Sarnafil

The Solution Organisation

To build the solution, first define the problem

Whole Life Costs & Living Roofs The Springboard Centre, Bridgewater

A Report By The Solution Organisation for Sarnafil

Report Authors:	Brad Bamfield
Report Date:	25th January 2005 – second edition
Report Ref:	**Sarnafil/001/006.2**

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Document version control:-

v1 – 19/01/05 Draft publication for review and critical comment.

v2 – 26/01/05 Revisions:-

6.2	Quantity of living roof increased to 1,000m2
6.2	Capital costs used in the WLC adjusted and note added.
6.2	Repair costs adjusted in line with quantity.
6.3	Energy savings adjusted in line with quantity
6.3	Savings from re-use of excavated material in bio diverse option increased in line with quantity.
7.1	NPV, TWLC & AWLC results amended.
7.2 & 7.3	Ranking results now tabulated for clarity
7.2.1	CO2 savings adjusted in line with quantity.
8	Title amended as wildlife review applies to bio diverse roof only.

V3 – 12/04/05 Corrections of minor typos

1 Report brief

The Solution Organisation were asked by Mark Harris of Sarnafil (UK) Ltd to produce a Whole Life Cost analysis report for the roof of the Springboard Centre, Bridgewater. The analysis was to include normal membrane and membrane with a living roof component to demonstrate the business case implications of each solution.

The report is to be submitted to the Southwest Regional Development Agency's (SWRDA) framework delivery team. Our lead contact is Steve Symonds of Kier Western.

2 Introduction

The SWRDA is a strong advocate of Sustainable Construction and has made a public commitment to promote sustainable construction techniques within their projects. To the SWRDA this means

> "environmental and social criteria are considered as an integral part of construction - from planning to completion."

The SWRDA has supported the development of 'Future Foundations: A Sustainable Construction Charter' developed by Sustainability South West and was one of the first organisations to sign up to the principles of the Charter for its own construction projects. The SWRDA web site cites examples of sustainable construction techniques to include the use of 'environmentally friendly' materials, incorporation of efficient waste management techniques, recycling of water and other resources and use of renewable energy sources.

It is within this context that the development of the new Springboard Centre will be delivered. It is, therefore, quite natural and appropriate that a "green roof" is considered for inclusion.

This report will review the financial and non financial implications of using a "green" roof over part of the building.

3 Difference between Whole Life Cost and Life Cycle Analysis

The terms Whole Life Cost, WLC, and Life Cycle Analysis, LCA, are used interchangeably, and often incorrectly, to describe what the user wants to do. There is also another term in common usage - Life Cycle which has no universally accepted meaning and can refer to WLC or LCA depending on who is using it.

3.1 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)
- Relevant - means those costs directly attributed to the asset under review.
- Identifiable - means we have to be able to quantify it in some way.
- 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.

3.2 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*

4 What do we mean by the term "green" or "living" roofs?

"Green" roof is a generic term for a roof that has evolved since 1900 and is now more appropriately called a "living" roof which is primarily divided into extensive and intensive categories.

- Intensive - used for public access with soil depths of 300 to 350mm in depth. It could include grass and even trees. Intensive roofs add a significant additional load to the roof structure and require substantial maintenance.
- Extensive – primarily used for environmental benefits that have no public access with soil depths of 25 to 125mm. They use a range of plants and growing mediums and add much lower loading to the roof structure.

The roof for this project is an extensive type which 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.
- Bio diverse – uses 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.

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

The financial analysis later in this report covers both Sedum and Bio diverse roof types.

4.1 Types of vegetation used.

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

In sedum roofs the plants most commonly used are succulents and other low growing plants that are capable of storing water in either fleshy leafs, 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 living 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."

Although plants are the most vital component of an extensive living 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, but 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 up 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. If half the plants need to be replaced within the first year, the apparent cost advantage quickly disappears.

It is also advisable to include native grass seeds over a newly planted roof because the seeds will sprout quickly and stabilise the soil layer until the living 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 living 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.

4.2 Insects and other wildlife

Wild life is attracted to the variable habitat provide by a Bio diverse roof and it is very possible to design different parts of the roof habitats to attach different ranges of visitors. The addition of a stony area will attract different insects and birds from the areas that have plants.

Sedum roofs are less attractive to wildlife but they do provide a viable habitat for a smaller range of visitors.

We discuss the types of wildlife attracted to this particular location in detail later in this report.

5 Benefits of living roofs

5.1 Plants

Plants provide a broad range of benefits, whether on the ground, submerged in water or on a rooftop. We are still exploring the natural processes of vegetation and how best to use it in the urban environment.

In photosynthesis, for example, plants use energy from the sun to turn carbon dioxide into oxygen and chlorophyll. Leaves collect dust, transpire moisture in the air and provide shade.

Plant roots, and their attached enzymes and micro-rhyzal fungi, filter and treat rainwater as it percolates through the ground.

All of this makes our environment more resilient. Transferring these processes to roofs can provide viable rainwater management, energy efficiency, urban ecology and aesthetic benefits.

5.2 Rainwater management

When rain falls on forested and open, undisturbed land, water goes through its natural cycle:-

- About 30% of the water reaches shallow aquifers that feed plants,
- A further 30% percolates and nourishes deeper aquifers, and
- Approximately 40% is almost immediately returned into the atmosphere through plant evaporation and transpiration.
- There is rarely any surface run-off.

In metropolitan or urban areas, by contrast, with buildings and streets providing 75 to 100% impervious surface cover, rainwater is distributed much differently.

- Only 5% infiltrates to shallow and deep groundwater aquifers and
- 15% evaporates into the air through vegetation.
- 75% of the rainwater becomes surface runoff.

To offset these reversed rainwater runoff patterns, communities build costly sewer 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.

Numerous studies have demonstrated a direct link between runoff from impervious surfaces and degradation of water quality in streams. Even relatively low levels of impervious surface cover (10 to 15% of total land area) in a watershed can make it difficult to maintain stream quality. Greater surface coverage (15 to 20% of the total land in a watershed) has been linked to dramatic changes in shape of streams, water quality, water temperature, and the health of the insects, amphibians and fish that live in these streams.[1]

Living roofs, especially when combined with Sustainable Urban Drainage (SuDs), can help ameliorate this problem because they absorb and recycle rainwater. The soil layer and plants soak up water that would otherwise immediately run off into storm sewer systems.

During research for City of Olympia, USA.[1], it was reported on average, between 60 and 75% of water is retained on an extensive living roof, stored in plants and the soil layer. Only about 25% of water becomes runoff, but this occurs several hours after the peak flow. When a living roof reaches full saturation, excess water slowly percolates through the vegetation layer to a drainage outlet.

Importantly the soil layer traps sediments, leaves and other particles, filtering runoff before it reaches the outlet. Of course, different soil substrates and vegetation provides different water retention capacities. As a rule of thumb research has found that, a 25mm deep sedum layer over a 50mm gravel bed retains about 58% of water, a 125mm deep sedum and grass layer retains about 67%, and a 100mm deep layer of grass and herbaceous vegetation retains about 71% of water.

Further, in a major 50mm rainstorm, generating about 15 litres of water per square metre, a 50mm thick extensive living roof would retain approximately 6 litres of water per square metre, or 40% of the total precipitate. This reduced runoff can be translated into reductions in down pipes and sizes, and less drainage in general.

Because rainwater that has passed through a living roof is partially filtered, it is particularly useful for re-use in watering ground based plants and landscaping. With the costs of potable water so high, it is a cost effective option to separate and re-use the living roof run-off reducing the amount of water purchased.

Of course reductions in water run-off reduces the amount of surface water that needs to be disposed of off site. Combining living roofs and water attenuation in SuDs can mean that there is no water taken off site and the natural cycle is emulated. In effect, the impact of hard surfaces are nullified in the context of the ground water percolation profiles both before and after construction.

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[1] City of Olympia, USA, Public Works Department*, Water Resources Program, Impervious Surface Reduction Study, Final Report*, (May 1995).

5.3 Energy management

Living roofs also slow building heat gain and loss. In warm climates, where air temperatures can reach 95°F or higher during the summer, roof surface temperatures can reach 175°F. These high temperatures directly impact both the indoor and outdoor environment of a building. The increased outside air temperature over roof surfaces contributes to and speeds up the chemical reaction that creates low atmospheric ozone, the primary component of smog[2]. The generation of ozone is particularly hazardous for asthmatics and people with breathing difficulties and is an invisible pollutant. The other effect of this heating is that inside the building, more air conditioning - and therefore more energy - is required for cooling.

However, with a living roof, the vegetation layer and the trapped air prevent rapid air exchange, which improves the energy performance of a building. Plants transform heat (energy from the sun) and soil moisture into humidity through evapotranspiration processes, naturally cooling the building. Effectively the same mechanism when humans sweat. This can result in a reduced cooling load inside the building, reduced heat reflection into the atmosphere, a healthier microclimate over the roof surface, and an extended lifespan for the roofing system.

In cold climates, the rate of heat loss through the living roof depends on the moisture level of the substrate. On average, extensive living roofs provide an additional 25% insulation at dry and slightly moist soil conditions. When the substrate is wet, the insulation value becomes negligible.

However, heat loss due to wind can be reduced by 50% with a living roof cover. Friction slows wind down and reduces the air and heat exchange. Contrary to that widely believed, the air exchange and heat loss is mostly prevented through air pockets between material layers and is only minimally affected by air trapped within the root zone of the vegetation.

Improved energy efficiency is not the only advantage of living roofs as they also reduce the urban heat island effect, the phenomenon of thermal gradient differences between developed and undeveloped areas by aiding in the vertical mixing of air. Since plants transpire moisture, the air above the living roof surface is much cooler than the hot air rising from surrounding hard surfaces. The hot air is replaced with cooler air from the vegetation, and thus limits the urban heat island effect and the chemical reactions that produce lower atmospheric ozone.

5.4 Urban ecology

Cities often effectively exclude greenery and nature - to the detriment of their residents. While living roofs are no substitute for open space and simply cannot replace the significant functions of forests, fields, gardens and open parkland, they do provide green space and wildlife habitat from which both urban and suburban areas can greatly benefit.

Living roofs can improve a building's visual impact, enhancing the locality, while creating additional habitat for birds and butterflies. As we have discussed living roofs also improve air quality which, in inner cities and urban areas is usually hot and dry, with the limited number of trees being unable to transpire enough water into the air to keep it cool and fresh. However, tree foliage also fulfils another function - filtering the air. For example, in a tree-lined street only 1,000 to 3,000 dust particles exist per litre of air. Whereas in non-vegetated areas the amount of dust can be three to four times as high, with approximately 10,000 to 12,000 dust particles per litre of air. Extensive living roofs have the potential to address the lack of evaporation and filtration through their plant systems .

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[2] *Green Roofs: An Ecological Balance*., Bauverlag GmbH, Wiesbaden and Berlin, Germany, (1995).

These air quality improvements are true for outdoor as well as indoor environments. Outdoor air improvements go hand in hand with the moderated surface temperature of a roof. The positive effect on the indoor environment is less obvious but has been documented in several cases. Pacific Telephone and Telegraph (PT&T) in Sacramento, CA, for instance, constructed a half-acre roof garden on its building in 1962. The constant indoor air environment provided by the living roof helps protect the company's sensitive telephone computer equipment, which requires a perfectly humidified environment.

5.5 Living roofs and Carbon Dioxide

Living roofs have an effect on worldwide levels of carbon dioxide in 2 ways;

- Sequestration and
- Reduction in energy required in the building

Sequestration. Because living roofs are built with plants which use photosynthesis to break down carbon dioxide into oxygen and energy (required for the plant to live and grow) we accept that they sequestrate $C0^2$. While it is now generally accepted that in temperate climates, with variable lengths of daylight, plant cover is a net sequestrator there are no accepted rules of thumb to quantify the amount. This is because plants only convert $C0^2$ during photosynthesis, which needs sunlight, so during the night the process is reversed when they take in oxygen and expel $C0^{2.}$ For this analysis we have not included any sequestration of $C0^2$ in the cost/benefit analysis.

Energy reductions. Living roofs effectively increase insulation and reduce heat loss and gain, through a number of mechanisms previously discussed, which results in lower energy requirements. Lower energy use translates into lower energy generation and lower levels of $C0^2$ emitted to atmosphere. We have used the increased insulation factors to calculate energy savings in financial terms and in tons of $C0^2$ saved.

6 The boundary conditions for the WLC analysis

The boundary conditions for this analysis are the assumptions that are used to calculate the comparisons. They include;

- The life expectancy of the products.
- The capital cost of the completed roof both for
    - Exposed and
    - Covered membrane
- The capital cost of installing a living roof both for
    - Sedum
    - Bio diverse
- The annual maintenance and repair costs for both membranes
- The annual maintenance and plant replacement costs for both types of living roofs
- The energy reductions due to insulation factors

6.1 The life of Sarnafil membranes

Sarnafil membranes have been extensively developed over the last 30 years and the durability has been consistently improved . Even so the first single ply products, that were installed nearly 40 years ago, are still in use and still are very effective with high durability.

As we discussed in the previous sections vegetation cover moderates the temperature extremes of the roof surface and prevents the roof from being exposed to ultraviolet (UV) radiation and cold winds that accelerate the breaking down of the roofing membranes. The result is an extended life span of a roofing system.

Therefore, this report uses the following life expectancy profiles for;

- Exposed single ply membrane – 30 years established by independent research and tests on Sarnafil products.
- Covered single ply membrane – 40 to 60 years established by extrapolation of existing examples and current industry accepted range. We will use 50 years in this analysis.

Although anecdotal evidence from existing roofs suggests that the real lives will be much longer.

6.2 Capital and maintenance costs of the roof

The notional Specification for a Sarnafil flat roofing system, complete with a 10 year Sarnafil guarantee for use as a Sarnavert living roofing system. 22mm plywood installed by main contractor, install a SBS G3 felt vapour retarder, 90mm Kingspan insulation, to comply with part L loose laid, Sarnafil TG66 15 installed as the main waterproofing, perimeter upstands are formed from Sarnafil TG66 15 membrane also loose installed cut and shaped to meet each detail as required, with a peel stop at the top & base to act as a restraint . Secured in place with iso-tak screws @225mm max centres.

The living roof area for comparison is 1,000m2. We have used the following budget capital costs of;

	£'s/.m2
Exposed roof	47.00
Covered roof with sedum mat	93.00
Covered roof Bio diverse	79.00

*Please note. The capital costs used in a WLC analysis may not be the same as the costs to complete a job. In WLC analysis elements common to all options being compared are excluded from the capital costs, for example, preparation and vapour barrier. The capital costs used here are **not** to be used as a budget to complete the works actual costs for the job can be provided on request*

We have used the following budget annual maintenance costs of;

	£'s/.pa
Exposed roof	150.00
Covered roof with sedum mat	600.00
Covered roof Bio diverse	150.00

We have used the following budget annual repair costs of;

	Yrs 1 and 2 £'s/.pa	Subsequent. yrs £'s/.pa
Exposed roof	0.00	0.00
Covered roof with sedum mat	2500.00	0.00
Covered roof Bio diverse	1250.00	0.00

Please note while we consider these prices to reflect the project they are budget prices used for comparison purposes only and do not constitute an offer nor will they form part of a contract. Sarnafil will provide a detailed quotation and tender on request.

6.3 Other financial implications

- Energy reductions:-

  The living roof area is approximately 1,000m^2.

  Using the current recognised fuel savings in Germany of 2 litres/m^2/per year

Estimated Electricity Savings: £5,200 per year
£5.20 per m^2 per year

- Use of locally sourced growing medium:-

  For bio diverse roof we try to re-use suitable material that is excavated from the foundations. If the material is suitable then we save the muck away costs and the growing medium import costs. There is also a lower transport impact with reduced vehicle movements to/from site.

  For this analysis we have assumed the excavated material is re-useable saving approximately £4,800.

7 The results of the analysis

7.1 The results of the Whole Life Cost Analysis

We have used the Whole Life Cost Forum's online WLC calculator. Details can be found at www.wlcf.org.uk

	NPV	Ranking	TWLC	Ranking	AWLC	Ranking
Exposed only	-49,160	3	51,500	3	1,716	3
Sedum covered	-21,268	2	-132,000	2	-2,640	2
Bio diverse covered	7,453	1	-175,800	1	-3,516	1

NPV is net present value using a 6% discount rate in a discounted cashflow, a negative number indicates cost rather than value. The highest positive number indicates best option.
TWLC is total whole life cost using a non discounted cashflow. A negative number indicates a net inflow of cash, highest negative number is best option.
AWLC is the TWLC divided by the life of the product. It is in effect the annualised cost of the product. A negative number indicates a net annual inflow, highest negative number is best option.

In financial terms the results produce a uniform overall ranking of:

Ranking	Roof type
1	Bio diverse covered
2	Sedum covered
3	Exposed only

7.2 Non financial analysis

We have used The Solution Organisation's standard qualitative multi-criteria analysis approach to convert each option to a single number to provide direct comparisons. Our approach does not use weightings and is therefore, more robust than other approaches. In this section we have considered environmental, performance and social impacts of the options.

The maximum score achievable is 105 and the rankings are:

	Points	Ranking
Exposed only	69	3
Sedum covered	80	2
Bio diverse covered	94	1

As with any qualitative analysis the results will vary each time the survey is completed with different contributors. The results here should not be considered as arbitrary values but as comparisons between the options.

7.2.1 CO2 savings

From separate calculations using industry accepted conversion rates the added insulation effects of bio diverse and sedum living roofs will save approximately 4.9t of CO^2 per annum or a total of 245t over the life of the living roof.

7.3 Combining the financial and non-financial results

The final stage in the appraisal process is to combine the two sets of results and produce a final ranking. However, as the rankings are the same for both financial and non financial criteria the resulting rankings will be the same.

Ranking	Roof type
1	Bio diverse covered
2	Sedum covered
3	Exposed only

8 Wildlife review for bio diverse roof Bridgewater in Somerset.

In discussing the species that the bio diverse living roof could be designed to attract we take a very conservative view, not wishing to promise too much. This is because habitats and locations are very individual and species that might be seen on a similar roof in another location may never visit our roof.

Although there is quite a track record of designing and installing living roofs from structural, construction, growing media, maintenance and plant species perspectives our naturalists are still a long way understanding all the mechanisms that influence individual and groups of species to be attracted to individual locations.

The naturalist members of the Sarnafil Living Roofs team, led by Dusty Gedge, are involved in a number of long term wildlife and plant surveys on completed living roofs which are designed to better understand the ecological relationships and complexities.

That said we can be very certain that a significant range of insects will visit our roof although it may be less attractive to birds because of the proximity to the park. We look at the two groups in the next section.

8.1 Insects

A number of Insects species associated with well drained low nutrient grasslands and meadows could be attracted to a bio diverse roof dependent on design and seeding:

8.2 Bees

Currently bee species have suffered a massive decline in the south west due to intensive agriculture and any wild or unoccupied areas will be a haven for:

Carder Bee
Shrill Carder
Short- haired Bumble
Large Garden Bumble

All these bees are listed as of Priority for nature conservation in the UK Biodiversity Action Plan (BAP)

8.3 Butterflies

According to a conversation between Dusty Gedge and the Somerset Biological Recording Centre there are number of species of butterfly, which are of local significance.

These species could well be attracted to a well designed bio diverse roof in the Bridgewater area:

Marbled white	Common Blue
Small Copper	Small Blue
Meadow Brown	Chalk Hill Blue
Small Skipper	

8.4 Other species

There are probably a further 10 –15 species of rare invertebrates [5 of which are on UK BAP] which are of importance in the South West that we could design the habitat to attract.

8.5 Birds

Bearing in mind that the location is bounded on 3 sides by a park it is unlikely that such a small area of roof, which is also fragmented, in the South West will have significant benefits for any protected or priority species of birds.

However, this roof is likely to benefit local insectivorous birds and depending on the terrestrial vegetation ultimately selected could provide a positive benefit for Song Thrush, a UK BAP Species, and House Sparrows.

9 Conclusions

The results demonstrate that a living roof is preferable to a normal plain single membrane roof for a number of reasons.

The results further show that the bio diverse roof is the most economical option due to a longer life and higher benefits from the additional insulation effects.

Further the bio diverse roof is also better from an ecological perspective as it attracts a wider variety of animals, insects and invertebrates.

However, to maximise the sustainable benefits the living roof needs to be designed at the earliest possible time in the construction process and certainly before the structural and drainage designs are complete

10 Next steps

The benefits highlighted in this report can only be realised if the individual specialist designers and the delivery sections of the supply chains work closely together from the earliest possible time.

We have not been able to quantify the benefits from a living roof on down pipes and drainage generally as these can only be established once the design of the various systems are coordinated.

However, there are benefits to be gained which will further promote the SWRDA sustainable development initiative.