Green Roofs Over Dublin

A GREEN ROOF POLICY GUIDANCE PAPER FOR DUBLIN

Draft guidelines for DCC to develop planning directives for the incorporation of Green Roofs in new development

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ABSTRACT

This report was prepared for the Planning Department as a study of ways in which a Green Roofs policy could support several key agenda within the city's Development Plan. While it can be seen that Green Roofs can provide a wide range of benefits with many synergies, the chief drivers from Dublin's perspective are climate change response, stormwater management, support for urban biodiversity, provision of extra open space, and reductions in energy demands of buildings.

The technologies involved in Green, or Living Roofs have been developed for close to fifty years, so while the idea may be somewhat new to Dublin and the rest of Ireland, there are many cities in other countries which have fully embraced Green Roofing. This document examines the lessons provided by a number of those cities where Green Roof policies are in place. Recommendations based upon the best practice established by their councils are set out as a suggested way forward for Dublin.

This summary also provides a more basic orientation to the technology involved, including definitions for the different types of green roofs and the principal benefits they offer. Below is a list of the areas where green roof implementation can have positive impact. These are all described in greater detail in the document:

* Climate change mitigation and adaption

* Stormwater Management, Sustainable Drainage and Water Quality

* Biodiversity

* Air Quality

* Amenity

* Economics

Examples taken from the experience of cities around the world highlight both the drivers behind developing green roof policy as well as implementation strategies. Starting with our closest neighbour, the cities examined and their respective green roof policy drivers are:

* London, England
Increasing biodiversity, reduction in stormwater runoff and the urban heat island

* Basel, Switzerland
Energy saving and biodiversity

* Munster, Germany
Stormwater management and increasing urban green space

* Stuttgart, Germany
Improvement of air quality and increasing urban green space

* Linz, Austria
Increasing urban green space

*Toronto, Canada
Stormwater management, air quality and the reduction of the urban heat island

* Chicago, Illinois
Reduction of the urban heat island and public health

* Portland, Oregon
Stormwater management and water quality

The final section poses recommendations for Dublin to roll out a Green Roofs strategy, as well as some ideas for building upon this to diversify greening activities through a range of add-on options.

CONTENTS

Chapter 1 - Why Green Roofs? 4
1.1 Definition Of Green Roofs And Brown Roofs 4
1.2 Intensive Greening 5
1.4 Extensive Greening 6
1.5 Additional Terminology 7
Green Roof FAQs 8

Chapter 2 - Why Green Roofs? 13
2.1 Why Green Roofs? 13
2.2 Benefits Of "Living Architecture": 14
2.3 A Quick Overview Of Benefits 14
2.3.1 Climate Change 14
2.3.2 Climate Change Adaptation 15
2.3.3 Climate Mitigation 17
2.4 Stormwater Management, etc. 17
2.5 Removal Of Pollution 20
2.6 Biodiversity 21
2.7 Air Quality 24
2.8 Amenity 24
2.9 Economic 27
2.10 Potential Economic Incentives 27

Chapter 3 - Green Roof Structure 29
3.1 Green Roof Layers 29
3.1 Root Barrier Layer 30
3.2 Drainage Layer 30
3.3 Substrate 32
3.4 Vegetation Layer 33

Chapter 4 - Int'l Green Roof Policy 36
4.1 Policy Examples 36
4.2 London, U.K. 36
4.3 Basel-City, Switzerland 40
4.4 Munster, Germany 41
4.5 Stuttgart, Germany 42
4.6 Linz, Austria 44
4.7 Toronto, Canada 48
4.8 Chicago, USA 50
4.9 Portland, USA 51
Summary: Lessons From Other Cities 55

Chapter 5 - DCC/ Irish Policies 56
5.1 Green Roofs And Current Policy 56
5.2 Climate Change Strategy 07-12 56
5.3 Dublin Climate Change Strategy 57
5.3.1 Energy 58
5.3.2 Planning 59
5.4 Dublin Strategic Drainage Study 60
5.5 Water Framework Directive 62
5.6 Biodiversity Action Plans 62

Chapter 6 - Recommendations 65
6.1 Council Buildings 65
6.2 Awareness & Education 66
6.3 Policy 67
6.4 Green Roof Officer 67
6.5 Interdepartmental Task Force 67
6.6 Irish Green Roof Initiative 67
6.7 Green Roof Research 68
6.8 "Living Architecture" Communities 68
6.9 Use The European System 68

Appendices 69

For ease of navigation, open the bookmark panel in Adobe Reader and click on table of contents entries

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CHAPTER 1 - WHY GREEN ROOFS?

Defining Green Roofs

Depending on geography and era, a variety of definitions and names have been assigned to green roofs. An orientation to these terms is helpful when deciding the type of green roof to be implemented.

1.1 DEFINITION OF GREEN ROOFS AND BROWN ROOFS

There are many definitions for green roofs currently in use. When green roofs are mentioned, a picture of a garden in the sky is often envisioned. However, in many cases green roofs are actually at ground level, forming the roof of an underground structure, such as a car park. A brief exploration of terms and definitions used in connection with Green Roofs will help to clarify.

Conventional roofs can be either sloped (pitched) or flat. A pitched roof is defined as a roof with a slope of greater then 10 degrees (Harrison, 2000) and has a surface (commonly of slate or concrete tiles or metal sheeting) which is supported by a wooden or metal structure underneath. Insulation is normally incorporated below the waterproof surface layer. A flat roof is defined as one with a slope of less then 10 degrees (Harrison, 2000) and can have a surface waterproof layer of bitumen with gravel covering, plastic sheet covering, a fluid applied membrane or an all-metal sheet.

Figure 1.1: Carpark cover, Schipol Airport, Amsterdam (© Erik van Lennep)

For the purposes of this document, green roofs will be defined by the three different types introduced by the German Landscape Construction and Development Research Society, known as the FLL (Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau). Germany is a world leader in green roof technology and theory, having started green roof installations in the 1960's. The FLL produce a reference guide to green roofs (FLL. 2002), which gives detailed guidance for green roof planning, construction and maintenance. In the absence of an Irish equivalent, this guide will be used and referred to later in this document.

According to the FLL, there are three methods, or degrees of roof greening:

- Intensive greening
- Simple Intensive greening
- Extensive greening

The categories are distinguished according to the construction methods involved, the depth of substrate and the varieties of plants grown on them.

1.2 INTENSIVE GREENING

An intensive roof provides the amenities that a normal ground level park or private garden would offer. Due to the depth of substrate, there is no limit to the plants that can be grown, from trees down to perennials and grasses. Structures such as seating, pergolas and pagodas can be incorporated and hard landscaping in the form of paths, can be included. The weights involved with an intensive green roof are considerable and the load bearing capacity of individual roofs will dictate whether or not they can support such an installation. In most cases, a decision to incorporate an intensive green roof is made at the planning and design stage. This type of roof requires regular maintenance and so full access must be permitted at all times. This would be the costliest greening option both in terms of construction and maintenance.

Figure 1.2: Intensive Green Roof in Baltimore, USA (courtesy C Clark))

1.3 SEMI-INTENSIVE GREENING

The planting on this category of green roof is restricted to smaller shrubs, perennials and grasses. The substrate layer would not be deep enough to sustain trees, but this does make it a lighter weight greening technique, and so applicable to more situations. There are no structures implemented on this type of green roof, and so reducing the extra load. Access is still required to the roof, as maintenance would need to be performed, although not as frequently as for an intensive roof. Overall, the simple intensive green roof is a less costly option then the previous type.

Figure 1.3 Simple Intensive Green Roof in Toronto (courtesy S Jespersen)

Figure 1.4 Green Roof planting here includes chives (courtesy S Jespersen)

1.4 EXTENSIVE GREENING

This is one of the lightest types of green roofs. The soil depth is a minimum of 15cm deep, but it is a specially formulated lightweight media, and so is referred to as substrate rather then soil. This substrate can sometimes be made from recycled materials, such as broken roof tiles. The plant selection is limited to mosses, succulents, and shallow rooting herbaceous plants and grasses. Depending on the plants chosen, extensive greening can be extremely low maintenance, with no additional irrigation required, and the plant population can be self-propagating. Maintenance is reduced to twice a year, to remove any weed trees which may have seeded in. Generally these roofs are not accessible other than by maintenance personnel. In general terms, this category is the least expensive to construct and maintain. In considering weight it can be the least demanding on the roof structure. Extensive greening is the ideal solution for roofs where access may be restricted, and in most cases are intended to be overlooked (English Nature, 2003).

For further technical descriptions of each of these categories, please refer to Appendix 1.

1.5 ADDITIONAL TERMINOLOGY

Figure 1.5 Extensive Green Roof in Washington (courtesy C Clark)

Another term that is frequently used is **Ecoroof**. This can sometime refer to an extensive green roof that has been planted in a naturalistic way (English Nature, 2003). However, the name Ecoroof has also been adopted in countries where a dry climate means that the vegetation on an extensive green roof is brown for half of the year. In such situations, using the word 'Green Roof' is somewhat misleading.

A **Brown Roof** is one which has had a substrate or fine rubble applied, but has been intentionally left unplanted. The purpose of this is to replicate ground level brownfield site conditions. By using recycled materials from other buildings such as brick rubble, crushed concrete and subsoils, it is hoped that these brown roofs will become colonised by local vegetation, invertebrates and birds. In this sense, brown roofs are primarily used for biodiversity purposes, while their esthetic appeal might be more of an "acquired taste" based upon appreciation of their function.

Living Roofs is the description used by Greater London Authority in their technical report to support the London Plan Policy. In this document the term 'Living Roofs' refers to:"green roofs, roof terraces and roof gardens. The term includes roofs and structures that may be accessible by workers or residents, and that may be intensively or extensively vegetated." (Greater London Authority, 2008)

Figure 1.6 Green Roof of American Society Landscape Architects ASLA (courtesy D Saunders)

Wet Roofs is a term being used to describe a more recent area of rooftop development, where constructed wetlands are incorporated to further diversify habitat, to hold back more rainwater, and to provide facilities for natural filtration of gray water produced within the building. (This biologically filtered water is then termed "Green Water" and can be reused for many non-potable functions such as irrigation, toilet flushing and laundry). The technologies behind wet roofs are only now being developed and explored, but interesting progress is being made in a number of different cities, including Sheffield UK, Portland Oregon and Mumbai India.

Earth Sheltered design resides at the far end of the Living Roof continuum, and refers to buildings where one or more sides are dug into the landscape to afford protection from prevailing winds, benefit from substantial thermal insulation, and achieve greater visual compatibility with natural landforms. Earth Sheltered buildings are a study and technology requiring separate treatment and so will only be noted in passing for their interest as part of the larger tool kit for living architecture.

CHAPTER 1: SUMMARY POINTS

There are three types of green roofs as defined by the German Landscape Construction and Development Research Society (FLL). The definition is based on their use, design and construction type. They are:

Intensive : Allows for a wide variety of plants, from trees, shrubs, perennials and grasses. Can include structural elements. Needs regular maintenace and has high weight considerations

Simple Intensive: Variety of plants is restricted to shrubs and grasses. Maintenance needs are reduced but are still required

Extensive: Low maintenance green roof solution. Very lightweight so can be retrofitted to most roofs. Restricted in plant varieties used; mosses, succulents, grasses and wildflowers.

Other terms for green roofs that may be found in other literature:

- Ecoroofs
- Brownroof
- Living Roofs

GREEN ROOF FAQS

While Green Roofs are relatively new to Ireland, they are a well tested technology with wide-spread uptake in many parts of Europe and beyond. The current technology used in building Green Roofs has been tested and proven since the 1960s, with many areas under green roofing for over 35 years. Still, many people new to the concept pose a somewhat familiar set of questions, which this FAQ section hopes to address.

What is a Green Roof?

The quick answer is: a roof with living vegetation, growing in a thin or thick substrate (growing medium). Other terms you may hear are living roofs, vegetated roofs, eco-roofs (= the American term for extensive green roofs), brown roofs (a term used in the UK for a roof designed for biological diversity, but which is not necessarily 100% covered with plants), sky gardens or roof gardens (the last two normally have thicker soil layers and provide accessible open space).

Is a Green Roof the same as a Roof Garden?

It can be, but it often differs both in the types of vegetation and maintenance regime, and in terms of use and access. These differences are explained later in the text.

Do Green Roofs leak?

People often ask if having all that moisture on the roof won't harm the building or the roof membrane. No. The membrane is waterproof, and it will stay so unless it gets physically damaged or aged. Bitumen membrane is mainly aged by the action of U.V.-light and fluctuating temperature extremes. The soil and vegetation cover will protect the membrane from these stresses. Only poor installation or incorrect specification of the 'standard' roofing materials will result in leaks on new builds. Unless the roof membrane is damaged while laying the green roof (never screw or nail through the membrane!), there is no reason why a roof would start leaking because it has a green roof, any more than a naked roof would. Leaks are less likely, in fact. When retro fitting a Green Roof on an existing building, extreme care must be taken not to damage the existing roofing material. However, as with a new build, the Green Roof itself will not cause leaking if all other materials are fit for purpose.

How do Green Roofs affect the life span of a roof?

A roof life is at least doubled with the addition of a green roof, thereby reducing the need to replace or repair the roof.

Do the plants grow into the original roof?

A root resistant or root inhibiting membrane must be included in the structured layers of the green roof installation. Once this is included, the original roof surface will be protected. Additionally, extensive (thin-substrate) green roofs use low-fertility growing medium which discourages colonisation by aggressive weeds and tree seedlings. The selection of plants installed favours species with shallow, mat-forming root systems. Semi annual maintenance removes any interlopers.

Will insects bother people in the building?

No. Insects adapted to living in that type of vegetation are not the same ones who are adapted to find opportunities in your kitchen. The odd beetle might lose its way, and end up inside, but they will not reproduce or cause problems there. Of course, living in a verdant, park like environment will lead to more stray insects than living in a city dominated by concrete, but these are indicators of a healthier habitat for people as well. For that matter, rats etc. do not find food on green roofs, and so do not live there.

Are green roofs sensitive to damage by wind?

Perhaps surprisingly, a green roof is less susceptible to damage by storms than many other roofing materials. For example in Malmö, Sweden in 1999, newly laid green roofs in Augustenborg were unharmed by a serious storm, while tin sheets and clay tiles on other roofs had blown off. The reason is that the wind can not pull the permeable mats up using suction. If a corner of the mat is lifted by the wind, it collapses again, instead of providing a big flat surface for the wind to catch, such as a tin roof does. In very windy places, however, it might be wise to use some erosion protection such as a net inside the soil, and fasten it well to the roof. Drainage, as well as prefabricated vegetation mats can be glued to the roof. (But never, ever, screw through the waterproofing membrane! Even using screws with rubber packing are not to be trusted in the long run.)

How do Green Roofs affect water drainage from the roof?

Research from around the world indicates that Green Roofs reduce annual run-off from roofs by at least 50%, and more usually by 60-70% - contributing to urban drainage and flood alleviation schemes. Moreover, the rate of release following heavy rainfall is slowed, reducing the problems associated with storm surges. With an increasing need for developments to have limited water run off, the UK's Environment Agency now highlight the use of green roofing in their May 2003 publication "Sustainable Drainage Systems (SUDS) – an introduction."

How do Green Roofs affect the buildings they are on?

Green Roofs lower the temperature inside the buildings beneath them during the increasingly hot summer months. They do this in two primary fashions: by sharply reducing the amount of heat absorbed by the roof itself, and through the evaporation of moisture from plants and their substrate. Thus, Green Roofs reduce the need for air conditioning in the summer and as a result reduce CO_2 emissions and keep a building cool. The cumulative effect of many green roofs in a neighbourhood further reduces the cooling demand on each individual structure located there. As an indicator for the significance of summer cooling in our latitudes, the UK already spends more money (uses more energy) cooling buildings in the summer, than heating them in the winter. Equivalent statistics for Ireland at this time have not been collected.

How do Green Roofs interact with wildlife?

New developments lead to a loss of habitats – green roofs can shelter biodiversity and support local biodiversity action plans by providing "compensatory habitat", and providing linkage between green areas. In particular they have been shown to favour many rare invertebrates found on brownfield sites, as well as ground-nesting birds such as the Black Redstart in the U.K.

How do Green Roofs affect the quality of life for people?

Green roofs contribute to a greener urban environment and quality of life, particularly for communities in high density developments. They can help to reduce noise (much the same as thick carpet in a dwelling), contribute to cleaner air, provide restful views for those overlooking them, encourage nesting birds which enliven the urban experience, provide additional open space when so engineered, and even provide places for growing food in the city.

Photograph courtesy of E Rooney

What sort of maintenance is involved?

The maintenance regime depends on the type of green roof installed. For example, an intensive green roof would require the same maintenance schedule as a garden or park on ground level. However, an extensive green roof would require much less attention once established. Perhaps two visits per year.

Does the roof require mowing?

This depends on the soil thickness and type of vegetation used. For instance moss-sedum mats for extensive green roofs never need mowing.

Does the roof require weeding?

Again, this depends on the soil thickness and type of vegetation chosen. Thin soil layers with extremely drought tolerant species, such as moss and sedums (stone crop), are not likely to get weeds, simply because it is too dry to support them. In certain spots a roof may be shaded, or get additional water from the drain of a higher roof, which might allow some grass to colonise the spot. Use of non-fertilised gravel in such areas will deter the grass. Normally, you do not weed an extensive green roof. Intensive or semi-intensive roof gardens do need weeding, as would any garden.

Does the roof require watering?

* Extensive vegetation and roofs designed for biological diversity: Normally no irrigation necessary. Some manufacturers recommend irrigation in the establishment phase. An unusually steep roof might need water during long dry periods.
* Semi-intensive and intensive roof gardens: A roof garden can be designed with drought tolerant plants that will not need irrigation, but normally, some of the plants chosen will have higher demands on water. A good idea is to have a built-in automatic irrigation system for such plantings.

Remember that one of the advantages with green roofs is their ability to take care of storm water and reduce the loads on municipal drainage and natural waterways. If irrigation is installed on a green roof, it is advisable to make it use recycled rainwater, to enhance the environmental benefits, and not to waste fresh water.

How do green roofs interact with photovoltaic panels?

Green roofs and photovoltaic panels are complementary technologies that improve each other's performance. The PV functions more efficiently thanks to the cooler ambient temperatures above the green roof, and the green roof benefits from the areas of shade. The synergistic relationship between green roofs and solar panels has been explained in "Future oriented and sustainable green roofs in Germany" (Appl, R. and W. Ansel. 2004), and in "Photovoltaic panels on greened roofs: Positive interaction between two elements of sustainable architecture" (Koehler, M. et al. 2002).

How to determine if an existing building will support a green roof?

The first step in considering a green roof for an existing building is to have its structural loading capacity assessed by a structural engineer. This figure, which must include both live and dead loads, determines the kind of green roof system the roof will support. Depending on the system used, extensive green roofs weigh between 60 and 240 kg/ m2 (Kolb & Schwarz, 1999). In retrofitting a ballast roof (gravel or paving slabs which hold down the waterproofing membranes), the weight of the ballast may match the loading required for an extensive green roof. Again, a structural engineer can provide this important information.

How much does a Green Roof cost?

As with any construction process, cost is dependant on specification. There are many variants which need to be considered when specifying a green roof. However, indicative costs are between €75 and €125 per m2 for extensive roofs and €125 to €175 per m2 for semi intensive and intensive roofs.

What financial benefits do green roofs provide?

Thirty-five years of experience with green roofs in Germany has demonstrated that a roof assembly covered with a green roof can be expected to outlast a comparable "naked" roof by a factor of at least two, and often three. Although modern green roof systems have not yet been in place much longer than 35 years, many researchers expect that these installations will last 50 years and longer before they require significant repair or replacement. For a building owner with a long-term investment in the roofing system, this benefit factor goes a long way toward paying back the initial investment in a green roof.

CHAPTER 2 - WHY GREEN ROOFS?

The Benefits

This chapter lists and explains the number of benefits related to green roof implementation. The main advantages that will be discussed are:

- Climate Mitigation and Adaptation
- Stormwater Management, Sustainable Drainage and Water Quality
- Removal of Pollution from Stormwater Runoff
- Biodiversity
- Air Quality
- Amenity
- Economic

2.1 WHY GREEN ROOFS?

Green roofs and vertical greening can be used as important tools to reverse some of the negative environmental and aesthetic problems that are experienced in our cities. Some other European cities have been using these types of greening technologies very effectively for decades, while more recently cities across North America and Australia have begun comprehensive roof greening programmes. A review of the benefits and international policy examples can help support a strategy for implementing green roofs and vertical gardens in Dublin.

2.2 BENEFITS OF "LIVING ARCHITECTURE" : GREEN ROOFS (AND LIVING WALLS)

Green roofs can provide numerous benefits, some of which are outlined in the diagram below:

2.3 A QUICK OVERVIEW OF THESE BENEFITS WILL HELP TO PLACE THEM WITHIN THE DUBLIN CONTEXT

2.3.1 CLIMATE CHANGE MITIGATION AND ADAPTATION

The Case: According to the National Climate Change Strategy 2007-2012 (Dept of Environment, 2007), there is a scientific consensus that climate change is happening. This change is directly related to man-made, greenhouse gas emissions. The National document in turn, refers to data published by the Intergovernmental Panel on Climate Change (IPCC). The IPCC published part of its Fourth Assessment Report (AR4) in 2007. This report states, "the warming of the climate system is unequivocal….This is linked to increases in the atmospheric concentration of long-lived greenhouse gases, particularly carbon dioxide, methane and nitrous oxide. These far exceed pre-industrial levels as a result of emissions to the atmosphere by human activities"

There are two primary strategies to deal with increasing temperatures: The first is to reduce the amount of greenhouse gases that are being produced; this is described as climate mitigation. The second is to endeavor to acclimatise to the shifts in temperatures. This is described as climate adaptation. Collectively they are termed climate response, and realistically, we will need to do some of each.

Green roofs can help us to respond proactively to both strategic agendas:

2.3.2 CLIMATE CHANGE ADAPTATION

Much of the reference material in regard to green roofs states that one of their biggest advantages is thermal insulation. This is true on buildings where there is poor insulation installed as part of the conventional roof such as garages, sheds and industrial units. However, with advances in building technology, the majority of new buildings have insulation designed into them, and so the internal environment of a building can be completely isolated from the external weather conditions. This is especially true in countries where building regulations require new developments to meet certain energy efficiency requirements

It is recommended therefore (CIRIA, 2007) that green roofs are not used as the only form of insulation on a building but rather in addition and as a compliment to it.

However, green roofs do have a huge impact on the changes in roof temperature during the day and night. The term, diurnal temperature change, is the difference between the minimum and maximum roof temperatures during a 24-hour period.

For example, a conventional bitumen roof will absorb a large quantity of solar radiation during a sunny day and can heat up to a temperature of over 35 degrees Celsius. If there is insufficient insulation underneath the roof, then the rooms below become uncomfortably hot and air conditioning needs to be turned on to cool the building interior. This overheating on the roof, leads to excessive use of air conditioning, which in turn increases the buildings energy needs and its production of carbon dioxide.

A study conducted by the National Research of Canada (Liu et al, 2003) quantified the thermal performance and energy efficiency of green roofs. This study found that a generic extensive green roof could reduce the temperature and the daily temperature fluctuations experienced by the roof membrane, significantly during the warmer months. In addition, the green roof moderated the heat flow through the roofing system and thus reduced the demand for internal air conditioning by 75%.

Appendix 2 provides additional examples of how green roofs can increase a buildings thermal efficiency

Figure 2.1 ASLA Green Roof just after planting (courtesy D Saunders)

Figure 2.2 A Portion of the roof or 'wave' sits over air conditioning unit (courtesy D Saunders)

Figure 2.3 the green roof 'wave' viewed from other side (courtesy D Saunders)

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2.3.3 CLIMATE MITIGATION

Urban areas can be up to 12 degrees Celsius warmer than the surrounding rural countryside. This is due to a number of reasons, most notably due to the heat absorbed and given off by buildings, roads and traffic; this is now referred to as the 'urban heat island' effect (Santamouris, 2001). There are two recognised methods of trying to reduce the urban heat island effect.

The first method is to increase the amount of vegetation in urban areas. In a recent study, scientists in the University of Manchester (Ennos, 2007) found that only a 10% increase in the amount of green space could reduce the surface temperature in towns by as much as 4 degrees Celsius. So if a relatively small fraction of buildings in an urban area had green roofs, there would be a significant cooling effect, even without creating new parks. Imagine what could be done with further greening.

The second method is to increase the reflectivity of roofs. The scientific term for this reflectivity is albedo. To increase roof albedo, light colored or reflective material ("white roofs") can be used to reflect a high amount of solar radiation back into the sky, rather then absorbing it. Green roofs also have a very high albedo. In addition, water evaporated by the leaves (evapo-transpiration) further cools the roof area. In Chicago the Energy Conservation Ordinance requires all new and refurbished roofs to install green roofs or reflective roofing in order to combat the urban heat island effect. Toronto has similar requirements.

While white or reflective roofing can ameliorate the heat island effect, and is preferable to black roofs for this reason. However the use of green roofs where feasible is preferable, as this combines the advantages of both increased albedo and urban greening on the same surface. Of course they deliver benefits beyond temperature moderation as well.

2.4 STORMWATER MANAGEMENT, SUSTAINABLE DRAINAGE AND WATER QUALITY

When rain falls on land that is covered in vegetation, the majority of it is absorbed by the soil, where it percolates down to join the water table. Plants absorb an additional amount of rain, and through the process of transpiration it is released back into the atmosphere. This is a balanced process. However, when rain falls on land covered by impermeable surfaces such as asphalt, concrete and roof tiles, there is no absorption and it runs off, directly into the drainage systems and from there into rivers and coastal waters. When storm intensity overwhelms the ability for the drainage system to handle runoff, we get flooding.

Currently the main purpose of urban drainage systems is to remove the water from the surface as quickly as possible. This type of system is costly to implement and is only dealing with the effects of impermeable surfaces, not the source problem. This results in approximately 75% of rainfall becoming surface runoff in cities, as opposed to the 5% surface runoff from a forested area. (Scholz-Barth, 2001) According to Scholz, there is a direct link between runoff from impervious surface coverage 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. Not only do storm episodes overload streams and cause erosion, but runoff from urban surfaces carries a high load of pollutants.

To combat surface runoff problems in urban areas an alternative solution has been sought, a drainage system that deals with the source of the problem and follows a principle of sustainable development. The term used to describe this is Sustainable Urban Drainage System (SuDs). The main aim of this system is to replicate the natural pattern of drainage.

The substrate and the plant layers in a green roof absorb large amounts of rainwater and release it back into the atmosphere by transpiration and evaporation. They also filter water as it passes through the layers, so the run-off, when it is produced has fewer pollutants. Also, there is a time delay between when the rainfall actually happens and when the reduced amount of water comes off the roof. This takes a lot of pressure off the urban drainage systems and as such, green roofs form an integral part of a Sustainable Urban Drainage system. Where stormwater retention and discharge reduction via green roofing are coupled with a variety of on-site features such as "rain gardens", wildlife ponds and constructed wetlands, a system can evolve which keeps virtually all rainfall from entering the municipal drainage system. Such measures also offer many opportunities for creative landscaping, additional biodiversity support, and amenity.

Figure 2.4 Rain gardens, Malmö, Sweden (© Erik van Lennep)

Please refer to Appendix 4 for examples which outline the advantages of green roofs in stormwater management.

In summary, the research examples in Appendix 3 show that the impact of green roofs on annual runoff reduction is dependent on a range of factors:

- Depth of substrate

- Substrate type
- Saturation of substrate at onset of rain event
- Angle of the roof
- Range of vegetation growing
- Intensity of rainfall
- Time of year

Therefore, statistics for stormwater diversion can vary widely. However, based on some of the figures shown, a green roof can reduce annual percentage runoff by between 40 and 80%.

Figure 2.5 Section through types of green roof structure

2.5 REMOVAL OF POLLUTION FROM STORMWATER RUNOFF

Rainfall runoff from roofs can contain pollutants for example, from bird droppings and atmospheric pollution. As well, a standard roof covering such as bitumen will give off a range of pollutants under heat stress, which then are carried along with the runoff. One of the roles of a sustainable urban drainage system is to remove some if not all of this pollution. Green roofs can retain and bind contaminants that fall on their surface either as dust or dissolved in rainwater. Research by (Johnston et al, 2004) found that 95% of heavy metals are removed from runoff by green roofs and nitrogen levels can be reduced. However care should be taken when choosing a green roof substrate as pollutants can leach out if it is not an inert type.

The Pennsylvania Department of Environmental Protection (2004) state that if water quality improvements are specifically required of the green roof, then an engineered substrate with 100% mineral content must be used. The purpose of this is to reduce the risks of contaminants leaking out from the substrate. This will reduce the risk of pollutants leaking out of the system. (They also recommend that the timing and amount of artificial fertiliser used on the green roof be restricted. Fertiliser should only be applied while the vegetation is getting established and even then, only a minimum amount. Excessive use of fertilisers on green roofs would only add to the pollution problems.) In addition, the environment agency found that it took approximately 5 years for a green roof to reach its maximum pollution removal capacity.

Overall, the most important issues that effect pollution absorption are:

- The type of substrate and organic matter content
- The range of vegetation planted and its maturity
- Type of maintenance schedule on the roof i.e.) if any chemical fertilizers are used.

Figure 2.5 Drain on an extensive green roof (Courtesy C Clark)

2.6 BIODIVERSITY

Figure 2.6 Green roof of grasses and sedums (Courtesy, D Saunders)

Green roofs have a great potential to aid and increase biodiversity levels in urban areas in addition to creating linkages between biodiversity 'wells' around the city.

One of the early drivers for green roof installation in Germany was to compensate for habitat that was destroyed by development. Overtime, the priorities for green roofs in Germany changed and their primary purpose was as a method of reducing stormwater runoff. This resulted in a change of vegetation specified on green roofs to types which hold a larger amount of water, such as varieties of sedum. This in turn led to a proliferation of generic, extensive roof installations tied to SUDS requirements, and these had reduced biodiversity value. However, green roofs for stormwater retention and biodiversity need not be mutually exclusive, they can cater for both.

A report by English Nature states the biodiversity advantages of green roofs as follows:

- Helping to remedy areas of deficiency by providing new habitat in areas which are currently lacking in wildlife habitat
- Creating new links in an intermittent network of habitats thereby facilitating movement and dispersal of wildlife
- Providing additional habitat for rare, protected or otherwise important species

It is a misconception however, that green roofs will behave in the same way as ground level habitats do. There is no natural plant succession on a green roof system. For example, a grass roof will not naturally progress to scrubland and eventually to forest. This is because there are a number of limitations to natural colonisation on a roof system, such as substrate material and depth. Green Roof management also requires certain elements from ground level habitats be kept out of a rooftop plant community. For example, plants with very strong growth habits such as bramble (Rubus fruticosus) and the Butterfly bush (Buddleja davidii) are very useful to biodiversity at ground level but would have a harmful effect on a roof as they spread so quickly they could take over the whole roof area. Indeed, in Dublin Buddleja will be one of the unwanted colonists weeded out of green roofs by a semi annual maintenance check. Careful consideration must be put into planting schemes and habitat creation.

Appendix 5 outlines additional research into green roofs and biodiversity. This study showed that the more diverse the green roof design in height and slope, vegetation type, substrate depth and type, the more diverse population of plant and wildlife will colonise and use the area.

Figure 2.7 Campanula portenschlagiana, a familiar colonizer of walls and roofs in Ireland (© Erik van Lennep)

Figure 2.8 Extensive green roof on several levels in Munich, Germany

Figure 2.9 Modular cultivation of native grasslands, Geneva Botanic Gardens (© Erik van Lennep)

Figure 2.10 Native orchids and grasses, Geneva Botanic Gardens (© Erik van Lennep)

2.7 AIR QUALITY

Cities are not known for their high air quality. Respiratory disease in particular has been associated with urban areas since the Industrial Revolution. Particulate matter, now mainly from vehicle engines, has been linked to poor health and breathing difficulties. An estimate by English Nature (English Nature, 2003) gave a number of 24,000 premature deaths per year as a result of air pollution in the UK.

Vegetation in urban areas can filter out airborne particles as the air passes over plants, settling onto the surfaces of the leaves and stems. This material is then washed off into the soil, by the movement of rainwater. Most of these benefits are related to larger vegetation, such as trees and shrubs. There has been little research done into the effect of green roofs in reducing urban air pollution. The ability of extensive roofs with low growing sedum-based vegetation is probably less in this respect. To achieve significant air cleaning benefits, it would also be necessary for a high density of green roofs to be used in an area rather then a few isolated installations.

2.8 AMENITY

Depending on the load bearing capacity of individual roofs, green roofs can play an integral part in the provision of both passive recreational space and even sports facilities in neighbourhoods where there is little ground level green space. Recreation space on a roof has the advantage in that access can be controlled, thereby making the area safer from vandalism and other antisocial issues that plague the same type of areas on ground level.

Access to garden facilities as well contributes to psychological well being. Areas of flat roof that would not have the strength to support heavy recreational use may be still strong enough for limited personal use, for example, accommodating some containerised plants. Roof spaces can have great potential in providing urban dwellers with the amenity and outdoor space essential for healthy living.

Concern is also now arising over the quality of food, how it is produced, and the energy required to transport it to market. Tied to energy costs, food prices are escalating. Roof spaces could be used in many cases for growing healthy food, particularly in high density, urban areas where street level garden space may be small or restricted.

Figure 2.11 Rooftop allotment, Geneva, Switzerland (© Erik van Lennep)

A noted example of rooftop food production is the Fairmount Hotel in Vancouver, Canada. The roof itself covers 195 square meters and has a soil depth of 45cm. The roof garden supplies all the herbs used in the hotel at an approximate yearly saving of 25,000-30,000 Canadian dollars. It also provides amenity space for hotel guests and the hotel is able to charge higher rates for the rooms adjacent to the roof garden.

The purely aesthetic value of green roofs should not be overlooked either. Even where the roof may be inaccessible, viewing a vegetated flat roof from surrounding buildings is much more appealing then looking onto a graveled or bitumen surface. This in turn has positive psychological impacts which have been noted by hospitals where convalescence is faster when patients have views onto green spaces, and businesses where workers report higher job satisfaction and exhibit more productivity when provided access and / or views onto green spaces.

Figure 2.12 Sedum plants placed underneath the walkway grill on the ASLA green roof (Courtesy D Saunders)

Figure 2.13 Side view of the walkway grill with Sedum plants growing through (Courtesy D Saunders))

Figure 2.14 Sedum hispanicum, commonly used species in native habitat, Barcelona (© Erik van Lennep)

2.9 ECONOMIC

Green roofs increase the lifespan of the roof membrane as it is no longer exposed to the weather elements. In general terms it is estimated that the lifespan of the roof membrane will be doubled under a green roof. This reduces the cost of maintenance and repair (Greater London Authority, 2008). There are reductions in energy costs, both in heating and cooling a building to which a green roof has been installed. These cost benefits are subject to the type of green roof installed and the location of the building. This has already been explored in this document and examples of energy savings can be reviewed in Appendix 2.

2.10 POTENTIAL ECONOMIC INCENTIVES

Depending on the type of policy implemented in Dublin, installation of green roofs could offer developers a range of advantages, such as:

- Approval for new developments could be fast-tracked if green roofs are specified in the planning application
- Reduction in stormwater charges could be transferred to developers on build projects
- Reduction in the size of stormwater cisterns and reservoirs which could lead to a reduction in costs.
- Grants may become available if buildings are planned to be more energy efficient
- Larger floor area may be granted to developers
- Compliance with government environment and energy policies could be enhanced.

Figure 2.15 Seating area on the ASLA Green Roof (courtesy D Saunders)

CHAPTER 2 SUMMARY POINTS

Benefits of Green Roofs for Climate Change Mitigation and Adaptation

- Green roofs reduce the diurnal temperature change on roofs thus reducing the air conditioning and heating needs of the building
- Green roofs reduce can reduce the urban heat island effect

Benefits of Green Roofs on Stormwater Runoff and Pollution Removal

- Green roofs can form an integral part of a sustainable urban drainage system
- Depending on the green roof structure, they can reduce the annual percentage runoff by between 40 and 80%
- Green roof performance will depend on the depth and type of substrate that is used and the type of vegetation
- Research by (Johnston et al, 2004) found that 95% of heavy metals are removed from runoff by green roofs and nitrogen levels can be reduced.
- It can take approximately 5 years for a green roof to reach its maximum pollution removal capacity
- They can help achieve objectives of Drainage Policy

Benefits of Green Roofs for Biodiversity

- They provide new habitats in areas that are currently lacking in wildlife habitat
- They can provide valuable 'arteries' of movement for wildlife through to other habitat areas and connect 'green corridors' in the city
- They can provide additional habitat for rare or protected species.
- They can help deliver actions outlined in regional and national biodiversity policy

Amenity Benefits of Green Roofs

- Green roofs can provide a safe, access controlled recreational area in neighborhoods
- They can provide additional space to grow food in urban areas

Economic Benefits of Green Roofs

- Green roofs can double the lifespan of a roof; reducing maintenance and repair costs
- They can reduce the energy costs of a building

Courtesy W Clark

CHAPTER 3 - GREEN ROOF STRUCTURE

In order to fully understand how green roofs function, it is necessary to understand their typical structure. This chapter outlines the different components of the green roof layered structure and discuss some of the commonly used plant varieties.

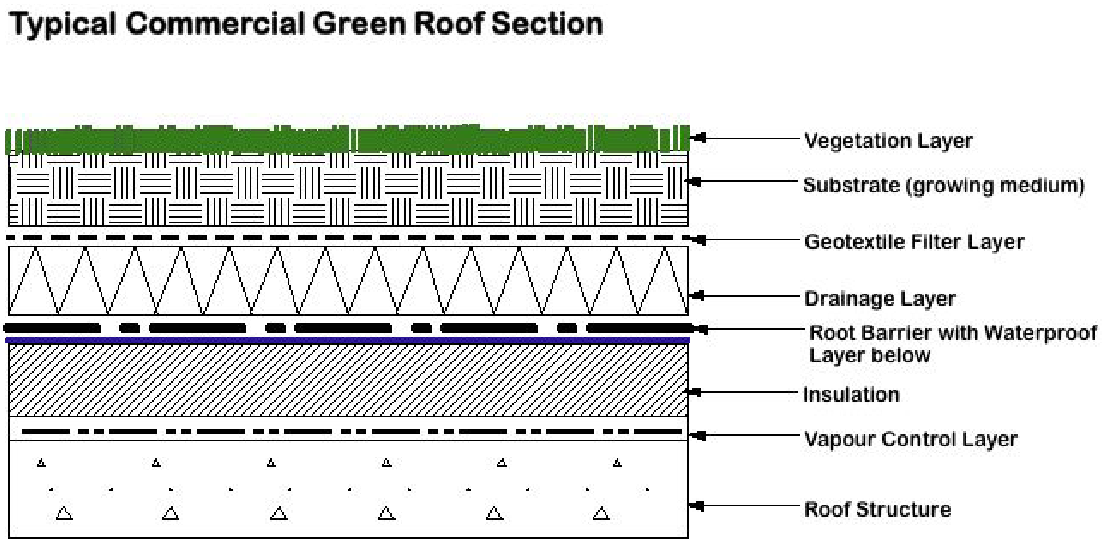
3.1 GREEN ROOF LAYERS

In all cases the green roof must be made up of a minimum for four layers or components. These are as follows (roof deck upwards):

- Root barrier layer
- Drainage layer with geotextile filter
- Substrate or growing medium layer
- Vegetation layer

Other layers may be added depending on the type and location of roof or the specifications of particular green roof manufacturers. Additional layers might include moisture mats, protection boards, water retention systems, irrigation systems and anchorage systems for larger plants, such as trees.

The drawing below is a typical section through the green roof layer. The drainage and the growing medium layers are the main elements in terms of volume and mass in the green roof structure.



3.1 ROOT BARRIER LAYER

This is an essential layer of the green roof as it stops the roots of the plants above from penetrating through and harming the waterproof layer. The root barrier can take the form of heavy polythene based material, which is placed above the waterproof layer. Or it can be installed as a biocide (commonly copper-based) within the actual waterproof layer.

3.2 DRAINAGE LAYER

The drainage layer works in tandem with the substrate in order to control water retention within the green roof structure. Inclusion of the drainage layer provides three main benefits:

- The risk of water ponding on the roof is significantly reduced, which is of utmost importance on flat roof locations.

- It ensures that the drainage conditions are preserved to ensure that the plant varieties on the green roof will survive and prosper. If for example, the green roof structure is too free draining then the plants may not have sufficient moisture to allow them to survive during dry spells. On the other hand, if water does not drain from the green roof fast enough, the plants will be waterlogged in times of heavy rainfall and will die.

- This layer will control the volume and timing of rainfall runoff and as such is an integral part of the stormwater runoff management system.

The geotextile material situated on top of the drainage layer is simply a fine material that prevents any fine particles of the substrate from sifting down and clogging the drainage layer. This filter though, does not prevent plant roots from penetrating down into the drainage layer, so plants have access to additional moisture in the drainage layer as well as the substrate.

Figure 3.1 Pallets of Sedum matting ready to be rolled out (Courtesy C Sosman)

Figure 3.2 Sedum matting being applied to roof (Courtesy C Sosman)

Figure 3.3 Irrigating the Sedum matting (Courtesy C Sosman)

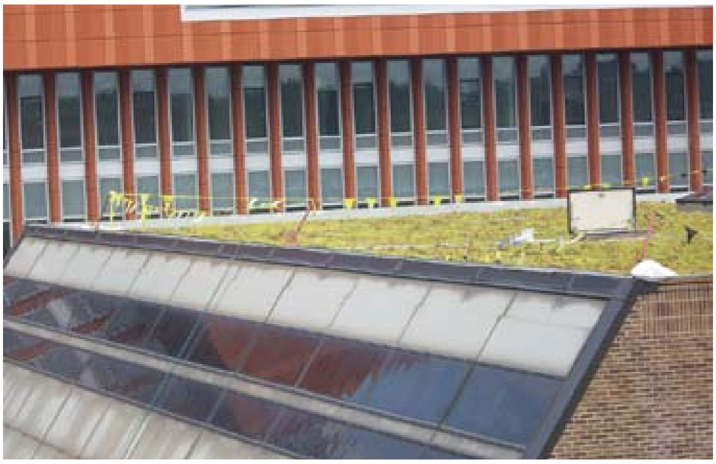


Figure 3.4 The completed extensive Sedum green roof (Courtesy C Sosman)

3.3 SUBSTRATE OR GROWING MEDIUM LAYER

This layer provides all the elements required for plant growth such as, mechanical strength, open pore structure, nutrients and drainage properties.

Plants on an intensive green roof need a deep and fertile substrate, usually topsoil. This means the maintenance requirements are increased in the form of annual mulching and replenishing of the soil, weeding and pruning. Also, bear in mind that topsoil is very dense and heavy when saturated so this significant load would have to be accommodated by the underlying roof structure. However, extensive roofs can be used in instances where weight and maintenance have to be limited. The substrate used for extensive roofs are usually lightweight and have low nutrient levels. This in turn dictates the plant varieties that can be grown on such green roofs, but this can reduce maintenance to one visit per year.

Figure 3.5 Sedum plants on an extensive green roof (Courtesy C Clark)

Figure 3.6 There are a large variety of Sedum species and varieties providing different flowering seasons and colours (Courtesy D Saunders)

3.4 VEGETATION LAYER

There are a number of ways of applying a vegetation layer to a green roof. They are as follows:

Plug Planting
This involves planting a pot grown plant directly into the growing medium on the green roof. Planting this way means that it may take time for the vegetation to establish, and irrigation may be required to ensure successful development. Birds have been known to disturb the plug plants when they are searching for insects.

Vegetation Mats
This is called 'roll-out vegetation'. The plants are grown on a membrane or mat, which is then harvested and rolled, brought to the green roof site and laid out on the growing medium. This method provides almost 100% vegetation cover immediately. The mats have to be installed very quickly to limit the disturbance on the plants. They need to be staked or secured to prevent them being blown away before the roots establish and they need to be irrigated directly after they are placed. In addition, the weight of the mats often requires use of additional equipment to lift them to the planting site. This is the most expensive way of planting a green roof.

Seeds and Cuttings
This is a slower way of planting up a green roof but it is quite cost effective. The seeds can be distributed by hand or by a method adapted from the "hydromulch" application used by some councils to revegetate roadway embankments.

Natural Colonisation
This method involves leaving the growing medium bare to be colonized naturally. The plants that develop will be those found in the general area so will have greater biodiversity benefits and this method is perhaps the cheapest and most environmentally sound way of planting a green roof.

Further explanations of the different varieties of plants that can be grown on green roofs are outline in Appendix 3.

Figure 3.7 Silene, another alpine plant suitable for extensive green roofs (Courtesy D Saunders)

Figure 3.8 Cotula hispidula ((© Erik van Lennep)

Figure 3.9 Mixed Sempervivum species (© Erik van Lennep)

CHAPTER 3 SUMMARY POINTS

Structure of green roofs requires a minimum of four layers:

- Root barrier layer
- Drainage layer with geotextile filter
- Substrate or growing medium layer
- Vegetation layer

Root Barrier Layer
Stops the roots of the plants above from penetrating through and harming the waterproof layer. The root barrier can take the form of heavy polythene based material, which is placed above the waterproof layer. Or it can be installed as a biocide within the actual waterproof layer.

Drainage layer with geotextile filter
Works in tandem with the substrate in order to control water retention within the green roof structure. The geotextile material that sits on top of the drainage layer is simply a fine material that prevents any fine particles of the substrate from sifting down into the drainage layer and clogging it up. This filter though, does not prevent plant roots from penetrating down into the drainage layer, so plants have access to the drainage layer as well as the substrate.

Substrate or growing medium layer
Provides all the elements required for plant growth such as, mechanical strength, open pore structure, nutrients and drainage properties.

Vegetation layer
There are a number of ways of applying a vegetation layer to a green roof:

- Plug Planting
- Vegetation Mats
- Seeds and Cuttings
- Natural Colonisation

Figure 3.10 Saxifraga longifolia (© Erik van Lennep)

CHAPTER 4 - INTERNATIONAL GREEN ROOF POLICY EXAMPLES

This chapter provides examples of green roof policy from around the world. Some of the cities mentioned have a long history of green roofs while others are only discovering their significance in helping to achieve a sustainable city.
The example cities are as follows:

U.K.: London, England

European Mainland:
Basel, Switzerland
Munster, Germany
Stuttgart, Germany
Linz, Austria

Canada: Toronto, Ontario

USA:
Chicago, Illinois
Portland, Oregon

4.1 POLICY EXAMPLES

The following section provides International and European examples of green roof policies and initiatives. These precedents are used to provide possible guidance for policy implementation in Dublin. Information for this section was sourced from Greater London Authority (2008), the official website of the city of Toronto and Lawlor et al (2006).

4.2 LONDON, U.K.

Green Roof Action Catalyst

A key motivator that brought attention to the benefits of green roofs in London was the protection of a bird, the Black Redstart (Phoenicurus ochruros). This is a "Rare" (not yet "Endangered") bird that nests on brownfield sites in the Greater London Area. These sites, specifically Canary Wharf, were being used up for development and there was concern that the Black Redstart population would drop significantly due to lack of habitat. Green roofs provided the solution to this as they can be used to replicate ground level brownfield sites and so are ideal nesting sites for the Black Redstart. Building on this, the Greater London Authority agreed that green roofs could resolve many other environmental problems in the city such as, reducing stormwater runoff volumes and reducing the heat island effect as well as others.

It was identified that lack of policy for green roofs was a major barrier in their implementation. In March of this year the Design for London and the Greater London Authority produced a technical document to support a 'living roofs' policy.

Green Roof Policy in London

An earlier document outlined the reasons to amend the London Plan in regards to implementing a policy for green roofs and living walls in London. This was submitted to the London Plan Examination in Public Body which agreed with its findings to implement a Living Roofs policy as part of the Further Alterations to the London Plan. The wording of the policy is as follows:

"The Mayor will and boroughs should expect major developments to incorporate living roofs and walls where feasible and reflect this principle in Local Development Framework (LDF) policies. It is expected that this will include roof and wall planting that delivers as many of these objectives as possible:

- accessible roof space
- adapting to and mitigating climate change
- sustainable urban drainage
- enhancing biodiversity
- improved appearance

Boroughs should also encourage the use of living roofs in smaller developments and extensions where the opportunity arises"

> "Boroughs should also encourage the use of living roofs in smaller developments and extensions where the opportunity arises"

Apparently initial drafts of the proposal sought to define the specific types of roofs that should be greened. This became an extremely long list so the term 'where feasible' was used instead. The onus now falls on the individual developer to demonstrate that roof greening would not be feasible in any particular case.

This technical report for Living Roofs and the policy statement contained therein aims to ensure London is a liveable city and capable of adapting to the environmental challenges ahead. It will also be used to inform the review of the Sustainable Design and Construction Supplementary Planning (SPG) section of the London Plan later this year.

In gathering information for the Living Roofs technical report, aerial photographs of London were used to calculate the approximate amount of flat roof space that would be eligible for greening. Flat roofs deemed eligible were those with a paved or shingle ballast surface and did not have any industrial coolers placed on them. The amount of green roof space was then calculated as a percentage of the total surface. Having these figures helped to establish approximate energy savings and reduction in stormwater runoff that could be gained by greening.

For example it was estimated that 3.2 million square meters of roof surface could be greened in four sample areas of London. It was further assumed that 80% of this surface would be extensively greened and 20% would be intensively greened. This area then equates to 256 hectares of additional habitat which is a larger area then Hyde Park and Kensington Gardens combined. Statistics such as these make it abundantly clear how useful greening roof spaces can be. The technique could be executed in the Dublin area to reinforce arguments for introducing green roof policy

Effectiveness

By producing this technical document and policy statement, the Greater London Authority has shown its commitment to green roof and vertical greening technologies. They have also demonstrated that using this type of urban greening can address many of the environmental and aesthetic issues experienced by cities.

The next step in the policy process is to implement a recommended greening standard for designers and developers to use. This standard would then be incorporated into the revision of the Sustainable Design and Construction Supplementary Planning (SPG) to the London Plan which, as mentioned already, happens later this year (2008).

The standard is only in draft form at the moment but under consideration is the following (Ref 3.1):

> "Essential Standard (Draft) The provision of either intensive, extensive or recreational roof space (or a combination of these) should be provided on all new development."
>
> "Mayor's Preferred Standard (Draft) A minimum of 70 per cent of the roof space should be vegetated to provide maximum benefit for SUDS, building energy performance and biodiversity.
>
> At least 25 per cent of the total roof space in any one development should be accessible to residents and/or workers.
>
> A roof with an average depth of 100mm substrate with 80 per cent of the substrate having an average holding capacity of approximate 2 litres/10mm/m2 equivalent providing a potential minimum capacity 20 litres/m2."

Figure 4.1 Semi Intensive Green Roof in London

LONDON, U.K.

Green Roof Catalyst

- Green roofs used as a protective habitat for the Black Redstart bird
- Identified that lack of policy for green roofs was a major barrier in their implementation

How is policy being Implemented?

- Agreement made in 2008 to include a Living Roofs policy as part of the Further Alterations to the London Plan
- Key statement "The Mayor will and boroughs should expect major developments to incorporate living roofs and walls where feasible and reflect this principle in Local Development Framework (LDF) policies"
- Aerial photographs of London were used to calculate the approximate amount of flat roof space that would be eligible for greening
- It is estimated that 3.2 million square metres of roof surface could be greened in four sample areas of London. It was further assumed that 80% of this surface would be extensively greened and 20% would be intensively greened

Green Roof Policy, Effective?

- By producing a technical document and policy statement, the Greater London Authority has shown its commitment to green roof and vertical greening technologies
- The next step in the policy process is to implement a recommended greening standard for designers and developers to use
- This standard would then be incorporated into the revision of the Sustainable Design and Construction Supplementary Planning (SPG) to the London Plan which happens later in 2008.

4.3 BASEL-CITY, SWITZERLAND

Green Roof Action Catalyst

The driver for green roof policy in Basel grew from an interest in energy savings and as a method of promoting biodiversity

Green Roof Policy

The relevant policies that encouraged green roof installation were as follows:

A public poll taken during the 1990's found that there was a majority of support for an electricity tax to encourage energy saving. This led to meetings with all the stakeholders involved and the fees from the electricity tax were used to provide subsidies for green roof installation over a two year period.

From 2002 the building regulations in Basel require that all new and renovated flat roofs must be greened using specific material in order to provide valuable biodiversity habitats.

The requirements are outlined below:

- The growing substrate has to be a minimum depth of 10cm
- Mounds with a diameter of 3m and a depth of 30cm should be included to support insect life
- The growing substrate should be a native mix and the vegetation has to be a native mix

Another promotion tool used by the Basel City Council is to hold regular contests for the best looking green roof.

Effectiveness

Over the two year period when the green roof subsidy was available, there were 135 applicants and approximately 85,000 square meters of roofing surface was greened. A result of the building regulations means that 15% of the flat roofs in Basel have also been greened. The two year incentive program ensured that there was a lot of media attention given to the green roof project and Basel achieved nationwide recognition. It also meant that when the building policy was implemented it was not met with any strong resistance because the program was such a success and all the stakeholders had been involved from the outset.

Figure 4.2 Extensive green roof in Basel

4.4 MUNSTER, GERMANY

Green Roof Action Catalyst

The city of Munster has been concerned with the impacts of increased urbanization since the 1970's, especially stormwater runoff and reduction in green space. Incentives were provided with the purpose of greening areas in the downtown core of the city. Later, in the 1990's efforts to implement a storm water management system was the main instigator of green roof policy in the region.

Green Roof Policy

The following list outlines how Munster has implemented a green roof policy:

In the late 1970's, financial incentives were provided to support environmental projects that would green the city core; green roofs were eligible for subsidies. The incentives varied over time, one example however was the 'Grey vs. Green' program which was allotted €25,000 per year to subsidize green roof installation, which led to an annual roof greening of 1000 square meters of roof surface. While this program ran, it spent its full allocation each year and the majority of applications were from residents seeking to green their sheds and garages. The incentive schemes were highly successful and led to increased environmental awareness among the population. They were finished in 2002 due to financial limitations.

Building on the heightened environmental awareness of the communities, Munster then implemented a stormwater charge. This took the form of charging property owners for the amount of impervious surface on their property. For example the stormwater fee is charged at €0.44 per square meter/year. If there is a green roof installed somewhere on site, the charge is reduced by 80% to €0.09 per square meter/year, depending on its rainfall retention capacity. So if the green roof has high water retention, then the charge is dropped even further to €0.04.

The property owner receives a water bill from the council, which outlines the area of pervious and impervious surfaces on their property and the charges incurred. The system is very transparent and the cost benefits of green roof implementation are easy to calculate. For example, a large industrial area of 17,000 square meters would have to pay stormwater fees of up to €7,480 per year if they have a conventional roof. Installing a green roof on the building reduces the stormwater fee to €1,496 per year.

The system is very transparent and the cost benefits of green roof implementation are easy to calculate.

Effectiveness

The incentive schemes implemented in the area were well received and they paved the way for the stormwater fee by increasing environmental awareness and highlighting the benefits of green roofs. The stormwater fee now makes it a financially sound idea to implement green roofs. The administrative costs associated with implementing the fee are large however, as the area of pervious and impervious surface for each property has to be calculated and in the case of any changes, reassessed and adjusted. The fee itself can absorb these costs.

4.5 STUTTGART, GERMANY

Green Roof Action Catalyst

Stuttgart is a highly industrialized area and its location in a valley basin makes it susceptible to increased levels of air pollution. The air quality deteriorated further as the city spread out and vegetation from the surrounding valley slopes were removed. In an effort to improve the condition of the air, the city officials created new zoning and building regulations. Part of this policy was to increase the amount of green space in the area and green roofs were included. Green roofing was not a new technology in Stuttgart as they had one already in place, which dated back to the 1920's.

Green Roof Policy

The following lists show how green roof policy is implemented:

In 1985 Stuttgart became the first German city to integrate green roofs in its local development plans. This requires new developments with flat and sloped roofs of up to 12 degrees, be extensively green to specific standards. The city council, in order to display its commitment to this regulation, started to install green roofs on public buildings the majority of which were implemented when the roofs needed to be replaced.

In 1986, financial incentives became available to encourage developers and residents to install green roofs. This incentive is currently still available. The incentive program is allocated €51,000 per year for subsidizing green roof implementation. The subsidy will cover either 50% of the installation cost or €17.90 per square meter. The incentives are very popular, with the funds being exhausted every year. To apply for the subsidy, a site plan, green roof design and approximate costs must be submitted to the council. There is also free consultation available for the council to advise on green roof construction

The council publishes a green roof brochure, which guides residents through the different types of green roofs, the benefits, waterproofing and weights and the selection of plants that can be used.

The council publishes a green roof brochure, which guides residents through the different types of green roofs, the benefits, waterproofing and weights and the selection of plants that can be used. It also gives direction on specific functions of a green roof, for instance, the percentage water retention capacity of different media thicknesses. The brochure uses the FLL document as its design standard.

Effectiveness

The methods used by Stuttgart have been successful. The regulations have resulted in approximately 105,000 square meters of public building roofs have been greened. Although implementing policy here was an effective way of ensuring green roof installation, it should be approached with caution. If property owners and developers feel that they are forced to add a green roof to their plans, it may become just another mandatory financial burden to them. This in turn may lead to very little or no maintenance of the roof, post installation. A green roof that is neglected can have a detrimental effect to the overall image and subsequent acceptance of these systems. Therefore, in addition to policy, efforts must be made to highlight the many benefits of green roofs to developers. They must perceive it as an asset to be exploited and a valuable addition to their building.

The financial incentive program has resulted in approximately 55,000 square meters of green roof on private buildings. In some ways the maintenance problems that can result from regulation green roofs do not appear when the roof has been installed with the aid of an incentive. This is because in the majority of cases, people who seek the incentive are already convinced of the benefits of green roofs and so are prepared and accept the maintenance of it into the future.

Green roof, Stuttgart

4.6 LINZ, AUSTRIA

Green Roof Action Catalyst

Linz is located on the Danube River and is the capital of the county of Upper Austria. It has a population of approximately 190,000. The main driver for implementing a green roof policy was lack of green space in the city. This was recognised in the Green Space Plan for Linz in 1984. This report pointed out the value of green space and the positive impact it has on urban climate, ecology, biodiversity, recreation, psychological health and local aesthetic. The outcome of the report was to target areas with very little vegetation or greenery and green roofs were the ideal solution for location where open land development was not an option, for example, industrial and commercial districts and underground structures. The main aim of the Green Space Plan for Linz is to retain an adequate 'greening' level and to augment areas lacking in green space. In 1985, green roofs were introduced into the development plan. (Austria is made up of nine counties and each of these has a Regional Development Planning Act, which outlines mandatory and optional regulations for inclusion in local development plans).

Green Roof Policy

The policy that Linz developed for green roof development had two strands. The first was to integrate green roof installation into the legally binding development plans. The second strand was to provide financial incentives to implement the policy.

The approved text for green roofs is quoted below. These extracts were taken from Linz 2002 (Grünflächenplan der Stadt Linz 2001):

Example Text for *Green Roofs in the City*:

> "New and proposed buildings with an area of over 100 m2 and a slope of up to 20 degrees, excluding shed roofs, are to be greened. The uppermost layer of the green roof construction shall as growing medium have a thickness of at least 12 cm and the coverage of living plant material shall be at least 80%."

Example text for *Green Roofs on Underground Parking*:

- "The roof surfaces of underground structures are to be greened. The uppermost layer of the green roof construction shall as growing medium have a thickness of at least 50 cm and the coverage of living plant material shall be at least 80%.
- Green roofs of underground structures must be built flush with adjacent neighbouring properties.
- When erecting underground structures, at least 30% of the site shall be left free for green areas over native soil."

> ... the council established a green roof subsidy, which was introduced in 1989 and was the first direct financial incentive for green roofs in Austria.

Once these additions were included in the development policy, the main hurdle to overcome was the reluctance for developers to implement it. Their reluctance stemmed from the additional costs of installing green roofs. To address this, the council established a green roof subsidy, which was introduced in 1989 and was the first direct financial incentive for green roofs in Austria. The subsidies were given out on extensive and intensive green roofs. Eligibility was based on the construction costs from the roof deck upwards and also included the cost of upgrading the structural load capacity of the roof itself. However, the design and administration fees were not included in the subsidy. Also, the subsidy is given no matter if the installation is voluntary or mandatory, as part of the development plan.

Another dictate of the subsidy is that the green roof is maintained after installation. In order to ensure that this is adhered to, only 50% of the subsidy is paid after construction and planting. The other 50% is paid out only once the vegetation has established. An inspector appointed by the council committee inspects the condition and care of the plants in addition to checking the invoices submitted for costs. The drawback of this method was that there was a lack of personnel to execute the checks, and long-term monitoring of the green roofs suffers because of this. However, aerial photography of specific sites has ameliorated this problem somewhat.

Figure 4.3 Example of green roof on an apartment complex in Linz

Effectiveness

Since the introduction of the green roof subsidy in 1989 up until 2001, 287 projects applied and received this financial support. A total of €4.77 million was spent in subsidies, which resulted in approximately 268,000 square meters of green roofs. Over 2001 and 2002, another €740,000 was spent on greening 47,000 square meters of roofs. As with any new policy, when it was first introduced, it was greeted with contempt and the majority of developers tried to work their way around it. However, because it was adhered to in policy, green roofs are no longer and issue of contention and building plans are now submitted with a green roof already included

EXAMPLES OF EUROPEAN MAINLAND GREEN ROOF POLICIES

BASEL, SWITZERLAND

Green Roof Catalyst

- Biodiversity

How was policy implemented?

- Public agreed to introduce electricity tax for energy saving
- Funds from tax used to fund green roofs over 2 year period
- After 2 years, building regulations require that all new and renovated flat roofs must be greened
- Strict guidelines to promote biodiversity: native soil and flowers to be used

Green Roof Policy, Effective?

- Very successful as all stakeholders were included from the start
- City recieved widespread publicity because of 2 year subsidy
- When included in regulations, no strong resistance due to initial subsidy program
- City holds annual 'Best Green Roof' competition

MUNSTER, GERMANY

Green Roof Catalyst

- Drainage and stormwater

How was policy implemented?

- Financial subsidies through 'Grey vs Green' Program
- Resulted in 1000m square of green roof implemeted p/a
- Stormwater fee then introduced
- Fee is based on amount of impervious surface on property (private and commercial property). Reduced by 80% if green roof installed

Green Roof Policy, Effective?

- Incentive scheme was a success and paved the way for the stormwater fees
- The stormwater fee now makes it a financially sound idea to implement green roofs

STUTTGART, GERMANY

Green Roof Catalyst

- Increase green space

How was policy implemented?

- First German city to integrate green roof policy in local development plans new developments with flat and sloped roofs of up to 12 degrees, be extensively green to specific standards
- Green roofs installed on public buildings to show commitment to policy
- Council publishes a green roof brochure highlighting types, benefits and installation advice

Green Roof Policy, Effective?

- Regulations have resulted in approximately 105,000 metres squared of public building roofs have been greened
- Was some resistance at first as regulations were implemented without prior consultation with stakeholders

LINZ, AUSTRIA

Green Roof Catalyst

- Increase green space

How was policy implemented?

- Implemented green roof policy into development plans
- Provided incentives to backup policy
- Provided subsidies to encourage developers to include green roofs
- Half of the subsidy was paid up front. The second half being paid after vegetation is established

Green Roof Policy, Effective?

- Up to 2001, a total of 4.77 million euros was spent in subsidies, which resulted in approximately 268,000 metres squared of green roofs
- Developers initially tried to find ways around the policy, but council adhered to it and now building plans are now submitted with a green roof already included

4.7 TORONTO, CANADA

Green Roof Action Catalyst

The Greater Toronto Area suffers from a range of environmental problems that affect other urban centres, such as combined sewer overflows, air pollution, smog and the urban heat island effect. It was recognised by the city council that the majority of these problems are caused by the lack of green spaces in urban areas and the profusion of impermeable surfaces. Green roofs were identified as the solution to many of these environmental issues.

Green Roof Policy in Toronto

In 2001 an Environmental study executed in the city, recommended the need for a green roof strategy for Toronto. The study found that green roofs would be of significant benefit in relation to stormwater management and reducing the urban heat island effect and the associated energy use for cooling.

Based on this, the city went on to hold consultation talks with all the stakeholders involved, to receive their input. The stakeholders consisted of developers and planners, green roof designers and suppliers, building owners and managers, and city staff. The outcome of the consultation talks was a document called "Making Green Roofs Happen" which outlined the opinions of the stakeholders and looked at examples from international leaders in green roof development. It also proposed measures to define green roofs, identify barriers to their implementation and solutions to answer these.

The 'Making Green Roofs Happen' document went on to be presented to Toronto's Roundtable on the Environment, which is an advisory body to the City Council on sustainable issues. Following the inclusion of several points made by the Roundtable, Toronto City Council approved the recommendations set out in the document to encourage green roof installation, and this in essence has become Toronto's green roof strategy.

The salient points of the strategy are as follows:

- Implementation of green roofs on city buildings
- Development of an approval process to be used as a tool for green roof installation
- Initiate a pilot grant program
- Develop an education and awareness initiative

The Green Roof Incentive Pilot Program was rolled out in 2006. The program offered a grant of CA$50 per square meter of eligible green roof area up to a maximum of CA$100,000. The thinking behind the grant was that it would encourage the construction of a variety of green roofs, which then could be used for research and educational purposes while at the same time creating a showcase that other cities could learn from.

The grant is open to all private property owners in the Toronto area with a water account. Each applicant must fill out a grant application form and be compliant with specific criteria, such as:

- The proposed green roof must cover at least 50% of the roof
- The plant varieties placed on the roof must be a specific mixture to support biodiversity and cannot be a monoculture
- The roof must have a maximum slope of 10 degrees
- The depth of the growing medium must be at least 150mm on new buildings. A reduction in depth may be considered for retrofitted roofs
- The green roof must be installed over heated spaces. Installation over non-heated structures, such as underground car-parks are not considered eligible for the grant

In addition to the above list each applicant must present site plans and green roof specifications to the council as well as a five year management plan for the green roof.
There were sixteen successful applicants in the first year of the program, a mixture of both commercial and residential buildings. The final date for applications for the second phase of the program was December 2007.

Effectiveness

The approach taken by Toronto to implement a green roof policy was very effective. The inclusion of all stakeholders from the beginning and their input into what became the strategy document made for a smooth process. Installation of green roofs on public buildings heightened public awareness and advertised the council's commitment to the green roof strategy. Building on this, the introduction of the pilot incentive program opened up the possibility of green roof installation to all residents with property in the Toronto area. It also made it financially easier for large commercial buildings to implement a green roof.

EXAMPLE OF CANADIAN GREEN ROOF POLICY

TORONTO, CANADA

Green Roof Catalyst

- To combat the effects of the Urban Heat Island
- To improve general environmental conditions in the city area

How was Green Roof Policy Implemented?

- Initial consultation with all stakeholders involved; developers, planners, city staff, building owners and managers, green roof suppliers and consultants
- Outcome of the consultations was a green roof policy document called "Making Green Roofs Happen". Toronto City Council approves and adopts policy
- City Buildings were the first to be greened as an example of the City's commitment to implementing green roofs
- Pilot incentive scheme was introduced under strict guidelines; $50 per square metre of eligible green roof area up to a maximum of $100,000
- Development of an education and awareness program

4.8 CHICAGO, USA

Green Roof Action Catalyst

Concern in regards to the Urban Heat Island effects was the main motivator behind green roof implementation in Chicago. This concern, along with poor air quality and the effects this has on public health.

The current Mayor of Chicago, Richard Daley became a strong advocate of green roof implementation in the city after seeing some of the green roof installations in Europe. In an edition of the National Geographic magazine, November 2004 he is quoted as saying, "I thought, with all the flat roofs in Chicago, you could reclaim thousands of acres for the environment and also help buildings with heating and cooling and controlling rainwater going into the sewer system…….When you look out over the city, instead of steel and concrete, you see something for the environment"

Green Roof Policy in Chicago

Chicago uses several different methods to implement green roofs across the city:

The Energy Conservation Code of 2001 states that all new and retrofit roofs have to meet a certain minimum standard for solar reflection. The Bureau of the Environment for the city has agreed that green roofs are a very effective method of reducing reflection while also mitigating the urban heat island and improving air quality.

Since 2003 the City Department of Planning and Development have been enforcing a green roof policy on development projects that are subject to review by the department or receive public financial assistance.

With the support of the Mayor, in 2003, the Chicago Department of the Environment planned and installed a green roof on Chicago City Hall. This covers an area of 1886 square meters and is used for research and demonstrations

To build on the above initiative, the Department of Planning and Development enlisted the services of the Chicago Urban Land Institute to provide seminars and presentations to the private sector to banish any misconceptions and apprehension in regards to green roof installation. They also completed a survey among the private sector to establish what types of incentives would encourage them to install green roofs.

The City has developed a website (www.artic.edu/webspaces/greeninitiatives/greenroofs) which supports green roof implementation and offers technical and construction advice. This website provides a map of the city with information on all the buildings that have already have a green roof. There is also information on green roof providers, and a featured project section.

Chicago offered a limited number of grants in 2005 worth $5000 each to aid development of small scale residential or commercial green roofs.

The Chicago Energy Conservation Ordinance went into effect in 2002 and includes a chapter from Chicago's Urban Heat Island Reduction Initiative which states minimum ASTM standards of solar reflectance and emissive's. The ordinance requires all new and refurbished roofs to install green roofs or reflective roofing. The ordinance had originally been set for implementation for January, 2002, but the City allowed additional time for public awareness and offered workshops to developers, designers and other interested parties.

There is currently no requirement for green roofs in the private sector.

Effectiveness

A figure available in 2004 shows a total of 80 green roofs implemented in Chicago, these include both municipal and private building (despite no specific policy for private implementation). This equates to a surface area of over 1 million square feet.

Figure 4.4 Simple Intensive Green Roof on Chicago City Hall

4.9 PORTLAND, USA

Green Roof Action Catalyst

The driver for green roof development in the city of Portland, derived from the concern regarding the pollution of the Willamette River by combined sewer overflow (CSO).

Green Roof Policy in Portland

Green roofs are referred to as Ecoroofs in Portland. The city has used a number of policies to ensure Ecoroof installation however these policies only apply to buildings in the public sector. The private sectors are encouraged to install Ecoroofs by applying stormwater fee reduction and floor area ratio bonuses. The following list outlines the policies used:

The city levies a stormwater management charge on all commercial, industrial and institutional buildings. This fee is based on the amount of impervious surface on the site and is charged at US$6.45 per 1000 square feet of hard surface per month. However, for owners who install a green roof that covers at least 70% of the roof area, the stormwater fee is reduced by 35%.

All City owned buildings must have a green roof installed that covers at least 70% of the roof. The rest of the roof area must be covered with an Energy Star rated roofing material, which reflects more of the suns rays. The stormwater fees that are mentioned in the above point have funded the majority of the green roofs on public buildings. The city also employs a team of green building consultants to aid City buildings in meeting green building policy requirements.

Under the City Zoning Code, developers are offered floor area ratio (FAR) bonuses when they implement certain options, such as a green roof: the bigger the area of green roof, the bigger the floor area bonus. In order to avail of the bonus, the developer has to sign an agreement ensuring both the green roof installation and its ongoing maintenance. Although long term maintenance continues to be a concern as the City does not have sufficient resources to continue checking the roofs.

When projects fall within the Central City District, development plans are subject to a general design review and must abide by architectural design guidelines. Inclusion of green roofs at the design stage will assist the proposal in being approved as they are considered an asset by the city.

Portland has funded green roof exhibitions and test sites and they have been officially recognized as a Best Management Practice in the City's stormwater manual

Some Portland residents have established a group called "Ecoroofs Everywhere" which aims to encourage green roof implementation in lower income areas. They do this by securing grants for small-scale installations and by negotiating with green roof vendors to get lower prices

Effectiveness

Portland is now considered one of the leaders in green roofs in North America. They have implemented policy quickly and efficiently resulting in approximately 2 acres of green roof installation and a further 2 acres committed to be built. Their promotion of green roofs has been so effective that some private sector buildings and citizens have decided to install them on their own initiative.

Figure 4.5 Green Roof on City of Portland,
Bureau of General Services

Figure 4.6 Close up on Portland Council building green roof

EXAMPLES OF AMERICAN GREEN ROOF POLICY

CHICAGO, USA

Green Roof Catalyst

- Combatting the Urban Heat Island Effect

How was Green Roof Policy Implemented?

- Initial support from high profile individual: Mayor of Chicago
- Chicago City Hall installed a simple intensive green roof
- City Department of Planning and Development have been enforcing a green roof policy on development projects that are subject to review by the department
- Chicago Energy Conservation Ordinance requires all new and refurbished roofs to install green roofs or reflective roofing
- City has developed a website which supports green roof implementation and offers technical and construction advice

Green Roof Policy, Effective?

- In 2004, 80 green roofs were implented (includes private and municipal buildings)
- This equates to a surface area of over 1 million square feet.

PORTLAND, USA

Green Roof Catalyst

- Concern over pollution of the Willamette River by combined sewer overflow (CSO)

How was Green Roof Policy Implemented?

- Green roofs referred to as 'Ecoroofs'
- Private sectors are encouraged to install Ecoroofs by applying stormwater fee reduction and floor area ratio bonuses
- When projects fall within the Central City District Inclusion of green roofs at the design stage will assist the proposal in being approved
- Stormwater fee is based on the amount of impervious surface on the site; with a green-roof covering at least 70% of the roof area, the stormwater fee is reduced by 35%
- Under the City Zoning Code, developers are offered floor area ratio (FAR) bonuses when they implement certain options, such as a green roof. The bigger the area of green roof, the bigger the floor area bonus

Green Roof Policy, Effective?

- Portland is now considered one of the leaders in green roofs in North America
- 2 acres of green roof installation and a further 2 acres committed to be built

SUMMARY: LESSONS FROM OTHER CITIES

While the cities profiled in this chapter have varied in terms of their original motivation for developing green roof initiatives, and while individual climate factors and local culture have given rise to a variety of strategies, there are several lessons which could benefit Dublin:

1) Do the homework. Establish the idea of green roofs as benefitting the city as a whole. If public awareness has been developed and green roofs presented as solutions to issues which impact everyone, then a broad base of support can be built. Bring the stakeholders into the discussion early, and provide clear and meaningful ways for them to stay involved.

2) Work with the building professions. It is essential to have their support and harness their creativity. Listen to their concerns, and engage them to suggest solutions to any barriers they identify.

3) Make it affordable. Most cities have used financial incentives to encourage uptake and reduce resistance. Whether subsidies, reduction of fees, tax incentives, or other tradeoffs were used, the higher initial costs of green roofs had to be offset until markets could demonstrate added values.

4) Make it non-negotiable. Cities with successful green roof programmes have used their powers to require uptake. When there is no get-out, and the city makes it easy and affordable to comply, new technologies become mainstream more quickly.

5) Walk the talk. One of the best ways to roll out a green roofs programme is to begin with the city's own buildings.

6) Invest in the solution. There are many ways in which cities can either directly invest or help to leverage outside investment in the development of local green roofing professionals. These include funded positions for green roof officers within the council, public demonstration and education projects, training for up-skilling designers, builders and maintenance professionals, and support for green roof business start ups.

CHAPTER 5 - CURRENT DUBLIN CITY COUNCIL AND IRISH POLICIES

This chapter explores how a new integrated green roof policy would help to achieve some of the objectives in current government policies.

The main policy documents focused on are:

- National Climate Change Strategy 2007-2012
- DCC Climate Change Strategy
- DCC Strategic Drainage Study
- Water Framework Directive (2000/60/EC)
- Dublin City Biodiversity Action Plan 2008-2012
- National Biodiversity Plan

5.1 GREEN ROOFS AND CURRENT POLICY

After reviewing the main advantages of green roofs and examples of their implementation in other cities, the next step is to look at how a green roof policy here would interface with current policy documents, both at the level of Dublin City Council and nationally.

5.2 THE NATIONAL CLIMATE CHANGE STRATEGY 2007-2012

Under the Kyoto Protocol, for the period of 2007 to 2012, Ireland has to limit its average annual emissions to only 13% above the levels emitted in 1990. This equates to 8.137 million tonnes of CO2. Further to this, the EU has made a commitment post 2012, that they will continue to reduce their emissions by an additional 30% (relative to levels in 1990). This 30% reduction is provided that other developed countries commit to a comparable emission reduction. However, even if there is no international agreement, the EU still commits to reduce emissions by a further 20%, post 2012. This means that there will have to be radical changes made across the Irish economy, "particularly in relation to the way Ireland produces and uses energy, in the built environment and in transport"

From reviewing the national climate change document, the Irish government is satisfied that it can meet the emission reductions target for 2012, however, it is the further reductions required post 2012 that are a concern. Depending on whether the EU commits to its 20% or 30% reduction, Ireland will have to reduce its emissions by 9.313 million tonnes in the first instance or 16.013 tonnes in the second instance.

It has been mentioned already in the advantages section of this document, that green roofs can help reduce a building's energy consumption and thereby its carbon emissions, when used in conjunction with regular insulation material. To date, there has been no research done in Ireland to quantify these reductions within the Irish context, but data from studies in other countries are broadly indicative.

As part of the Energy Performance in Buildings Directive, from July 2008, all new public service buildings over 1000m squared, must display their Building Energy Rating. All existing large public service buildings will have to display this as of January 2009. This rating will show the actual energy use of the building by its current occupant and will be used to show improvements over time. This directive could stimulate the installation of Green Roofs on several Dublin City Council buildings and this would also permit accurate data to be collected on how green roofs impact on the buildings' energy consumption. Regular updates about plant species growth and general performance could be published on a dedicated website. This would increase the profile of green roof installations in Dublin and show that they are a viable technology.

The government strategy document also mentions that the Environmental Research Technological Development and Innovation (ERTDI) Programme, which is in turn funded by the Department of the Environment, Heritage and Local Government and operated by the Environmental Protection Agency, supports a wide range of projects to improve the level of research and development work on environmental technologies and eco-innovation in Ireland.

As an example, this programme funded a community composting project in Ballymun. This same programme could possibly be used to help fund a green roof installation test site in Dublin. This project would provide green roof data and information that is available for other European cities but not currently for Dublin.

5.3 DUBLIN CLIMATE CHANGE STRATEGY

In response to the publication of the National Climate Change Strategy, Dublin City Council published their Climate Change Strategy for Dublin. This document outlines ways in which Greenhouse Gas Emissions can be reduced in the Dublin area and since Dublin City is the largest local authority and the capital city, what happens in this area has ramifications on a national level.

The Dublin strategy looks at five focus areas:

- Energy
- Planning
- Transport
- Waste Management
- Biodiversity

A Green Roof policy would impact on three of the focus areas outlined in the strategy document; Energy, Planning, and Biodiversity. Green Roofs could also contribute to waste management as composted material can be incorporated into the substrate on intensive and semi-intensive green roofs. In such situations, composting sites can be located on roofs as part of an integrated roof garden facility, tightening an important resource and energy loop by keeping and transforming compostables on site.

Energy and planning will be discussed below, while biodiversity in relation to climate change will be covered in the Biodiversity Action Plan section. Each of these will be discussed in turn in order to outline how green roofs can help address some of the existing city objectives and concerns, but it is important to realize that the cumulative advantages presented by "stacking" of functions and benefits increase the ecological and social value of green roofs on an exponential scale.

5.3.1 ENERGY

The energy section of the strategy document is mainly concerned with efficient heating technologies. Although discussion in the DCC document is mainly focusing on efficient heating technologies, the council is committed to supporting and exploring a wide range of energy solutions. This is important as our changing climate coupled with a rapid increase in both commercial buildings and apartment complexes which rely on mechanical systems for ventilation means that cooling our communities may become an issue in the future. As mentioned earlier it has been proven that urban areas have significantly higher temperatures than the surrounding countryside. This is commonly referred to previously as the "urban heat island" effect. The reasons for increased temperatures are described in Chapter 2, Section 2.3.

Sedum album, Fenit, Co. Kerry (© Stephen Kelly)

In 2007 the Intergovernmental Panel on Climate Change issued its fourth assessment report (IPCC, 2007). This report provided future climate change projections on the basis that no efforts were made to reduce greenhouse gas emissions. It found that there would be a rise in average global temperatures of 1.8° C to 4.8° C, by the year 2100. This in turn would result in extensive melting of snow and ice, rising sea temperatures and regional precipitation increases and decreases. It went on to state that even if greenhouse gas emissions were stabilised in 2007, some warming effects would still occur due to climate processes and feedbacks and the associated timescales.

A report produced by the Community Climate Change Consortium for Ireland (Mc Grath et al, 2005) provided future climate predictions for Ireland from 2021 to 2060. The report concluded that there would be a rise in mean monthly temperatures of 1.25ºC to 1.5ºC. The largest rise will be in the East and South-East, with the greatest warming in July.

There will be significant changes in rainfall patterns especially in the months of June and December. In comparison with current levels of rainfall, it is predicted that rainfall in June will decrease by 10% and in December it will increase by 10-25%.

Finally, a report produced for the Environmental Protection Agency (EPA) by the Irish Climate Analysis and Research Unit (ICARUS) reinforces this prediction of warmer temperatures in Ireland. The report states that July temperatures will increase by 2.5ºC by 2055 and maximum July temperatures of 22ºC will be experienced by most of the country. In January the south and south-east of the country will have temperatures in the region of 7.5ºC – 8ºC. This also means that winters in Northern Ireland and the midlands will be more like that now experienced by the southern counties. (Sweeney, 2003)

So while no Irish studies have been conducted to prove that temperatures in urban centres in Ireland are higher then the surrounding countryside, there is sufficient data to show that temperatures all around the country are going to rise and that buildings will need to be able to conserve energy by reducing heating during the winter and cooling/air conditioning during the summer. In addition to insulation, green roofs can aid in this.

An interesting development along these lines is a new energy saving concept that will be integrated in the tallest building in Europe, the Okhta Tower in St Petersburg, Russia. The tower will be cased in two glass and steel sensor-lined 'envelopes' with plants and shrubs filling the buffer zones in between. The plants provide natural thermal insulation during winter and create a rich source of fresh air to ventilate and keep offices cool during the summer. This green buffer zone will use sensors to respond to the weather and will help to significantly reduce heating costs, according to the RMJM Architects, the British architect team that designed it.

Further details of how green roofs can reduce the energy needs of buildings can be found in Appendix 2

5.3.2 PLANNING

As stated in the Climate Change Strategy for Dublin, the residential and commercial areas are two of the largest producers of CO2; in fact they are responsible for 74% of the total country emissions. Because of this, new building regulations require "designers of large buildings to consider the economic, environmental and technical feasibility of installing alternative/renewable energy systems." Although there is no specific reference to green roofs in this passage, a green roof policy could be fitted into this context.

As mentioned earlier in the benefits section of this document, green roofs are best used in addition to effective insulation material. It is recommended therefore (CIRIA, 2007) that green roofs are not used as the only form of insulation on a building but rather in addition and a compliment to it. The ideal time to install a green roof is in conjunction with installing new insulation. This is particularly relevant when considering some of the refurbishment work on some of the 26,000 social houses in the Dublin area, the majority of which were built pre-1990, when there were very few if any energy regulations. An example already exists in York Street, Dublin where the refurbishment project for the area, executed by Harrington Architects included installation of solar panels, composting facilities and green roofs. A Green Roof policy would enable projects like this to become the norm in all regeneration projects around the city.

In conclusion, a Green Roof policy for the city could help achieve several of the actions proposed in the planning section of the Climate Change Strategy for Dublin city. The actions are listed below:

- Target and promote a carbon neutral Sustainable Communities demonstration project in each of the five framework development areas
- Carry out a pilot demonstration project for Passive House Standard Housing in one of the new Social Housing schemes
- Introduce requirements demanding highest energy saving standards in planning permissions for alterations of existing buildings
- Seek to establish financial support for delivering local advice, guidelines and information to building owners in order to encourage refurbishment of older buildings

5.4 DUBLIN STRATEGIC DRAINAGE STUDY (GREATER DUBLIN STRATEGIC DRAINAGE STUDY: REGIONAL DRAINAGE POLICIES VOL. 3 MARCH 2005)

The Greater Dublin Strategic Drainage Study is a policy document developed in 2005 by Dublin City Council. Its objective is to prepare plans and strategies to manage storm-water runoff in urban areas in addition to assessing the current runoff management practices.

This study states that at present, urban areas consume large volumes of drinkable water while discharging ever-increasing quantities of foul sewage and storm-water. In consequence, "traditional supply and disposal of water involves costly, energy-intensive treatment and reticulation systems, with their associated environmental impacts"

An alternative management system is therefore recommended. The name of this alternate system is SuDs; Sustainable Urban Drainage Systems. SuDs has been mentioned already in this document as green roofs comprise a major element in these systems. In the drainage study, SuDs is used to refer to Sustainable Drainage Systems. The 'Urban' was omitted as the system was deemed not to be limited to urban areas.

SuDs is a completely different way of handling storm-water runoff. In the past, the main emphasis was on handling the volumes of water and clearing it from the surface but his systems is an integrated approach that "addresses water quality, water quantity, amenity and habitat". According to the drainage study, it is of the utmost importance to consider all of these aspects when implementing SuDs. Green roof installations are integral to a SuDs system. Appendix 4 provides statistics to support this claim, while the chapter on city examples, shows that in many cases, storm-water runoff management was the driving force behind green roof policy. However, in the strategic drainage study, green roofs are only given a passing mention as an alternate method of assisting runoff control.

A Green Roof policy could become central to the implementation of SuDs, as Green Roofs reduce the quantity of run-off, improve water quality and provide valuable new habitat in a urban areas. It is also important to note that the drainage study recommends that a "SuDs system be mandatory in all new developments unless the developer can demonstrate to the Local Authority that its inclusion is impractical due to site circumstances or that its effect on the control of run-off would be minimal, such as for rural sites". Again Green Roof policy would aid in reinforcing this recommendation.

Sedum album, Fenit, Co. Kerry (© Stephen Kelly)

5.5 WATER FRAMEWORK DIRECTIVE (2000/60/EC)

The Water Framework Directive (WFD) evaluates all the objectives used to protect aquatic environments and it aims to ensure that the relevant steps are taken to achieve the objectives. In essence the framework promotes a sustainable approach to water management. One main requirement is to manage surface runoff such that its impact on the surrounding environment is mitigated. This may mean that SuDs techniques will have to be used as the method of reducing the rate and volume of runoff and to remove pollution. As mentioned already a Green Roof policy would help meet these requirements.

Under this same directive, Ireland has to achieve a 'good water status' in surface and groundwater by 2015 and according to the Environmental Protection Agency (EPA), this will be a challenging target to meet.

In regards to water management, if Dublin City Council implemented a Green Roof policy, it would create another template by which they could achieve some of the objectives outlined both in the Dublin Strategic Drainage Study and the Water Framework Directive. It is especially significant since DCC is the lead agency coordinating the WFD in the Eastern part of the country.

5.6 DCC BIODIVERSITY ACTION PLAN AND NATIONAL BIODIVERSITY PLAN

There are three main advantages that green roofs provide in relation to biodiversity; these have already been discussed in Chapter 2. However, it is necessary to review these advantages again with a view of linking them to current Irish initiatives on the subject, primarily the Biodiversity Action Plan from DCC and the National Biodiversity Plan. These plans are intended to outline the importance of wildlife conservation, the actions that need to be taken and the resources that will be required.

Biodiversity advantages of green roofs as follows:

- Helping to remedy areas of deficiency by providing new habitat in areas which are
- currently lacking in wildlife habitat
- Creating new links in an intermittent network of habitats thereby facilitating movement and dispersal of wildlife
- Providing additional habitat for rare, protected or otherwise important species

Two of the major threats to biodiversity outlined in the Dublin City Biodiversity Action Plan are loss of extent and habitat fragmentation. Loss of extent refers to the removal of an area of habitat. In urban areas replacement sites are not easily found. However, implementing a green roof policy would help in creating additional habitats in an urban centre.

The second threat, habitat fragmentation, refers to breaking up large areas of habitat into smaller areas thereby making it more difficult and dangerous for fauna to travel between them for food and shelter. Green roofs would provide both a valuable transport network and help link green corridors through the city. This is especially important when taken into the context of biodiversity and climate change. As described by the Climate Change Strategy for Dublin, the impact of climate change on biodiversity will depend on 'a species or habitats capacity to change'. The most vulnerable are those who have a restricted range and have no means of moving from one area to another. In response to these threats, Dublin City has agreed to "identify opportunities for new habitats, buffer zones and wildlife corridors". Green Roofs provide one potential solution to aid Dublin City in meeting this objective.

It is important to note that one of the actions of the National Biodiversity Plan is to "encourage and promote beneficial effects on biodiversity". This would be the outcome if a green roof policy were introduced in the Dublin City area. It would serve as an example for other councils around the country as an effective way of enhancing biodiversity as well as the other benefits previously mentioned.

GREEN ROOF EXAMPLE IN DUBLIN

As part of the regeneration project currently running in Ballymun, a simple intensive green roof has been incorporated into one of the new community buildings. The Ballymun Regional Youth Resource (BRYR) is housed in this new building which is known locally as "The Reco". This green roof, a first for Ballymun, was implemented in the design stage, and so the relevant structural requirements were developed around it. The green roof is accessed by a flight of external stairs which run along the side wall of the central courtyard. The roof is split into a decked area and a large area of soil substrate, the depth of which allows for the growing of small shrubs and perennials.

Also housed in this community building is a restaurant selling fresh, healthy and nutritious food to the visitors to the centre. It is planned get the some youth groups to grow a variety of vegetables on the semi-intensive green roof to sell in the restaurant. Therefore this green roof is providing an educational function in that local teenagers will learn how to grow their own food. It is also providing a space where local grown vegetables can be produced. This is in addition to the environmental and economic benefits listed earlier in this document.

As well as having implemenented this green roof, Ballymun Regeneration Ltd then went on to commission a Green Roof Feasibilty Study. This study looked into the possibility of greening some of the existing new buildings in Ballymun, and also looked ahead to further greening possibilities in the area. The recommendations made by this document are currently being investigated.

This is an example however of the steps that are being taken already in the Dublin area to implement roof greening strategies. Ballymun Regeneration are setting the standard in taking steps to implement further roof greening and vertical gardens in an urbanised area.

CHAPTER 5 SUMMARY POINTS

A Green Roof Policy for Dublin would connect with and help to achieve objectives in the following current policy documents:

- National Climate Change Strategy 2007-2012
- DCC Climate Change Strategy
- DCC Strategic Drainage Study
- Water Framework Directive (2000/60/EC)
- Dublin City Biodiversity Action Plan 2008-2012
- National Biodiversity Plan

National Climate Change Strategy 2007-2012

Green roofs can aid Ireland in reaching its carbon emmission reduction targets.

DCC Climate Change Strategy

Energy

There is sufficient data to show that temperatures all around the country are going to rise and that buildings will need to be able to conserve energy by reducing heating during the winter and cooling/air conditioning during the summer. In addition to insulation, green roofs can aid in this.

Planning

Green Roof policy for the city could help achieve four main actions proposed in the planning section

- Target and promote a carbon neutral Sustainable Communities demonstration project in each of the five Framework Developmetareas
- Carry out a pilot demonstration project for Passive House Standard Housing in one of the new Social Housing schemes
- Introduce requirements demanding highest energy saving standards in planning permissions for alterations of existing buildings
- Seek to establish financial support for delivering local advice, guidelines and information to building owners in order to encourage refurbishment of older buildings

Water Framework Directive (2000/60/EC)

One main requirement is to manage surface runoff such that its impact on the surrounding environment is mitigated. This may mean that SuDs techniques will have to be used as the method of reducing the rate and volume of runoff and to remove pollution. A Green Roof policy would help meet these requirements. It is especially significant since DCC is the lead agency co-ordinating the WFD in the Eastern part of the country

Dublin City Biodiversity Action Plan 2008-2012

Two of the primary threats to biodiversity outlined in the Dublin City Biodiversity Action

Plan are loss of extent and habitat fragmentation. 'Loss of extent 'refers to the removal of an area of habitat. In urban areas replacement sites are not easily found. However, implementing a green roof policy would help in creating additional habitats in an urban centre.
The second threat, habitat fragmentation, refers to breaking up large areas of habitat into smaller areas thereby making it more difficult and dangerous for animals and insects to travel between them for food and shelter. Green roofs would provide both a valuable transport network and help link green corridors through the city.

CHAPTER 6 - CONCLUSION

Based on the research done to complete this document, the concluding chapter will provide several recommendations of how Dublin may proceed in implementing a green roof policy

6.1 RECOMMENDATION: COUNCIL BUILDINGS

Dublin City could review some of its existing and new council buildings with a view to installing green roofs, and where appropriate other measures such as living walls on them. This would demonstrate the city's commitment to enabling a green roof policy while at the same time providing green roof sites from which to collect valuable data. The majority of the statistics presented in this document are from American and European green roof sites. It would be invaluable to have similar data for the Irish context. This data could then be used to reinforce the benefits of green roof implementation to developers.

This step would also fit in with the Energy Performance in Buildings Directive. As from July 2008, all new public service buildings over 1000m squared, must display their Building Energy Rating. All existing large public service buildings will have to display this as of January 2009. This rating will show the actual energy use of the building by its current occupant and will be used to show improvements over time. This directive could facilitate the installation of Green Roofs on several Dublin City Council buildings and this would also permit accurate records to be kept of how the green roof impacted on the buildings energy consumption.

In addition, the potential for green roof implementation should be kept in mind and mentioned during the public consultation of the Docklands Development Plan.

Central Bank, Dublin (© Erik van Lennep)

Could this ...

become this?

La Planeta, Barcelona (© Erik van Lennep)

6.2 RECOMMENDATION: PUBLIC AWARENESS AND EDUCATION

Other cities have found that raising public awareness of green roofs have helped greatly in implementing a green roof policy. An example of this is Sheffield in the UK. They are currently trying to implement a green roof policy and one of their strategies was to install extensive Sedum green roofs on some of the bus shelters around the city. This received a lot of positive response from the public and started dialogue about the benefits and uses of green roofs. This type of publicity is then supported by educational seminars for developers, planners, architects and other stakeholders, to answer any of their concerns and to get their feed back. Information booklets can also be published and circulated.

6.3 RECOMMENDATION: POLICY

Although this is the third recommendation, implementing a green roof policy is the most important step. In all other city examples, this was always the most vital aspect to ensure that green roofs are included on new and existing buildings, both private and commercial. Once enacted in policy, it is very difficult for developers to avoid it in the long term. Linking the policy to a financial gain in the form of reduced stormwater fees can make acceptance somewhat easier. Although Dublin City Council currently do not enforce any such fees it may become necessary in the future.

It is important to emphasise that to aid acceptance, green roof policy should be enacted AFTER the city council has shown its own commitment and has raised awareness and received feedback from the various stakeholders.

6.4 RECOMMENDATION: GREEN ROOF OFFICER

It can be of benefit to employ a green roof officer to ensure that any policy introduced is adhered to. This person would continue to promote green roof inclusion and act as liaison between the varying departments within the city council that are using green roofs to meet their own policy objectives. Again taking Sheffield as an example, the green roof officer appointed there conducts green roof education courses for professionals. They also offer green roof tours around the city and provide guidance for other councils wishing to follow their example.

6.5 RECOMMENDATION: INTERDEPARTMENTAL TASK FORCE

Due to the way in which several disciplines must be called upon in the development of green roofs (planning, architecture and landscape architecture, engineering, biology and horticulture), and the range of positive impacts already discussed, it makes sense to establish an interdepartmental task force on green roofing within the city council.

6.6 RECOMMENDATION: IRISH GREEN ROOF INITIATIVE

The city could play a key role in catalyzing a broad stakeholder, national group to study, develop, and promote green roofing across the island. By organizing one or more information events, perhaps in conjunction with national departments of environment, energy and agriculture, Dublin could help to kick start development and information exchange on this timely and badly needed technology. The city could also look to creative ways to stimulate and support local start-ups providing expertise, materials and services for green roofing.

6.7 RECOMMENDATION: GREEN ROOF RESEARCH, INTERPRETATION , DEMONSTRATION, AND RESOURCE CENTRE FOR DUBLIN

As in Sheffield, Vancouver, Malmo and several other cities, a dedicated demonstration, research and resource centre for green roofing would facilitate faster and more coordinated development of indigenous green roofing solutions. The proposed Dublin City Biodiversity Interpretive Centre could provide this facility, as could the National Botanic Gardens. Such a facility would ideally be located within the urban fabric to emphasise the suitability of green roofs as urban strategies.

6.8 RECOMMENDATION: "LIVING ARCHITECTURE" COMMUNITIES

The city has an unparalleled opportunity to test and refine the layering of a suite of sustainable technologies and "living architectural" strategies within the framework redevelopment areas.

By partnering with research and private sector bodies as well as with state government, resources could be focused within two or three test bed neighbourhoods to demonstrate the cumulative benefits of community greening initiatives, and to study ways in which these technologies can best be integrated with one another.

Green roofs, rain gardens, biodiversity corridors, green schoolyards, living walls, allotment sites, street tree varieties and planting schemes, microgeneration, community composting and more could be effectively integrated within such areas in a way which maximised local stakeholder involvement. The results of these studies could then be used as a basis for further planning within Dublin city, but would be equally of use to other cities.

6.9 RECOMMENDATION: USE THE EUROPEAN SYSTEM TO FAST TRACK TRAINING AND EXCHANGE OF KNOWLEDGE.

Dublin is officially twinned with Barcelona, Liverpool and San Jose. Developing additional relationships with cities which are already Green Roof leaders should be considered. There is a wealth of knowledge already accumulated by decades of experience as briefly outlined in this study document. Creating twinning relationships and other sorts of exchange is stimulating for both partner communities, and can be used to bring in additional resources (financial as well as expertise) which Dublin might otherwise have difficulty allocating at this time.

APPENDICES

Appendix 1

Technical Description of Green Roofs

A 1.1

Type of Green Roof	Distinguishing Factors
Intensive	**Depth of Substrate:** 150-500mm **Vegetation Type:** All categories, trees, shrubs, perennials **Public Access**: Usually incorporated into the design **Weight:** Considerable weight involved, in most cases roof has to be specially designed to support it **Maintenance:** High, would need regular watering, feeding and general upkeep **Relative Cost:** High
Semi-Intensive	**Depth of Substrate:** 150-500mm **Vegetation Type:** Limited to shrubs, perennials and grasses **Public Access:** Not essential **Weight:** Moderate, but still requires some additional structural support **Maintenance:** Some maintenance always necessary, decreases overtime **Relative Cost:** Moderate
Extensive	**Depth of Substrate:** 20-200mm **Vegetation Type:** Restricted to mosses, sedums and grasses **Public Access:** Not needed **Weight:** Very light can be implemented on most roofs without additional structural support. **Maintenance:** Some required when plants are establishing but depending on species can be self propagating **Relative Cost:** Low

Appendix 2

Thermal Efficiency of Green Roofs : A Summary of Research

A 2.1
A study undertaken by Nottingham Trent University showed that the membrane underneath a green roof does not show as much temperature fluctuation as underneath the membrane of a conventional roof, as shown in the table below (Santamouris, 2001):

	Winter	Summer
Mean Temperature	0 degrees Celsius	18.4 degrees Celsius
Temp. under membrane of a conventional roof	0.2 degrees Celsius	32 degrees Celsius
Temp. under membrane of a green roof	4.7 degrees Celsius	17.1 degrees Celsius

A 2.2
Yet another study carried out in Toronto, published on their official website, found that the citywide energy savings resulting from a reduction in the need to cool buildings, as a consequence of roof greening, would be approximately CA$22 million. This equates to 4.15Wh/metre squared per year. The same study also concluded that there would be a reduction in peak demand of approximately 114.6MW, leading to fossil fuel reductions of 56,300 metric tones per year

A 2.3
A further study in Toronto estimated that the city comprised 50 million m2 of potential roof space that could be greened. Overall it was estimated that the effect of greening the rooftops would lead to 0.5-2°C decrease in the Urban Heat Island effect. The study estimated that a reduction of this magnitude would lead to indirect energy savings citywide from reduced energy for cooling of CA$12 million (€7.4m), equivalent to 2.37 kWh/m2 per year

A 2.4
A study by Environment Canada, found that a one storey building with a grass roof with a growing medium of 10cm, reduced summer air conditioning needs by 25%. Another study by the same group also found that a 20cm extensive roof, decreased heat gains by 95% and heat losses by 26%, compared to a control roof with no greening installed.

A 2.5
Research carried out by the green roof specialists ZinCo estimated that 2 litres of oil per year are saved per metre square of green roof. They also analysed domestic buildings with flat roofs and suggest that there could be a 3-10% winter saving on fuel bills

Appendix 3

Plant Varieties used on Green Roofs

A 3.1
The table below shows the weights of different plant varieties used on green roofs:

Vegetation	Depth of Substrate (mm)	Vegetation Weight (kg/m sq)
Extensive green roof with grass, moss and sedum	50-100	10
Extensive green roof with plants and small shrubs below 0.5m	100-150	15
Intensive green roof with plants and small shrubs below 1m	150-200	20
Intensive green roof with larger plants and small shrubs below 3m	200-400	30
Intensive green roof of large plants and small trees below 6m	400-1000	60
Intensive green roof of large plant and trees below 10m	1000+	150

(Date for the table above from FLL, 2002)

Appenidix 4

Advantages of Green Roofs in Stormwater Management

A 4.1
A study by VanWoert et al (Van Woert et al. 2005) which looked at the effects of stormwater retention on various different types of roof and their slope, showed that overall, roofs with a 2% slope and a 4cm depth of media absorbed the maximum amount of runoff which was 87%.

The table below shows the percentage of total rainfall retention over a 14 month period (August 2002-Oct 2003), from four different roof platform treatments

For the purpose of this study, a light rain event was less then 2mm of rainfall, medium was 2-6mm of rainfall and heavy was greater then 6mm of rainfall:

Treatment	Light Rain (%)	Medium Rain (%)	Heavy Rain (%)	Overall (%)
2% Slope, 2.5cm media depth	95.1	82.9	64.7	69.8
2% slope, 4cm media depth	97.1	85.5	65.1	70.1
6.5% slope, 4cm media depth	94.9	83.1	59.5	65.9
6.5% slope, 6cm media depth	95.8	84.6	62.0	68.1

A 4.2

Below is a table produced by the FLL which shows the reference runoff co-efficients (C) of green roofs according to their thickness. This co-efficient is the amount of runoff produced in relation to the amount of precipitation received

Greenroof Thickness	Roof slope of up to 15 degrees	Roof slope over 15 degrees
> 50 cm depth	C = 0.1	
> 25-50 cm depth	C = 0.2	
> 15-25 cm depth	C = 0.3	
> 10-15 cm depth	C = 0.4	C = 0.5
> 6-10 cm depth	C = 0.5	C = 0.6
> 4-6 cm depth	C = 0.6	C = 0.7
> 2-4 cm depth	C = 0.7	C = 0.8

The coefficients shown are based on a rainfall event of 300l/(s/ha) on roofs that had previously been saturated and left to drain over 24 hours.

A 4.3

Another table produced by the FLL shows the annual average water retention capacity and the annual runoff coefficient/permeability factor according to green roof thickness.

Type of Green Roof	Thickness in cm	Vegetation Type	Average Annual Water Retention in %	Annual Run-off Coeffi-cient/Perme-ability Factor
Extensive Greening	2-4	Moss, Sedum (Iceplant)	40	0.60
	>4-6	Sedum,moss	45	0.55
	>6-10	Sedum,moss,perennial	50	0.50
	>10-15	Sedum,perennial,grass	55	0.45
	>15- 20	Grass, perennial	60	0.40
Intensive Green-ing	15-25	Lawn,shrub, perennial	60	0.40
	> 25-50	Lawn,shrub, perennial	70	0.30
	>50	Lawn, shrub, perennial, tree	>90	0.10

These values are based on a location with 650-800 mm of annual precipitation and multi-year records. In regions with less precipitation, the retention capacity is higher and in regions with higher precipitation, it is lower.

Statistics from Met Éireann-The Irish Meteorological Service, estimate that the annual rainfall in the eastern half of the country averages between 750-1000 mm per year. Rainfall in the west averages between 1000-1250 mm per year.

Therefore, the retention capacity of green roofs in Ireland would be lower then the figures shown in the table above.

Although the Irish Climate Analysis and Research Unit (ICARUS), based at NUI Maynooth has predicted that there will be an increase in precipitation in winter by 11% and most of this will be in the northwest of the country. This will lead to increased flooding. Thus we need to start planning for methods of capturing increased rainfall.

A 4.4
Another study undertaken by Mentens et al (2003) looked at 628 records from 18 papers, mainly taken from Germany. They derived a runoff equation from their research:

Annual runoff in mm = 693 – (1.15 x annual rainfall) + (0.001 x annual rainfall2) – 8 x substrate thickness

Annual rainfall inserted in the formula must be mm/year and substrate thickness is in cm. The formula is valid where annual rainfall is between 554mm and 1347mm and substrate depth is between 30mm and 380mm.

Using this equation for (presumably flat) roofs in Brussels showed percentage annual runoff as follows:

- Standard Roof 81%
- Standard Roof with 50mm gravel 77%
- Green Roof of 50mm depth 50%
- Green Roof of 100mm depth 45%
- Green Roof 0f 150mm depth 40%

A 4.5
A study carried out in Sheffield, England by Dunnett et al in 2005 used test cells measuring 0.6mm by 0.6mm, which were planted with different types of vegetation in a natural soil substrate, and the runoff was monitored over three years from 1997 to 2000. The results of this study showed a reduction in the total annual volume of runoff of 40-45%, depending on vegetation type.

A 4.6
A study by Koehler in Germany found that seasonality can also impact the amount of runoff retained by a green roof. Due to the greater amount of water that can be returned to the atmosphere during the summer months, water retention can be between 70 and 90% on an extensive roof with a depth of 100mm. In winter however, the retention levels on the same roof can drop to 70%.

Appendix 5

Green Roofs and Biodiversity

A 5.1
Swiss studies by Brenneison, 2004 and English Nature have outlined several key features which should be included when trying to attract a rich selection of invertebrates to green roofs. They are as follows:

- Use a variety of substrate types

- Use a variety of substrate depths and allow for bare areas of soil and gravels
- Use a variety of plant structures from low to dense vegetation
- Use local wildflowers seeds

A more naturalistic green roof system will ensure the maximum amount of invertebrate biodiversity

A 5.2
Enhancement of biodiversity through green roof installation is very much linked to plant species or vegetation type used. The green roof on an office building housing the corporate headquarters for The Gap, in California, used native grasses found in the prairie areas of the region. This linked the building with its surrounding landscape and extended the distribution of natural plant communities into an urban setting (Burke, 2003).

A 5.3
One of the most detailed studies into the biodiversity value of green roofs has been carried out in Basel, Switzerland (Brenneison, 2003). A total of seventeen green roofs were monitored, including turf roofs, Sedum roofs, and specially designed roofs with landscaped surfaces created using local waste material substrates and rubble which were either left to colonize naturally or capped with thin layers of native topsoil. Two groups of invertebrates that are good indicators of vegetation structure were monitored; ground beetles and spiders. In the first three-year period of the experiment, 78 spider and 254 beetle species were found. In addition to this, 18% of the spider species and 11% of the ground beetle species were classified as Endangered. A comparison between the fauna found on these roofs with similar brownfield habitats on the ground, found very little difference in the numbers of spiders and ground beetles.

A 5.4
This same study mentioned above also investigated bird activity on the roofs. The primary reason for birds visiting the roof was to search for food. Birds commonly using the Green roof included Black redstart (Phoenicurus ochruros), Wagtail (Motacilla species) and House sparrows (Passer domesticus). Black redstarts are classified as Rare in the UK with only 66 pairs in the country. In Deptford Creek in London, 1000m2 of Green roofing was put in place which is now home to a number of pairs of these rare birds. These species would naturally occur in open landscapes such as high mountain areas and on riverbanks. Green roofs in the suburbs, located closer to rural areas, were less frequently visited. Apparently, the lack of green spaces and food in densely built urban areas resulted in more use of the new habitats on the roof.

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PROFESSIONS INVOLVED

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- Engineering
- Planning
- Ecology
- Landscape Design
- Sustainable Design
- Communications