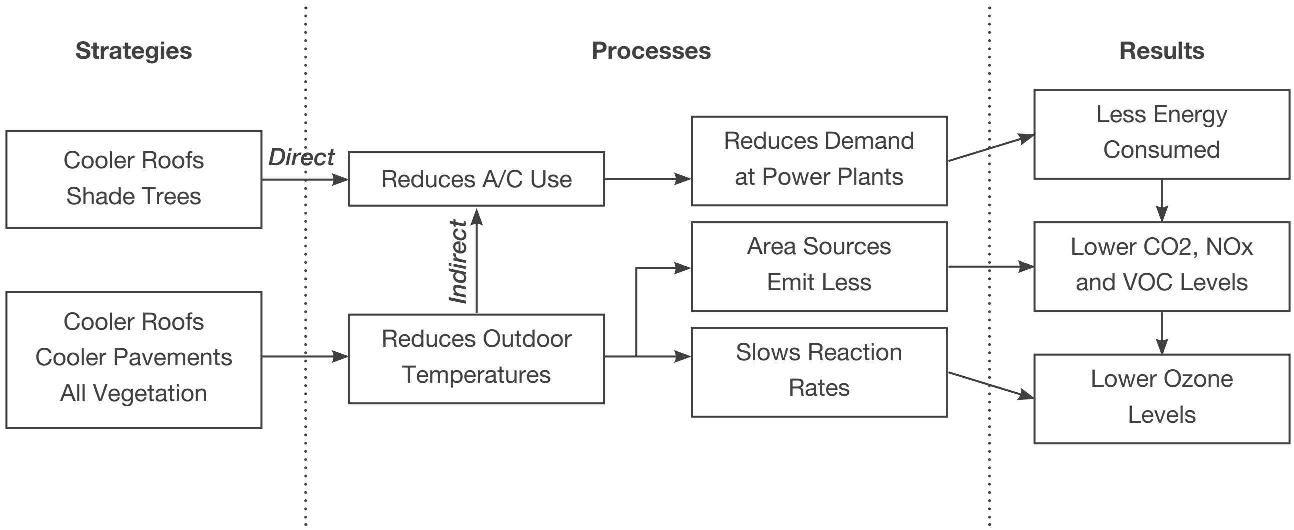
The daily range in temperatures for the exposed and Green Roof is 600°F and 60°F respectively. Large ranges in maximum and minimum temperatures over the 24 hour cycle causes severe heat stress on all the roof components including expansion and contraction and out gassing of volatiles. This also means the surface waterproof covering is more likely to fail early.

Reducing the heat load and stress increases all the component's lives and reduces the heat transferring into and out of the building.

Additionally the reduced range with a Green Roof allows the building to reach an even heat loss/gain profile. This in turn allows the air-conditioning and heating to be designed for lower extremes and to work at higher efficiency. It also allows the plant to be suitably downsized.

The impact on the sustainability of a Green Roof can be demonstrated in graphical form in Figure 3 below.

Figure 3 Impact of Green Roof on emissions



Source: Banting et al, Oct 2005 p18

Green Roofs lead to lower energy consumption and therefore, through lower generation, to lower CO_2 emissions. It's clear that if there is lower energy consumption then there will be cash savings, but Green Roofs and sustainability can affect developer's income and profit in many more ways.

8. How can anyone make money from sustainability?

This is a question many developers are asking and it can be difficult to demonstrate until the principles of NPV are understood.

Essentially sustainability can provide income or reduced cost and sometimes it can do both. Green Roofs are one of the best examples of increased income, reduced cost and lower impacts on the environment. A win/win option.

Often sustainability will produce benefits that translate into future benefits which might be realised by the occupier or long term building owner rather than the developer. However, NPV will demonstrate those future benefits which can increase the present value of the development by improving rent and yield and reducing void periods.

9. Long-term costs & the 'people factor'

Recent and widely reported research into office accommodation has identified the relationship between capital cost, the cost in use and the cost to the business of assets as:

Capital Cost	Cost in Use	Business Costs
1	5	200

Source: "The long term costs of owning and using buildings" - published by The Royal Academy of Engineering (November 1998).

What this means is that to operate and maintain the building will cost 5x the capital costs over the life of the building. However, the cost of using the building for the occupier is 200x the capital costs.

However, as we have seen most developers are very focused on build cost, i.e. the initial capital cost. This is due to the way most developments are funded with two funding sources:

1. Development capital. This is a short term funder who takes the risk while the building is constructed and while the developer finds tenants. The cost is around 2% higher than the long term funding.
2. Once the building is occupied the short term funds are replaced by a long term funder.

All developers have good sales and marketing teams that are focused on attracting tenants and can advise the design team on what the target tenants will want. What most developers lack is the ability to maximise the value of the final product.

Critically these relationships appear to work in reverse as well. So, if a developer just focuses on lowest capital cost, ignoring performance and cost in use, the effect of reducing the capital cost by 10% could be:

Capital Cost	Cost in Use	Cost to Business
1	5	200
- £100k	+ £500k	+ £20m

This means that a reduction of £100k in capital cost which cuts performance can cost an additional £550k in building running and £20m in occupation and employment costs for the occupying business.

The real reason we build buildings is to provide a warm, dry, safe place for an organisation to employ people, to do what it does, to earn profit. In simple terms a company employs 100 people. If a building provides an efficient working place then the benefits impact the bottom line immediately with no intervening costs

***Table 3** Effect of efficiency gains on P and L account*

Efficiency	par	5%	10%
Employees	100	100	100
Earnings	3,500,000	3,675,000	4,042,500
Earnings/Employee	35,000	36,750	40,425
Increase in proftability	0	175,000	367,500

In this example, a 5% efficiency brings £175,000 additional profit which is attributable to each year of the building's life.

This workforce efficiency can be generated in a number of ways but an obvious example is a building with inefficient air-conditioning, which will soon over heat, resulting in staff being unable to work efficiently in temperatures over 25°C. An actual example of this is a newly refurbished Government office in central London where one of the client requirements was to reduce energy consumption. They opted for a naturally ventilated building with no air-conditioning however, in the summer the temperatures exceed 280°C and now all desks have 1.5kWh personal fans adding 1.5MWh per year to the building consumption. With urban temperatures rising the building will fail on more days a year.

Once the impact on the cost in use and the building user is understood the impact on development income starts to become more obvious. However, there are a few problems still to overcome.

10. How can the value of developments be improved?

Buildings are valued by combining the hard facts with soft issues, such as letability and local competition. The hard factors can be broken down to:

- The size in square feet. That is the gross net lettable, remove common parts and toilets and only measure the space the tenant can use.

- The rent. This is the amount of rent stated on the lease excluding service charge.

So stage 1 is size x rent which gives gross income (earnings) per year.

An example is a building with 1,000 sqft net letable and a tenant at £20 /sqft/year.
So the earnings are 1,000 x £20 = £20,000 each year of the lease.

However, to value a building we need to multiply the income per year, the £20k from above, with a factor that reflects the security provided by the building to ensure future letting potential, the future cashflows which is an NPV calculation.

Factors that affect the value:

- Length and type of lease. Some valuers and purchasers favour 25 year FR&I (fully repairing and insuring) the traditional UK institutional lease. But it is now a bit out of favour with a lot of tenants and purchasers. With a 10 year lease the tenant has the option to leave without obligation and the owner can refurbish and increase the rent and hence value but this will mean they have rental income voids.

- The creditability of the leaseholder. This is called the covenant. A blue chip FTSE listed tenant is deemed less risky than a small business.

- The reletability of the building. This is a factor to cover how easy will it be to re-let the building at the end of the lease or when the tenant disappears. There are lots of things that affect this such as floor to ceiling height, flexibility, location, elevation treatment (will it look nice in 10 years?) the quality of local competition and how will the decision makers and their employees like the building.

- The maintenance profile of the building. If good quality design and materials are used the cost of maintenance is reduced and higher positive cashflows are generated in the future. This is translated into a higher NPV and current valuation. A good example is the roof's waterproof layer. A built up roof is cheap but will last only 10 years or so whereas a single ply membrane will last 25 years. So the built up roof is replaced twice during the single ply life. The impact of replacing the roof is substantial which is why the additional capital cost is more than offset by the increased value of the development.

- User acceptability of the building. If the building is unacceptable to the users, for any reason, the tenancy is at risk and the relettability is lowered.

Currently there is a big push from Government to avoid air conditioning, as a way of reducing energy consumption, and use naturally ventilated systems. Naturally ventilated buildings are like the old electric storage heaters - they were fine for part of the day but were too cold or too hot the rest. The offices with natural ventilation systems are not comfortable places for staff to work in. This is now widely known amongst occupiers so if there are 2 competing buildings, one with and the other without air-conditioning, the air-conditioned will be occupied first.

So the value of naturally ventilated buildings is much lower than air conditioned or good comfort cooled. This is an example of how focusing on one element of sustainability, energy reduction, and ignoring the people elements leads to failure.

Therefore, generally the better the building the higher the value. The value is determined by taking the fixed criteria, the square feet x the rent, and multiplying it by a number of years that reflects its value compared to other similar buildings. This is known as “years purchase” and is a measure of quality as well as value. This years purchase must also balance the price paid to the developer with the time left for the investor to make his return.

The basic value equation is:

net lettable space x rent x no. years purchase = value

However, years’ purchase can be expressed as a % called yield, where yield is the inverse fraction.

$$\textit{yield \%} = \frac{100}{\textit{years purchase}}$$

To convert a yield to years’ purchase use this calculation.

$$\textit{years purchase} = \frac{100}{\textit{yield}}$$

Many in the property world use yield and years’ purchase to provide a shorthand comparative value and quality descriptor. The following table demonstrates the values from a range of yields for the same £10,000 income.

***Table 4** Comparison of yield and years’ purchase*

Yield %	Year’s Purchase	Value
5%	20.0	£200,000
8%	12.5	£125,000
10%	10	£100,000
12.5%	8.0	£80,000
15%	6.7	£66.667

As the yield is an inverse you will see that the lower the yield, the higher the value. This is counter-intuitive and therefore not widely understood. However, if a developer says something will reduce the yield by a half a percent you now know that it will increase the number of years purchase and increase the income!

Property investment funds have very quickly identified that tenants do not stay in buildings that do not provide the right working environment for their staff. In our example, therefore, a building with poor natural ventilation will be harder to let, now and in the future, and the number of years’ purchase (yield) offered will be lower.

Conversely Green Roofs, which have a wide range of financial, environmental and social benefits, provide a significant positive effect on the value of the development. We now need to look at Green Roofs in more detail.

11. Green Roofs and Planning Approval

From a planning perspective, Green Roofs can help to satisfy a range of needs which will increasingly have to be considered as part of a planning application.

Sheffield's Head of Planning, Les Sturch, has stated:

"By using a Green Roof an applicant can provide benefits which satisfy a number of planning policy requirements at the same time; for instance sustainable drainage, reduced energy consumption, improved biodiversity and better air quality.

We are increasingly expecting developments to demonstrate holistic approaches to dealing with these environmental issues."

Whilst adding a Green Roof will not ensure a successful planning application it will add to the credibility and desirability of the building in the eyes of the planning office.

12. Green Roof definitions

A succinct definition of a Green Roof is found on Wikipedia.

A Green Roof is a roof of a building which is partially or completely covered with plants. It may be a tended roof garden or a more self-maintaining ecology.

Ref en.wikipedia.org/wiki/Green_roof

A Green Roof development involves the creation of green and living areas on top of a man-made structures. This green space can be below, at or above grade (ground level), but in all cases the plants are not planted in the “ground’ but on top of a structure over a useable space.

Many ground level “gardens” are in fact Green Roofs over car parks or amenity space. (Pictures FTW Gardens and Canary Wharf). Green Roofs can provide a wide range of public and private benefits.

Green Roof systems may be engineered, with proprietary drainage layers, filter cloth, growing media and plants in pre grown mats by the roofing supplier, or each component of the system may be installed separately in layers by a Green Roof contractor or even the original ground worker.

Green Roofs can be used in many applications, including commercial, industrial, government and residential applications. In Europe, they have been widely used for many years for their storm water management and energy savings, as well as their aesthetic benefits.

13. Types of Green Roofs

Green Roofs refer to the environmental benefits of plants on roofs, rather than to the colour green. In fact with many roofs planted for their biodiversity they are anything but green, often being referred to as ‘brown roofs’ as they change through the seasons

This section will provide descriptions of the types of roof and their differences, usually soil depth and planting regime.

“Green Roof” is a generic term that has evolved since the early 1900’s and is now often called a “living” roof. Green Roofs are primarily divided into extensive and intensive categories.

Intensive Green Roofs

For intensive Green Roofs, the growing media is fairly deep - usually more than 300mm – and supports shrub and tree growth. A roof top garden or a patio is an example of an intensive roof.

The saturated weight is 3.3kN/m^2 or more and irrigation is necessary in most cases. They require a lot of maintenance, like any other well-kept garden does. Intensive roofs provide real social benefits for building occupiers with recreational space.

Semi-extensive Green Roofs

Usually 150-300mm inches deep with a saturated weight of 1.4 – 2.4kN/m^2. Whether irrigation is necessary or not depends on the regional climate and on the kind of plants that are used.

Shrubs, perennials, herbs and grasses can be used on semi-extensive roofs and they are usually accessible to staff. They can include hard paved areas and are attractive to a wide range of invertebrates.

Extensive Green Roofs

Typically 75-150mm deep with a saturated weight of 0.7-1.4kN/m^2. They are ideal for the growth of drought-tolerant plants, particular succulents like Sedum.

They don’t need irrigation and only little maintenance. Due to the low maintenance, they are often the roof of choice for building owners looking to reduce costs and improve the environment.

The extensive roof type can be further sub-divided into:

- Sedum – plug planted or mats – is often used when aesthetic or visual impacts are important. A sedum roof tends to be visually consistent throughout the year. Some suppliers offer roofs, primarily sedum mats, with thicknesses of around 50mm. It is generally accepted that roofs with less than 60mm of growing medium will not survive and will require extensive maintenance and replanting.

- Biodiverse – using a number of local plants and alpines with locally sourced growing mediums, where possible. The visual aspect will change with the seasons particularly during winter. Biodiverse roofs are more attractive to wildlife and can be designed to attract and sustain local birds, insects and invertebrates.

Extensive Green Roofs normally have a thinner growing medium but can offer as much amenity and recreation if planting is designed rather than merely specifying a sedum mat. A semi-extensive roof in Grey's Inn Road, London installed 2 years ago has a simple paved area with plastic chairs and tables for staff. It is in great demand all day and one employee said he came in an hour early to have coffee on the roof and prepare for the working day.

They are usually less costly to install than intensive Green Roofs and are less costly to maintain, as they do not require mowing, irrigation or any other form of intensive management. Extensive Green Roofs generally provide greater biodiversity interest than intensive roofs. Usually they are planted with or colonised by, mosses, succulents, wild flowers and grasses that are able to survive on the shallow low-nutrient substrates that form their growing medium.

Commercial systems in the UK generally use sedums (Sedum spp.) as the principal plant species in the vegetation layer. Sedums, which are low growing succulents, are often used as they are drought and wind tolerant, form a dense covering and can be very visually attractive. These sedum based systems generally come in two forms:

- a blanket/mat system,
- a substrate-based planted or hydro seeded system.

Often blanket systems are the only type that can be used on existing buildings due to load restrictions. On new build, however, where additional structural loading can be taken into account during the design and construction process, substrate systems (which can comprise recycled materials) are preferred because of the greater environmental benefits they bring.

The construction of the roofs will be discussed further in the next section.

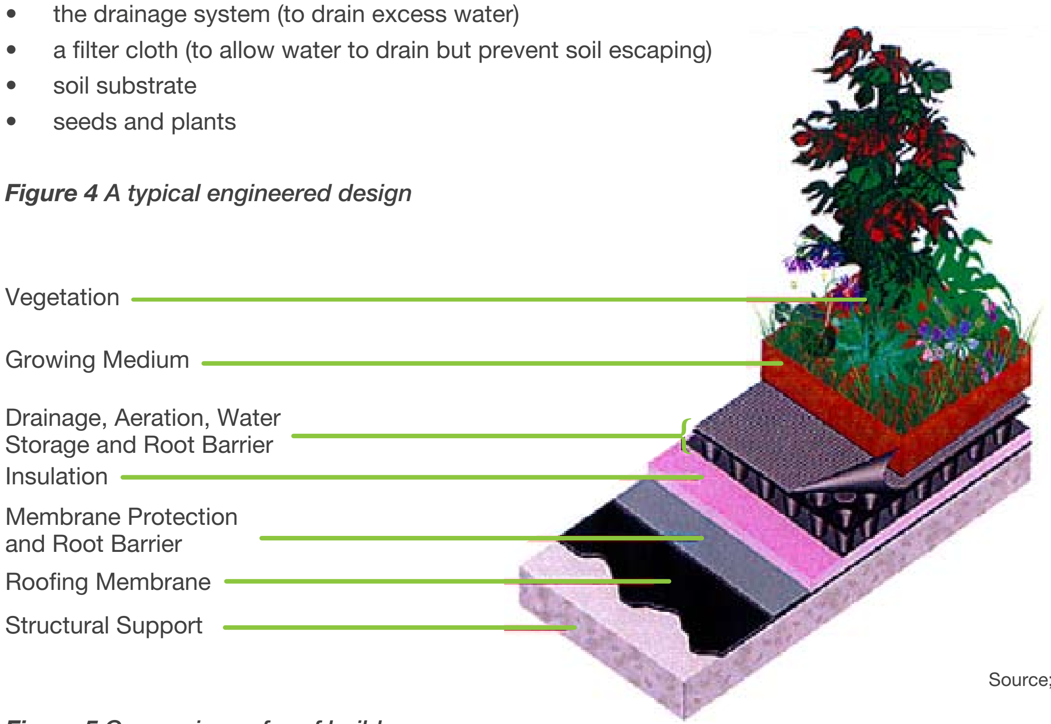
14. Construction of Green Roofs

Essentially, a Green Roof system consists of layers that imitate natural processes of evapotranspiration and filtration, and also protect the building and roof.

The basic components are:

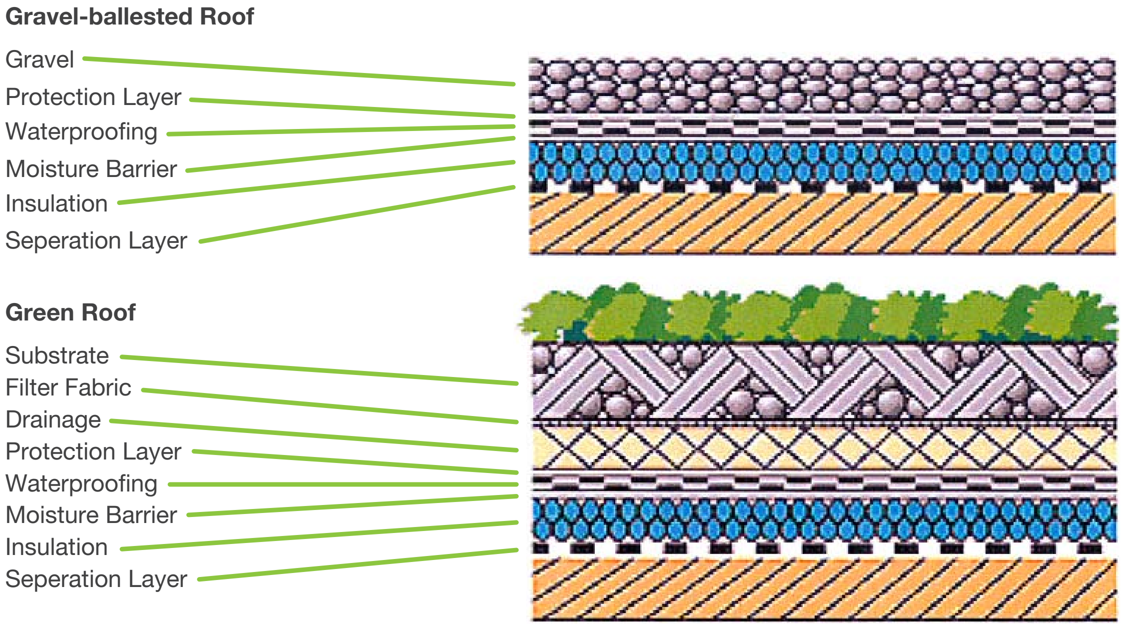
- a waterproof layer
- a root repellent membrane
- the drainage system (to drain excess water)
- a filter cloth (to allow water to drain but prevent soil escaping)
- soil substrate
- seeds and plants

***Figure 4** A typical engineered design*



Source; England et al 2004

***Figure 5** Comparison of roof build-up*



14.1 Types of vegetation used for a Green Roof

Vegetation is the most important layer of a Green Roof. Plants add aesthetics and also determine the success or failure of the project, depending on their hardiness.

Biodiverse (extensive) roofs offer the easiest and lowest cost option. Many seed suppliers offer "local" wild flower mixes which can be as low as £0.19 per m^2. The downside is the roof may take 2 or 3 seasons to become established. However, the additions of annuals such as such as cornflowers will add colour and interest while the roof matures.

Any well designed roof, of any type, should include timber and stones to encourage invertebrates to colonise the roof.

Of course the extreme solution is to allow the roof to self seed which is especially effective if reusing the top soil of an existing brown field site. Although, this make take several seasons to mature and may suffer from soil erosion if not planted with grasses or similar.

Although plants are the most vital component of an extensive Green Roof, they are often the most neglected due to cost concerns. Plant plugs with fully established root systems quickly spread out their roots horizontally and form a dense vegetation mat in a few growing seasons.

Plant cuttings (mostly from sedum) can also be spread over the soil layer. While these cuttings may eventually form roots, it can take twice as long before the roots can actively hold the soil in place, prevent wind erosion and use water.

From an initial-cost perspective, plant cuttings are more economical because they are less labour intensive to install. However, the survival rate of cuttings is only about 50%, compared to 80% for plant plugs with established root systems reducing the whole life cost benefit as if half the plants need to be replaced within the first year, the apparent cost advantage quickly disappears.

The plants most commonly used in sedum roofs are succulents and other low growing plants that are capable of storing water in either fleshy leaves, bulbs or roots. Plants successfully used in shallow soil beds on roof surfaces include various species of sedum, sempervivum, creeping thyme, allium, phloxes, anntenaria, armeria and aubrieta, as well as numerous others. What makes these plants good Green Roof candidates is their ability to adapt to alpine conditions with little soil, no water, high winds and high sun exposure. These plants have to be real "survivors."

It is also advisable to include native grass seeds over a newly planted roof because the seeds will germinate quickly and stabilise the soil layer until the Green Roof plants start to spread. However, this adds to the appearance changing seasonally and during wet and dry periods. Grasses will grow during wetter periods, and the alpine natives will flourish and display their flowers during long hot and dry summers.

Mosses should be avoided as Green Roof vegetation. While their sponge-like forms do soak up and retain a lot of water, they can pose a fire hazard in a drought.

Intensive roofs will use any plant found in gardens today and range from ornamental trees to lawns but this increases the maintenance cost and they must be extensively irrigated in dry spells.

14.2 Biodiverse

There is a type of vegetation that is growing in popularity often called Biodiverse which uses a number of local plants and alpines with locally sourced growing mediums, where possible. All types of construction can be used for Biodiverse roofs.

These roofs often include a local wild flower mix and so the visual aspect will change with the seasons particularly during winter.

Biodiverse roofs are more attractive to wildlife and can be designed to attract and sustain local birds, insects and invertebrates.

***Figure 6** Biodiverse roof being installed at Sharrow Primary School, Sheffield*
(This is currently the largest biodiverse roof outside London)

Source: The Green Roof Centre

14.3 Summary

***Table 5** Comparison of roof benefits*

	Water Attenuation	Water Runoff	Energy Reduction	Biodiversity	Maintenance	Sustainability
Engineered						
Sedum Mat	✓	✓	✓	✓	Medium	✓
Sedum	✓✓	✓✓	✓ to ✓✓	✓ to ✓✓	Medium	✓
Extensive	✓✓✓	✓✓✓	✓✓✓	✓✓✓	Very Low	✓✓
Biodiverse	✓✓✓	✓✓✓	✓✓✓	✓✓✓✓	Very Low	✓✓✓
Intensive	✓✓✓✓	✓✓✓	✓✓✓	✓✓✓	Very High	✓✓
Naural						
Sedum Mat	✓	✓	✓	✓	Medium	✓
Sedum	✓✓	✓✓	✓ to ✓✓	✓ to ✓✓	Medium	✓
Extensive	✓✓✓	✓✓✓	✓✓✓	✓✓✓	Very Low	✓✓✓
Biodiverse	✓✓✓	✓✓✓	✓✓✓	✓✓✓	Very Low	✓✓✓✓
Intensive	✓✓✓✓	✓✓✓			Very High	✓✓✓

Poor ✓ – Very Good ✓✓✓✓

In considering the cost benefit analysis of any project it is important to establish the basic parameters which are reviewed fro Green Roofs in the next section.

15. Financial and economic factors for Green Roofs

The cost benefit analysis of a Green Roof has a number of factors that can affect the result. This section will look at these before we move onto the analysis of some typical roofs.

15.1 Biodiverse

There has been some debate recently over the costs of installing Green Roofs. The cost is very project specific however, we offer some guidance for approximate prices in the table below. Engineered roofs are designed and installed by the roofing supplier and 'natural' roofs are designed by a specialist and can be installed by the site groundworker:

***Table 6** Guide to installed cost of different roof types*

	Engineered £/m²	Cost £/m²	Natural Construction £/m²	Cost £/m²
Warm roof expose	55		55	
Sedum Blanket	110	+55	95	+40
Sedum Plug	120	+65	80	+25
Biodiverse	120	+65	75	+20
Inverted Roof				
Shingle	70	+15	70	+15
Paving	75	+20	75	+20
Sedum Blanket	110	+55	95	+40
Sedum Plug	120	+65	80	+25
Biodiverse	120	+65	75	+20

Table 6 uses a single ply membrane roof as the base cost and shows the additional cost for the different Green Roof build-ups. Note that for an inverted roof, replacing the paving with a natural Biodiverse roof means no additional cost.

15.2 The product life of a Green Roof

The life of a Green Roof is often hard to define, Acks (2003), states that a Green Roof will at least double the life of the waterproofing layer when compared to a normal exposed roof.

This doubling of the life of the waterproof layer is now widely accepted in the UK and European roofing industry although it is not currently reflected in standards or warranties.

***Table 7** Comparison of the lives of exposed roofs and Green Roofs*

	Exposed (years)	Green Roof (years)
Built Up	10	20
Mastic	12 - 15	25 - 30
Single Ply	25	50
Metal	15 - 25	30 - 50

When assessing the life of a compound product, such as a roof, the selection of the components needs to be addressed to ensure maximum financial benefit is achieved.

For example the screws used to mechanically fix a single ply roof have different lives depending on the material. However, they have little impact on the overall initial capital cost. The life of an alloy screw is between 10 and 15 years whereas a stainless steel screw is lifed at 40+ years.

So to reduce the initial cost marginally the developer requires the subsequent owner to refurbish the whole roof 10 to 15 years earlier than should be required. **The NPV comparison is in table the following below:**

***Table 8** Comparison of NPV of screws in a single ply roof*

	Cost	**NPV**
Stainless steel screws	5	200
Alloy screws	+ £500k	+ £20m

This means that to save £5,000 capital cost the owner of the building has to pay out for substantial remedial and replacement work between 10 and 15 years later.

15.3 Maintenance costs

Maintenance costs are divided into two categories, annual and cyclical. Annual costs are incurred every year and cyclical are recurrent costs but outside the annual cycle. For example annual costs will include outlet inspection and cleaning whereas cyclical will include replacement of the waterproof layer at the end of its life.

The maintenance costs are varied by the type of roof. For extensive roofs, previous studies indicate little difference between Green Roof and standard roof maintenance costs.

Acks (2003) for example, assumed $0.60 per square foot for Green Roofs and $0.10 per square foot for standard roofs without any data, and Wong et al. (2004) assumed identical annual maintenance costs for standard (exposed roofs) and inaccessible Green Roofs. The article pointed out that an exposed roof required more frequent replacement of the waterproof layer.

Today the UK industry accepts that the annual maintenance cost of an extensive roof and an exposed roof is generally the same and that the life of the roof waterproof covering is doubled.

In contrast intensive roofs require more maintenance as they are equivalent to a garden or park and plant selection has a big impact on maintenance costs.

15.4 Energy costs

All previous studies into Green Roofs have derived energy savings but the calculation of the benefits vary enormously. Many studies relate the savings to a monetary value and the difference between the values in Acks 2003 and Wong et al. 2004 is in excess of 100%.

This a fairly unhelpful method as the energy saved should be measured in definable units, kilowatt hours (kWh), without the addition of variables such as cost/kWh.

The actual amount of reduction is building and location specific. However, there is now a number of good quality studies that have been completed, on broadly similar 100mm deep substrate roofs, that provide consistent data giving upper and lower figures,

***Table 9** kWh savings from 100mm Green Roofs*

Location	**kWh/year/m²** [1]
Toronto	4.15
Germany	4.0
Barclay's Tower Canary Wharf London [2]	39.1

Notes on Table 9:

1. The savings are averaged over the year
2. Depth of substrate is slightly lower at 80mm

The data from Barclay's Tower is particularly valuable as it was a retrofit sedum mat roof where there is 3 years of records without the Green Roof and for each year since its construction. The variation between the results can be due to a number of factors such as location, exposure and type of heating and cooling used.

Unfortunately we are unable to provide a simple one size fits all energy saving amount/m^2 but the range is now fairly consistent across studies.

In the next section we look at how these factors combine to improve the value of the development.

15.5 How Green Roofs can influence yield

In section 10 we looked at factors affecting yield. Green Roofs can increase the value of a development because they improve all the factors considered in setting the years purchase and therefore yield:

- Lower energy costs over the life of the building
- Lower refurbishment costs of roof by extending waterproof layer life
- If the roof is occupier accessible then there is significant employee benefit
- Provides a Planning benefit
- Increase rental value
- Decrease void periods
- Will increase the yield applied in valuing the development
- Reduced constructor costs if considered early enough and the design is adjusted to maximise potential benefits.

Charlie Green, Director of The Office Group, owners and managers of 175 Gray's Inn Road, London WC1 is unequivocal in attributing the reduction in voids on his Green Roof.

"These offices have enjoyed a faster take up of space than in our other buildings. This is directly attributable to having the roof,- with a number of tenants stating they preferred us to our competition because of the Green Roof, with some even enduring long commuting journeys"

In essence a building with a Green Roof will have a higher Net Present Value and that translates into a higher years purchase for valuation purposes.

If we compare 2 buildings with the same 10,000 sqft floor area and rent of £250,000; 25 year FR&I lease with 10 year break clause, and a building life of 35 years.

***Table 10** Comparison of NPV & Yield for 2 identical buildings 1 with a Green Roof*

	Building 1	**Building 2**
Green Roof	No	Yes
Rent pa	£250,000	£250,000
Void	6 months	3 months
Energy pa	£30,000	£24,000
Roof referbishment	£150,000 (Year 15)	None
Net Present Value	£963,646	£1,212,678
Yield	7.22%	6.73%
Yield Improvement		0.48%

Data for table 1
Building 1, no Green Roof energy cost £30,000pa 6 month void in year 10, £150,000 roof recover in year 15.
Building 2, Green Roof, 20% saving on energy £24,000pa, 3 month void in year 10, no roof refurbishment costs.

This supports the proposition that the use of a Green Roof can increase value and improves yield by 0.5%. Varying the rent and cost of construction maintains a consistent 0.48% improvement. However, as the DCF theory predicts, changing the Discount Rate does change the yield for a Green Roof, as table 10 below illustrates.

***Table 11** Value changes with Discount Rate*

Discount Rate	**Improvement in Yield**	**Absolute value improvement**
4%	0.48%	£120,000
10%	0.80%	£200,000

16. Process

To maximise the benefit to the developer and the environment, the Green Roof should be included in the client brief and designed from pre-inception. Only then can the design team design their components to take advantage of the effects of a Green Roof.

The two main areas of impact are:

- Drainage - reduced runoffs allow smaller and fewer rainwater outlets with less surface water to dispose of. This leads to lower cost drainage, which when combined with SUDS, can reduce the offsite requirements to zero.

- Mechanical and electrical - with lower thermal gain in the summer and loss in the winter the cooling and heating loads are reduced and the designs can be more effective and economical. Also the use of Green Roofs provides higher efficiencies in the Air Handling Units and Solar Heating.

However, both of these benefits are difficult to ascertain in financial terms as they require an alternative design to be completed and so far there has been limited research that has attempted this.

Current research appears to be lacking in terms of quantifying other benefits of Green Roofs, Banting et al (2005) sums up the research into costs and benefits very succinctly;

Researchers have provided empirical evidence of benefits... However, many of these benefits are very dependent on the specific Green Roof designs implemented on buildings. Such results cannot be easily extended to typical Green Roof installations without having an impact on other benefits.

The Eastside Report for Birmingham states that there are drainage gains to be made where Green Roofs are incorporated early. However, their attempts at reducing the cash gain to a % of building costs was not successful as the volume of a building may vary substantially for 2 similar roof areas. Consider the two case studies Barclays Tower (over £200M build cost) and Paradise Park (1.2M). The Green Roofs were 850m^2 and 400m^2 respectively and would constitute 0.0105% and 1.8% of build costs.

The current traditional design team usually does not include anyone qualified to design or supervise a Green Roof. It will be necessary to include these following skills:

- Substrate and drainage layer design
- Planting regime.

A good Green Roof design will balance the benefits of the Green Roof and the costs of the additional structural requirements, if any. The specialist Green Roof consultant should be appointed at pre-inception and they must be fully integrated into the team as a key member, otherwise the benefits of a Green Roof will be at risk. However, not all roofs need to be extensively designed, they can be very simple:

Figure 7 The Cube live/work development, Sheffield

Source: The Green Roof Centre

16.1 Green Roofs and Solar Panels

There is a perception that a building can either have Green Roofs or solar production at roof level but not both. In fact there is substantial evidence from Germany and the US that the use of both solar or photovoltaic panels (PVs) and Green Roofs provides dual benefits in terms of energy production and energy saved.

The Green Roof element increases the efficiency of solar production by reducing fluctuation of temperatures at roof level, the diurnal effect (see section 8), and by maintaining a more efficient microclimate around the solar panels. The current evidence is based on data from PVs but is equally applicable to solar water heating and the efficiency of air conditioning plant.

We have seen that the temperature at 1m above an exposed roof can rise to 600C this causes the air to rise causing a turbulent heat haze over the roof. Everyone has seen the wavering effect of looking through a heat haze and it is this interference, occlusion, with the passage of sunlight which reduces the effective amount of sunlight striking the solar collectors surface lowering the energy conversion.

***Figure 8** PVs on a white roof*

Gregg et al. while researching PV efficiencies for United Solar Ovonic LLC, found the performance of photovoltaic panels is lowered by 0.5%/ºC above or below 25ºC . Therefore at 600ºC the efficiency is reduced by 17.5% affecting the payback period and economic viability of PVs.

***Figure 9** Photovoltaics and Green Roofs, Switzerland*

However, the use of a Green Roof maintains the ambient temperature at roof at about 25ºC allowing the PVs to work at optimum efficiency

Photos: Livingroofs.org

Figure 10 *Exposed roofs and Green Roofs with solar panels*

If we bring these two pictures together, it's fairly obvious how hot the uncovered roof can be and it is easy to appreciate how a Green Roof conditions the air and improves the efficiency of solar energy collection panels.

16.2 Green Roofs and Solar Water Heating Panels

Solar water heating panels are the most cost effective method of solar energy collection and they benefit the same way PVs do when the air around them is cool and interference free.

Using solar water heating panels on a Green Roof ensures the maximum return on investment and maximum production of hot water for the solar heating array.

16.3 Green Roofs and Air Conditioning AHUs

The air handling units of an air-conditioning system are usually found on roofs. However, we have seen that on hot summer days the air temperature 1m above the surface can be over 400C which means the air temperature has to be reduced by about 220C before it can be used.

However, a Green Roof means the temperature above the roof remains around 250C which means the AHUs only have to reduce the air temperature by 70C, which means they use less energy and can be smaller.

16.4 The benefits of Green Roofs for insulation properties

Green Roofs have a substantial thermal mass and provide a moderate insulation value depending on the season. These combined properties significantly reduce diurnal temperatures at the boundary between Green Roof and building structure (the diurnal temperature being the daily maximum to minimum temperature range).

The diurnal temperature range for a conventional construction ‘warm-roof’ waterproof layer can be very large; for example, the surface of a typical bitumen waterproof layer may exceed 50ºC during a sunny summers day, whilst falling to just above 0ºC at night. A roof with a low level of insulation below the waterproof layer will allow the space below to heat up quickly in hot, sunny weather.

The increased internal temperatures in the floor below the roof contribute to making the internal building environment uncomfortable for the buildings’ occupants. Overheating can lead to increased use of air-conditioning, which in turn will lead to increase in energy consumption. During cold weather, the opposite effect applies, resulting in a demand for extra heating of the floor directly below the roof and, hence, increased energy consumption. The energy used for heating and cooling has a financial as well environmental impact.

High temperatures in top floors of buildings also cause the man-made components of the building to emit volatile elements which can have a detrimental effect on the building occupants, often referred to as “sick building” syndrome.

Building products that can be affected include:

- Floor coverings – carpets, vinyl tiles
- Wall coverings – paint, papers
- Suspended ceilings
- Furniture.

The Green Roof has the same energy providers as a conventional roof, but it has the additional energy consumers of evapotranspiration and photosynthesis. Unlike a conventional roof, the Green Roof is a living system that reacts to the environment in a number of important ways:

- Water is stored within the substrate and is utilised in evapotranspiration by the vegetation layer; this process uses up a considerable proportion of the incoming solar radiation in comparison to a non-Green Roof.
- The Green Roof has a large thermal mass, which stores energy and delays the transfer of heat to or from the building fabric.
- Plants absorb solar radiation for photosynthesis converting CO2 to oxygen.
- Plants also loose water through their leaves to cool themselves.
- Evaporation from water stored in the substrate cools the surface and area above the roof.
- The plants provide protection from wind cooling by disrupting air flow across the surface.
- Plants have a higher albedo (solar radiation reflectivity) than many standard roof surfaces

The use of a Green Roof compared to conventional surfaces can have a significant impact on the energy balance within a given building and on the immediate environment surrounding the building. This is particularly relevant if a building has poor insulation and poor ventilation, which can lead to, increased use of air conditioning and therefore increased energy use.

Studies have shown that the membrane temperature beneath a Green Roof can be significantly lower than where the membrane is exposed. Table 2 shows the average temperatures under the membrane of a conventional roof and of the same membrane under a Green Roof in a study undertaken at Nottingham Trent University in 2005.

Table 12 *Study of temperatures under membranes of a conventional and a Green Roof*

	Winter	Summer
Mean Temperature	0°C	18.4°C
Temperature under membrane of conventional roof	0.2°C	32.1°C
Temperature under membrane of Green Roof	4.7°C	17.1°C

Source: www.greenroofs.co.uk

This correlates with the Liu study , which compared a conventional roof system with a Green Roof system.

"The average daily energy demand for space conditioning caused by the reference roof system was 20,500 BTU to 25,600 BTU (6kWh to 8kWh). However, the Green Roof system's growing medium and plants modified the heat flow and reduced the average daily energy demand to less than 5,100 BTU (2kWh) –a reduction of more than 75%."

Reducing the temperature of the roof covering improves the energy efficiency and there are a number of different ways a Green Roof can be constructed to realise the benefits.

16.5 Rainwater management

When rain falls on forested and open, undisturbed land, water goes through its natural cycle and water is taken up by the plants, (transpiration), evaporates or percolates through to lower levels. However, in urban and metropolitan areas, with buildings and streets, the hard landscape and drainage systems mean that the evapotranspiration and percolation is reduced and the run off significantly increased.

Green Roofs move back towards the structure and water retention profile of the natural environment. When Green Roofs are combined with SUDS the profiles become very similar indeed.

Table 13 *Comparison of rainwater effects*

	Natural	Urban	Green Roof
Evaporation & transpiration	40%	15%	45% to 70%
Shallow aquifers	30%	5%	20% to 45%
Deep aquifers	30%	5%	0% to 10%
Run off	Effectively 0%	75%	10% to 0%

- shallow aquifers is the depth of soil that feeds plants,
- evaporation and transpiration often called evapotranspiration returns water to the atmosphere

The CIRIA (2000) report assumes that for design purposes a Green Roof provide a reduction equivalent to 30 - 50% annual runoff values.

The Environment Agency generally looks for new developments to attenuate surface water run-off back to the same as the original green field rates where possible.

The usual method to achieve this is by providing storage below ground but this is an expensive option and although rates vary the average is between £800 - £1,000 per cubic metre of storage volume provided.

To offset the reversed rainwater runoff patterns in urban areas, communities build costly drainage systems. While rainwater collection, storage and treatment systems deal with the impacts of sealed surfaces, they fail to address the source of the problem. In many cases, runoff is directly drained - untreated - into open water bodies and receiving streams, significantly increasing their pollution levels.

The combined impact of ongoing development within urban areas and climate change has created higher peak storm water flows leading to an increased occurrence of downstream flooding and pollution.

Figure 11 *Sheffield Wednesday football ground 26th June 2007*

Source: The Guardian web site

As a consequence, Sustainable Drainage Systems (SUDS) are now required to minimise the impact of both new and existing developments. They are designed to manage the adverse environmental consequences resulting from urban storm water runoff, and to contribute to environmental enhancement wherever possible. The use of Green Roofs can provide a essential role in achieving this as they successfully achieve source control, which is the fundamental concept of SUDS, i.e. the control of rainfall at or as close as possible to its source.

Around 30% to 40% of rainfall events are sufficiently small that there is no measurable runoff taking place from greenfield areas (it all infiltrates or evaporates). In contrast, runoff from developed areas takes place for virtually every rainfall event. This means that streams and rivers are more subject to overload. In addition, whereas for greenfield areas small events would be treated through natural filtration processes, development runoff can flush surface pollutants directly into the receiving waters. Where it is possible to provide replication of the natural behaviour of a greenfield site (described as interception storage) then this should be provided.

By using Green Roofs as a source control technique, the volume of runoff entering the underground drainage system, and thus the amount of storage capacity required within this system, can be reduced considerably. This is particularly important in dense urban developments where space for surface level SUDS components such as ponds and wetlands will be limited. It is also an important consideration when looking at the true cost implications of installing a Green Roof as the reduction in underground drainage infrastructure should be taken into account as well as the reduced number of downpipes and the smaller pipe network, etc.

When rain falls on a Green Roof it will first pass into the substrate and possibly pass through until the absorbency of the soil is activated (although through-flow will generally be low). It is then adsorbed by the substrate (and possibly the drainage layer) and taken up by plants in the same manner as on a greenfield site. For most small storm events the volume of rainfall is removed by evapotranspiration. Only when the soil is fully saturated will water percolate through to the underlying drainage layer in significant quantity.

Livingroofs.org identify the processes involved in the operation of a Green Roof as:
- Retention of rainwater in substrate and drainage layers
- Uptake of water and release by plants as vapour (transpiration)
- Uptake of water and biochemical incorporation by plants (photosynthesis)
- Evaporation from substrate due to wind and sun

There is a significant amount of published information that demonstrates the performance of Green Roofs in attenuating storm water runoff by reducing peak flow rates and volumes. Although there is a variation in performance, depending on rainfall patterns and location, this is no different to other SUDS components such as pervious pavements, or even greenfield catchments.

- The benefits of a Green Roof in terms of drainage can be summarised as:
- A Green Roof will typically intercept the first 5mm and more of rainfall (i.e. provide interception storage).
- The amount of storm water stored and evaporated is primarily dependent upon the depth of the growing medium and type of planting. In the summer a Green Roof can typically retain between 50% - 70% of the runoff.
- It has been demonstrated in Germany, between 40% - 100% of rainfall can be retained depending on the season.
- 75% of rain falling on extensive Green Roofs can be retained in the short term and up to 20% can be retained for up to 2 months.
- As the rainfall events become longer or more intense, the positive effect of a Green Roof remains as there is still a significant reduction in peak runoff rates.
- This increase in the 'time of concentration' means that a Green Roof will be beneficial throughout a wide range of rainfall conditions.
- The above benefits collectively mean that by incorporating a Green Roof into new development, there will be a reduction in the amount and cost of the overall drainage infrastructure required to serve that development.

Green Roofs retain, bind and treat contaminants which are introduced to the surface either as dust or suspended/dissolved in the rainwater.

A recent London Ecology Unit publication reported that 95% of heavy metals are removed from runoff by Green Roofs and nitrogen levels are also be reduced. In addition, Auckland Regional Council advise that Green Roofs are accepted as removing 75% of total suspended solids. Their study showed the total discharge of nitrogen and phosphate from the conventional roof and the Green Roof was:

***Table 14** Green Roof reduction in Nitrogen and Phosphates*

	Nitrogen mg /m³	**Phosphate mg/m³**
Conventional roof	265	145
Green Roof	70 mg/m³	75 mg/m³
Reduction	74%	49%

However, one of the greatest benefits of a Green Roof is its impact on visitors and users, in an accessible roof, which is referred as the amenity value.

16.6 Benefits of Green Roofs for amenity

The use of flat roof space for recreation is not a new concept. Many schools dating from the Victorian era have playgrounds at roof level, although not all are in use anymore.

In one case, North Haringey Primary School, such a playground has been transformed into a roof garden, planted with a variety of species to reflect the ethnic diversity of the school.

***Figure 12** North Haringey School amenity space on roof*

Source: Livingroofs.org

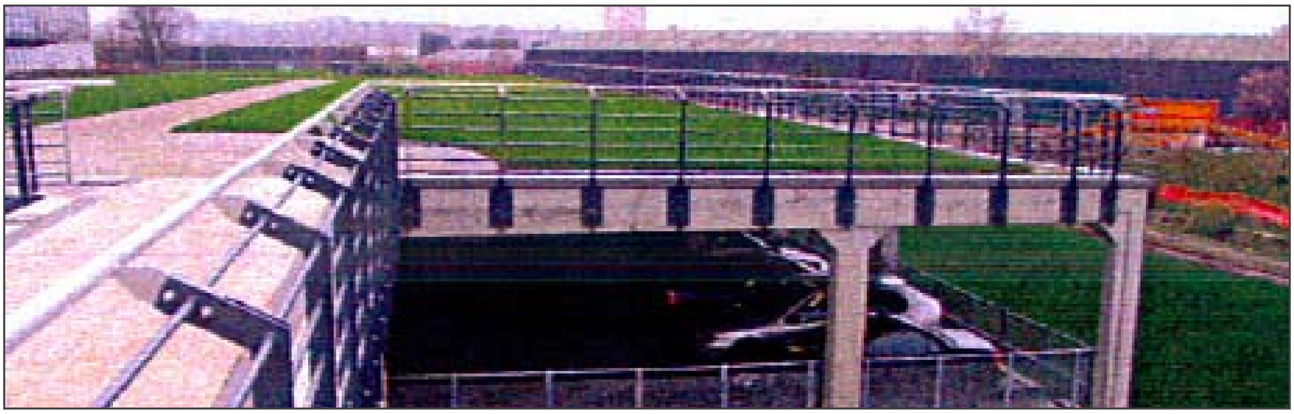
Moorgate Crofts Business Centre is an excellent example of a multi-use Green Roof. The semi-extensive Green Roof reduces rainwater runoff, decreases enrgy requirement, and allows elevated views across the Don Valley from its conference rooms suplemented by the planting. It also provides a social amenity for staff and visitors to relax and unwind.

***Figure 13** Moorgate Crofts Business Centre, Rotherham*

Source: Rotherham Metropolitan Borough Council

The White Rose Office Park in Leeds is home for a range of 'Blue Chip' corporate tenants. The developer, Munroe K, has been keen to create a very specific architectural and landscape style (see below). The style is simple, highly contemporary and stylised.

***Figure 14** White Rose Car Park Green Roof*



Source: Mitchell Harris Partnership

The desire to include a series of grass roofs over underground car parking was initially based on practical and aesthetic ambitions; however this has yielded a recognised environmental benefit in the attenuation of water runoff from the site. This added benefit was clearly demonstrated during the recent heavy rains in South Yorkshire when examination of the water outfall points serving the grass roof identified a delayed and more controlled level of water run-off from the green roof areas.

Another good example of how Green Roofs can make excellent amentity space is the planned St Vincents Park in Solly Street, Sheffield which is a commercial car park incorporating residential units and B1 offices with a rooftop public park. The Green Roof will be an intensive roof with substrate depths ranging from 280mm to 1100mm. It will be planted with wild flowers, bulbs, climbers, shrubs, hedging tree Planting and have extensive grass/lawns. It was the winner of the Green Roof Centre 2007 Innovation Award

***Figure 15** St. Vincent's Park artist impression*

Source: Coda Studios

The site was designated by the St Vincents Action Plan for a park/public amentity/open space. Street level access and financial constraints meant it was viable to create a park on rooftop of the building.

The Green Roof/park will improve the visual appearance and environmental performance of the building and more importantly provide a much needed amenity for local residents and visitors. It would be an interesting exercise to see how many users of the new park appreciate that St.Vincent's is infact a Green Roof?

Green space is recognised as being beneficial to health; reducing stress levels and providing ‘escape’ from the stresses of urban living. This benefit is exploited by hospitals especially in Germany where such buildings commonly have Green Roofs. The increasing density of new developments where there is relatively little green space at ground level is becoming the norm in the capital. The provision of green space for amenity, both for public and private use, can be achieved through the provision of Green Roofs. It could be argued that the provision of Green Roofs may become a necessity, as there is a trend towards high quality and high-density inner city apartments for young professionals who may demand high quality green spaces within developments.

Observations by Hutchinson (2003) on one Green Roof in Portland, Oregon noted a number of activities going on such as dog walking, clothes drying, cooking, eating and drinking, and even the setting off of fireworks. Golf course and football pitches have been implemented at roof level in other parts of the world.

16.7 Urban Heat Island Effect (UHIE)

Urban areas have a higher average temperature than surrounding rural areas; this difference in temperatures is called the urban heat island effect (UHIE) and is caused by the reduction in green space through urbanisation and the large amount of hard surfaces that provide high thermal mass.

Summers by 2050 will be 1.5 - 3.5°C hotter... in central London the urban heat island currently adds 5 - 6°C to summer night time temperatures and will intensify in the future. London Climate Change Partnership.

The dark surfaces of roofs exacerbate the UHIE by absorbing summer heat and reflecting it back to the atmosphere during the night. As the UHIE increases there is greater need for air conditioning and therefore energy, as buildings heat up. Furthermore increases in the UHIE effect can lead to increased levels of air pollution in cities particularity ozone, which combined with an increase in temperatures can exacerbate health problems, especially in the old, young and vulnerable.

As a “quick fix” solution to avoid thermal gain into the buildings many roofs are now “white” roofs which is either the natural colour of the surface of the waterproofing or it has a painted surface. However, a white roof reflects 70% of the energy back into the atmosphere increasing the UIHE

On the other hand the Green Roof effect of evaporation and transpiration acts to cool air. Furthermore by providing a cooler surface at roof level the Green Roof reduces the need for air-conditioning and the emission of waste heat into the atmosphere. The combined effect is to reduce the UHIE.

A modelling exercise undertaken in New York by the New York Heat Island Initiative determined that providing 50% Green Roof cover within the metropolitan area would lead to an average 0.1 - 0.80°C reduction in surface temperatures. It noted that for every degree reduction in the UHIE roughly 495 million KWh of energy would be saved. There is no reason to doubt that comparable relative reductions could be achieved in the UK.

Reducing the UHIE in a metropolitan area is a virtuous circle in that a global reduction in temperature means less energy used by buildings which means less heat released to atmosphere and the UHIE will reduce even further.

A number of research projects have concluded that Green Roofs are the single most effective weapon against the Urban Heat Island Effect.

17. Case Studies

We have seen that there are easy costs/ benefits to establish and there are other costs and benefits that are very difficult because they depend on the ability of the design team to maximise them.

In the following case studies we demonstrate how to use NPV to determine whether a Green Roof is an economic option. We are only considering the direct benefits of extended roof life and energy reduction in these case studies as they are the easiest to identify. In the case of Barclay's Tower the roof is inaccessible and will therefore have limited effect on value from an amenity perspective and the saving in energy has limited impact due to the size of the building.

When considering this approach for any new building the extent of delivering the other benefits will depend on the design, location, the professional team and the determination of the client.

17.1 Barclays Tower Canary Wharf

Barclays Tower is a 1million sqft (92,750 $m^{2)}$ office block with 34 floors. The Green Roof is at 140m above street level.

The extensive roof was installed in 2005 and used light substrates planted with drought and wind tolerant plants. The substrate is locally sourced recycled crushed brick and concrete (from Charlton, SE London, less than 5 miles travel). This substrate has had a small amount of soil, pine bark and shingle added to it and has been seeded with a wildflower mix. On the surface of crushed brick and concrete there are circles of large pebbles. These provide bare areas for rare insects that like dry exposed sites.

***Figure 16** Sedum mat area of the roof Barclay's Tower*

The roof was partially planted with a sedum mat to provide resistance to soil erosion due to the wind on the exposed site. The use of the wildflower mix in the substrate meant that as the roof matured a wide range of plants developed avoiding the monoculture of sedum mats.

Since the building was occupied in 2002 there are 3 years of pre and 2 years post Green Roof energy data. In the financial appraisal the energy savings have been averaged.

Table 15 *The Canary Wharf data*

The size of the roof	850m^2
Energy costs	£0.17 /kWh
Life	30 years
Discount rate	7%
Green Roof life	30 years
Non-Green Roof life	25 years
Maintenance	The same for both roofs
kWh to CO2 conversion factor	0.43kg CO_2

Table 16 *Barclay's Tower Financial Appraisal*

The results of the financial analysis are:

	NPV	**Capital Cost**	**Energy kWh/pa**	**CO_2 t/pa**
Non-Green Roof	(55,364)	£46,750	0	0
Green Roof	(3,402)	£63,750	29,750	13.1

Table 16 shows that a Green Roof costs £17,000 more to install than an exposed roof. However, an NPV calculation provides the real value of the longer life and annual energy savings provided by the Green Roof at £58,766 more than the exposed roof .

Equally over 30 years the Green Roof will save approximately 390 tonnes of CO2 from being emitted to the atmosphere.

17.2 Paradise Park Children's Centre:

The building was built with a brown roof over the habitable area. This has provided a small increase in the thermal insulation properties of the roof. Of greater benefit than reducing heat loss, however, is the increased thermal inertia of the roof due to its mass. This thermal mass delays the flow of heat into the building when there is a heat gain due to a high sun altitude.

The depth of the brown roof is approximately 150mm and its thermal mass slows the transfer of heat through the roof by about 1 hour for every 25mm of dense material. Therefore with a depth of 150mm of high mass material the solar gain through the roof during the summer is slowed by up to 6 hours. The highest gain through an exposed flat roof, in the summer, is at noon, the maximum flow of heat through this roof is therefore delayed until early evening. As the building normally closes at 5pm the occupants no longer will be overheated in the building, so obviating the need for air-conditioning.

Richard Pearce Building Services Engineer says:

"*The heat gain for the building is approx 28kW and the electrical energy that would be used during the period of heat gain would be about 9.4kW per hour. If air-conditioning was used over a summer period the approximate energy use would be 3,800kW/hrs, the equivalent of about 1.6 CO2 e tonnes per annum.*"

Table 17 *Paradise Park Data*

The size of the roof	400m[2]
Energy costs	£0.17 /kWh
Life	30 years
Discount rate	7%
Green Roof life	30 years
Non Green Roof life	25 years
Maintenance	The same for both roofs
kWh to CO_2 conversion factor	0.43kg CO_2

Table 18 *Paradise Financial Appraisal*

The results of the financial analysis are:

	NPV	**Capital Cost**	**Energy kWh/pa**	**CO_2 t/pa**
Non-Green Roof	(26,053)	£22,000	0	0
Green Roof	(18,200)	£34,000	1,190	0.52

Table 18 shows that a Green Roof costs £12,000 more to install than an exposed roof. However the NPV shows that the benefit of the Green Roof with its longer life and the energy savings each year, over the full 30 years, is £7,853 less than the exposed

Equally over 30 years the Green Roof will save approximately 15.6 tonnes of CO_2 from being emitted to the atmosphere.

In these case studies we see how with just two benefits, most Green Roofs will pay for themselves. However, there are a number of barriers that might be raised before a successful Green Roof can be completed.

18. Barriers to Green Roof implementation

A report by the Ecology Centre to the GLA on implementing Green Roofs within the London Plan concisely identifies a number of perceived barriers to implementation of Green Roofs.

The report uses a survey by Ingleby in 2002 of architects, ecologists, local planners and engineers in London which identified a number of concerns regarding Green Roofs. It is clear that these concerns arise because Green Roofs are a relatively new technology for the mainstream UK construction industry and they are unaware of experience in other countries.

The main concerns the Ecology Centre cite are:

- Lack of common standard
- Fire Hazard
- Maintenance
- Cost
- Structural issues
- Leakage and damage to waterproofing
- Lack of expertise
- Lack of policy

Each of these barriers will be looked at in detail below.

18.1 Lack of common standard

The lack of a British Standard is often cited as a real barrier to whole-scale uptake of Green Roofs. The major UK suppliers of engineered Green Roofs are fully signed up members of the German FLL–the Landscape Research, Development & Construction Society. This body provides standards for landscaping in Germany, whilst standards used in Switzerland, Austria, Hungary and Italy, are variations on the FLL. Japanese and North American standards are also based on the FLL. The FLL covers all aspects of Green Roofs from waterproofing, soils, vegetation, treatment on intensive Green Roofs [tree planters etc], balconies, installation methods and procedures, and maintenance. The guidance stipulates DIN standards for specific areas of greening. The FLL accept that their standards are viewed by some to be over rigorous [pers. comm. Gedge 2004].

Therefore the lack of standards in the UK is only likely to be an issue where a supplier is either not an affiliate of or does not work to FLL standards. Over the last 2 years a number of the largest Green Roof suppliers in Germany and Switzerland have set up partnerships with UK waterproofing companies and the majority of these abide by or are affiliates to the FLL. The largest companies supplying Green Roofs in the UK have been in operation for much longer than this and are recognised as leading Green Roof suppliers both in the UK and Germany.

18.2 Fire hazard

Although there is a perception that dry vegetation during the summer months could lead to fires being started on Green Roofs, the FLL standards also have strict guidelines on this issue. These include high levels of fire resistance and fire proofing for membranes and other layers beneath the soils and vegetation. Furthermore there are strict guidelines regarding the use of firebreaks and the amount of combustible material permitted in Green Roof soils.
Extensive roofs are only considered to be fire resistant if

- the substrate/soil is at least 30mm deep
- the substrate/soil contains less than 2% organic matter
- there is a 1m wide gravel or slab 'fire break' every 40m
- gravel/shingle strips are provided around all structures penetrating the roof covering. These gravel/shingle strips should be at least 300-500mm in width, or 1m in width where they are to act as firebreaks on large roof areas.

In contrast to the UK rather than considering a Green Roof a fire hazard, in Germany they are considered to provide a protective barrier preventing the waterproofing elements from catching fire. For this reason it is possible for building owners to get a reduction of 10 to 20% on fire insurance in Germany when a Green Roof is installed.

Considering the millions of square metres of Green Roofs that have been installed in Germany and Switzerland over the last 25 years, to these standards, it is clear that fire hazard should not be viewed as a real barrier to uptake in the UK.

18.3 Maintenance

Maintenance of a Green Roof will depend on the roof system and what is desired from it. Intensive and semi-extensive Green Roofs are in many ways a high rise version of a garden, and therefore will require similar level of maintenance. This will include weeding, mowing, hedge trimming, fertilising and irrigating.

It is often stated that even semi-extensive wildflower meadows need an annual mow to maintain floristic diversity. However, it is possible for this to be a neglected aspect and there are a number of instances in London where such management has not been undertaken. This 'lack' of maintenance has had no impact on the building, but merely reduced the value of the meadows from an ecological point of view.

Extensive Green Roofs, which also may not be amenity spaces, need very low maintenance. A 1-2 year inspection will normally suffice to weed out unwanted plants, remove deep roots and, if necessary provide fertilisation. For the first year such work is generally covered by the installation team, after which it becomes the responsibility of the building owner or the building management team. It is generally accepted in the roofing industry that annual maintenance on Extensive Green Roofs and exposed roofs is now the same in terms of days and cost

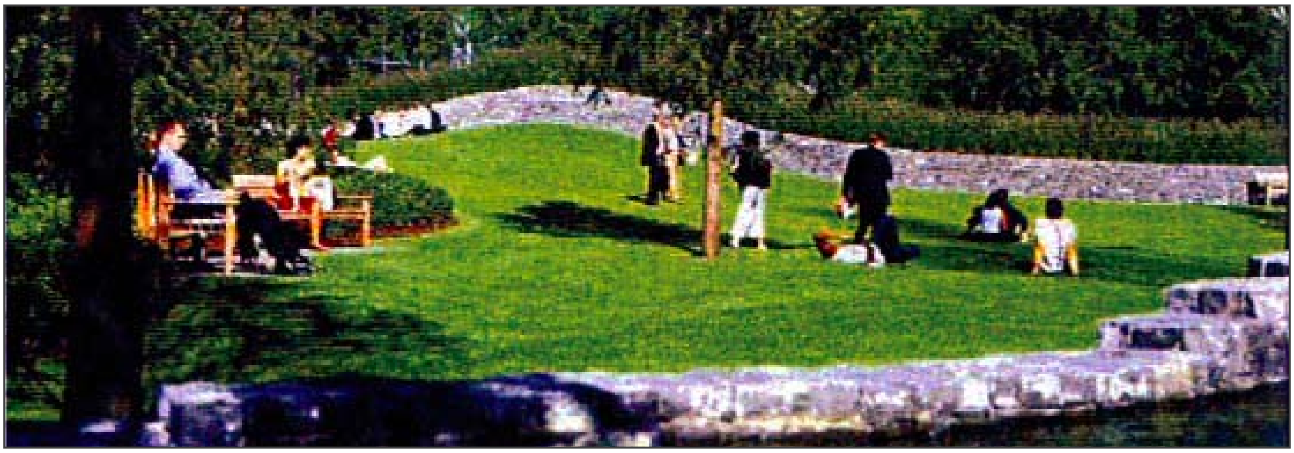
Contrary to a common perception the use of a Green Roof can have a positive impact on maintenance in that intentional vegetation within the system keeps out unwanted vegetation that can harm the integrity of the building's fabric. On grey roofs and other conventional roof systems buddleia (butterfly-bush) and other shrubs can become established and potentially cause problems. The presence of a root barrier and competition from other plants can limit this significantly.

In fact even a plain roof needs maintenance and the facilities manager for Barclays Tower in Canary wharf says that his sedum mat roof needs less maintenance than the exposed sections of roof.

18.4 Cost

The cost of a Green Roof will vary depending on the system used. It will also depend on the height of the building, number of intrusions, size and type of system, depth of insulation required and many other factors. Intensive Green Roofs can vary in cost depending on the amount of vegetation cover and the type of vegetation.

***Figure 17** Jubilee Park Canary Wharf London*



Source: Living Roofs and Walls Report, Ecology Consultancy Ltd, EPG Clear and Savills Hepher Dixon

An indicative cost is £140/m^2 inclusive of waterproofing and insulation. The use of large trees, furniture, planters and irrigation will increase costs - for example, a planting scheme of this nature at Jubilee Park in Canary Wharf that included trees, fountains, irrigation system etc. resulted in costs as high as £453/m^2 (pers. comm. Anthony Partington). However, these costs may be balanced to a certain extent by increased building 'value'.

An indicative cost for a semi-extensive Green Roof is in the region of £80 - £120/m^2, but again could be more depending on the types of plants used, water features and furniture.

An indicative cost for an extensive Green Roof will depend on the type of system used. The cost will also vary depending on whether it is a warm or cold roof.

Table 5 outlines some indicative figures for Green Roofs, including waterproofing and insulation.

Warm roofs may be restricted to a sedum blanket with a thin substrate layer unless there is greater structural loading, and the cost of a Green Roof on a warm roof is always going to be higher than the normal cost of the roof. However, when an inverted roof system is used the structural capacity to hold a Green Roof substrate-based system is already present as an inverted roof needs ballast, which conventionally is shingle or paving.

Furthermore a substrate based roof can result in other cost savings due to the reduction in the number of drainage outlets and in the amount of storm water amelioration at ground level. Further cost savings can be factored in when the reduced energy needs within the building are also taken into account. In Germany, for similar reasons, it is recognised that a Green Roof is the most cost-effective method of roofing over a 25 year period.

A recent study in Birmingham Eastside by Hyder Consulting estimated that a single plot with Green Roofs could realise a saving of £100,000 through a reduction in surface water amelioration costs. The study then considered the cost of increased structural requirements for the buildings in question to hold a substrate based Green Roof; these were considered conservative at £53,000.

The cost saving to the plot through the use of a Green Roof to reduce on site storm water storage and other drainage costs was around £47,000 which is the same as installing 3,000m^2 of Biodiverse Green Roof.

The current vogue when discussing Green Roofs is to try and relate the additional capital cost to a % of the total build cost. This is derived from the current desire to reduce all cost projections to a simple % addition. This is not only irrelevant it also does not identify the real cost benefit outcomes.

The problem with Green Roofs is that they do not fall within any expertise of the existing design team and they therefore look for simple solutions rather than extending the expertise available to the team.

18.5 Structural issues

The usual reason given for objecting to a Green Roof is the perception that the cost of additional structure required to carry the increased load outweighed any financial benefit. This was tested by a study carried out in London, by Livingroofs.org, which revealed that 92% of developers perceived that "the physical structure of many buildings prevents the establishment of Green Roofs", compared to only 27% of Structural Engineers.

The current requirement to provide thermal mass, in order to apply with Part L of the current Building Regulations, is leading designers away from thin lightweight roofs and back to structures that will accommodate Green Roofs with little or no increased strengthening.

Below are the loadings of the various roof coverings available. They exclude those for an exposed standard warm roof i.e. without any additional roof treatment:

***Table 19** Green Roof additional loadings*

Roof type	Loading lower (kg/m2)	Loading upper (kg/m2)
Gravel Surface	90	150
Paving slabs	160	220
Vehicle Surface	550	1500+
Extensive Green Roof sedum mat	60	90
Extensive Green Roof substrate based	120	150
Intensive Green Roof	200	500

NOTE: loads are fully saturated.

Structural issues are linked to cost as outlined above. In the case of an inverted substrate based Green Roof there should be relatively limited or zero need for extra structural load.

Hyder Consulting in the drainage policy report for Birmingham Eastside state,

Even on single ply roof constructions where ballast is not normally required, the increase in load is unlikely to exceed 20%. Due to the constraints placed on designers by British Standards and Codes of Practice, it is possible that an increase in load of this magnitude could be accommodated without modification of the structural sizes.

There can be issues regarding Green Roofs and structural loads on lightweight industrial buildings that can lead to increased costs. However, savings in the need for storm water amelioration tanks could well balance out the extra cost for a Green Roof.

18.6 Damage to Waterproofing

Concerns are often expressed that Green Roofs will leak. Historically flat roofs are perceived as more vulnerable to leakage due to the effects of the climate (UV, frost and ponding) on waterproofing systems.

Most established Green Roof suppliers provide FLL rated root barriers, which protect water-proofing membranes from the potential negative impact of roots. Furthermore established companies will leak test before the implementation of the Green Roof element.

Contrary to perceived wisdom in the UK, in Germany it is accepted that a Green Roof adds value to the waterproofing by protecting membranes from the effects of climatic factors. In general a Green Roof can extend the life of a membrane by a factor of two if not longer (this is dependent on quality of waterproofing, installation and Green Roof system). However, extended warranties and guaranties are not offered in the UK.

18.7 Lack of Expertise

Roof gardens and terraces are not new. In London there are several well known examples:

- the Queen Elizabeth Hall has a series of roof gardens,
- the world famous roof garden at Barkers of Kensington was installed in the 1930s,
- No. 1 Poultry, home of Conran's Coq d'Argent restaurant, has a lawn at roof level.

A short walk around central London reveals that roof gardens are more common than may be first realised.

The large scale use of extensive and semi-extensive Green Roofs though is relatively new especially at a commercial level. A number of projects were completed in the late 1980s and early 1990s, but the use of Green Roofs in new developments has only been really considered in the last 5-10 years.

During this time, roofing companies in the UK have gained a track record of delivering Green Roofs, although there continues to be a lack of understanding and expertise of the full range and performance of Green Roof systems outside of the roofing industry.

However, the overall perception that there is a lack of expertise in the UK regarding the provision and implementation of Green Roofs is not really true if the design team take the time and effort to find specialist assistance.

Now that the design of the Natural Green Roof is more widely understood, and sites such as www.livingroofs.org and www.thegreenroofcentre.co.uk provide standard designs and details, the installation has moved away from specialist suppliers, such as the roofing supplier, to general contractors and groundworkers. This opens up the industry to competition which will invariably reduce costs.

18.8 Lack of Policy

There is no central Government guidance and therefore we lack consistent local policies across the UK.

Other cities around the world have adopted a number of measures to promote Green Roof

Basel	Building Regulations
Beijing	Policy Targets
Berlin	Financial Incentives and Mandatory Policy Requirements
Chicago	Building Regulations and Financial Incentives
Cologne	Financial Incentives
Linz	Planning Policy and Financial Incentives
Munster	Financial Incentives
Portland, Oregon	Financial Incentives
Seattle	Mandatory Policy Requirements
Tokyo	Planning Policy and Financial Incentives
Toronto	Financial Incentives
Vancouver	Planning Policy and Building Bylaws

In summary the principal means by which the fifteen cities surveyed encourage or require Green Roof developments can be summarised as follows:

i) Direct Financial Incentives - Grants and subsidies;
ii) Indirect Financial Incentives - Reduced drainage charges or larger development allowances;
iii) Ecological Compensation - The green factor approach;
iv) Building Regulations and Planning Policy.

In addition, many of the cities are sponsoring demonstration projects and the provision of information to developers.

Conclusion

This report has served to reinforce the long accepted environmental benefits of Green Roofs. However, poorly constructed financial arguments focusing on capital cost often cause developers to drop Green Roofs on "cost grounds."

In response, this report clearly demonstrates that by using standard financial appraisal techniques such as Primarily Net Present Value (NPV) and Internal Rate of Return (IRR), and by including the 'cost in use' as well as 'capital cost', the medium financial benefits significantly outweigh the initial cost considerations.

Green Roofs of all types provide a positive Net Present Value to both the developer and the occupier which means they are better off with a Green Roof than without one.

When using the Whole Life Cost approach, the authors have not found a single example of an exposed roof being more cost effective than a Green Roof.

Further, we have shown that Green Roofs have a positive effect on the development yield of around 0.5%. This relatively small percentage improvement goes straight to the developer's bottom line and has a significant impact on the profitability of the project.

This argument alone is enough to ensure that Green Roofs become the common option for roofs on all types of developments. This report emphasises that the maximum benefit is achieved through Green Roofs that are accessible to building occupiers.

The adoption of Green Roofs is not a surprise as any "technology" that:

- Reduces letting voids
- Increases letability
- Protects and improves the environment
- Delivers cost saving to the building occupier
- Reduces CO_2 emissions
- Reduces surface water off site requirements
- Reduces the size and complexity of the on site drainage system
- Provides a positive social impact on staff
- Improves staff productivity
- Reduces energy consumption in the building
- Improves the performance of solar production of energy
- Reduces the overall Urban Heat Island effect
- Provides positive local PR
- Receives positive support from the local planners

will increase the value of the development!

What other environmental improvement can be added to a building with so many benefits?

Useful sources of information

If you consider adding a Green Roof to your next development, guidance and advice is available from:

- The Green Roof Centre, Sheffield University. www.thegreenroofcentre.co.uk
- Living Roofs, the independent UK website to promote Green Roofs. www.livingroofs.org
- Building GREENer - Guidance on the use of green roofs, green walls and complementary features on buildings (CIRIA, July 2007)

For more information from The Solution Organisation:

Email info@thesolutionorganisation.com

Web www.thesolutionorganisation.com

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