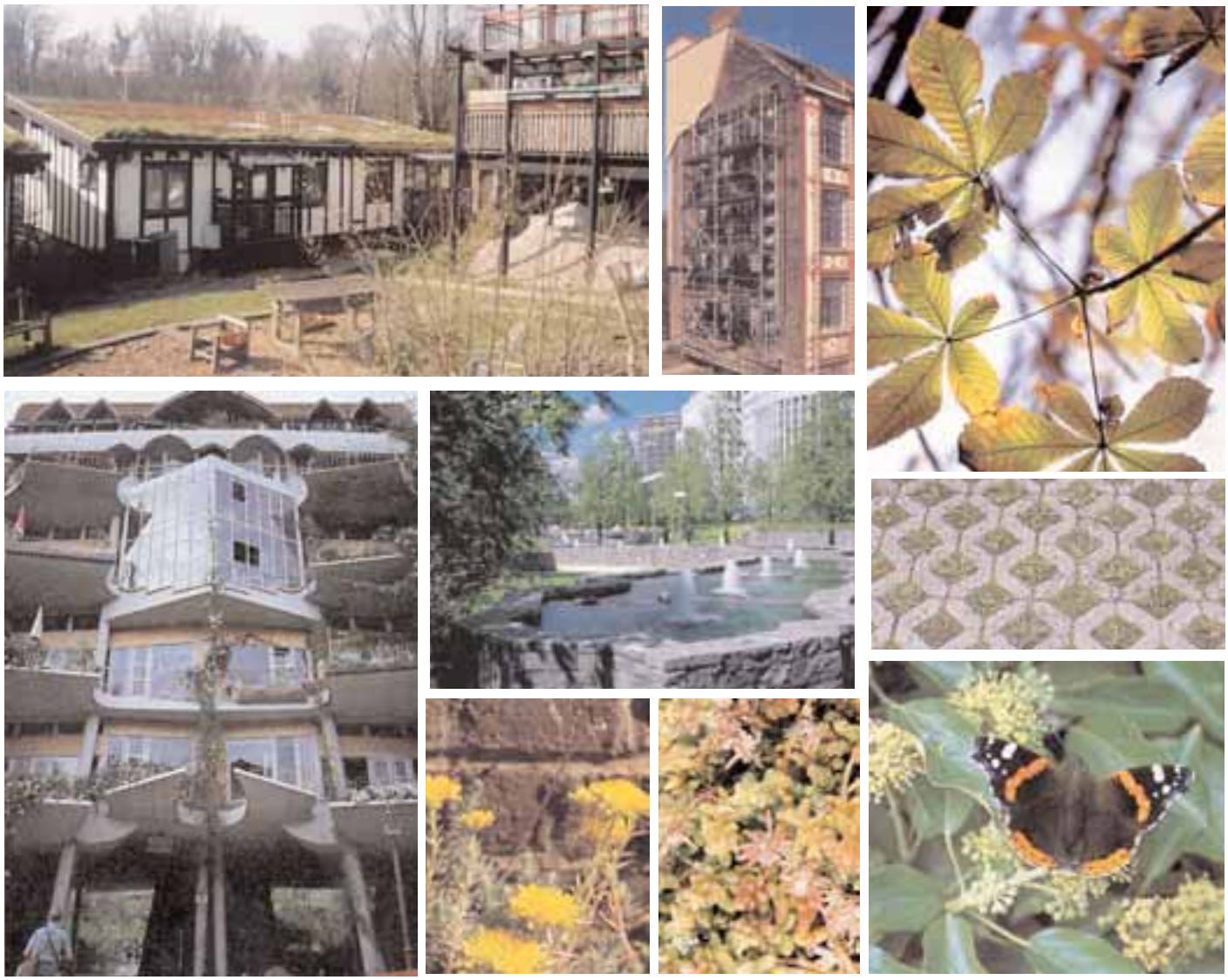
MAYOR OF LONDON

Building Green

A guide to using plants on roofs, walls and pavements



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John Newton has worked on environmental issues for over 20 years. He has managed nature reserves in both Norfolk and Suffolk, been Deputy Director of London Wildlife Trust, and Environmental Manager for the property company Rosehaugh. He now runs his own consultancy specialising in ecological and environmental research and assessment.

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Southwark Crown Court

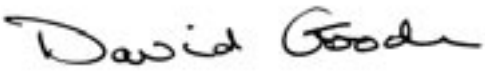
preface

This book is a significant new departure for the London Ecology Unit. For some years the Unit has been providing an advisory service on ecology and nature conservation in the urban environment. Much of our work has been concerned with protecting important natural habitats, which are increasingly under pressure for development. Local groups regularly campaign to save particular wild areas simply because they are the only places in the neighbourhood where anything resembling the natural world can still be seen, especially in the densely built-up areas of inner cities. We frequently argue for the protection of such places, many of which have developed entirely by chance, not by design.

I am constantly made aware that if we were to design cities to include nature the picture could be very different. The Ecology Unit has already been successful in creating new habitats, where people can experience wildlife in their local neighbourhood, and this has led us to appreciate the considerable opportunities for creation of new habitats presented by the built environment itself. It is for this reason, therefore, that the Ecology Unit has produced Building Green in an attempt to encourage more widespread use of plant life within the built environment, whether in new developments, or within the existing fabric of the city.

In embarking on this project we were fortunate to establish a partnership with John Newton whilst he worked with Rosehaugh plc, and he was able to bring his considerable experience from the viewpoint of major new developments. We have also capitalised on our links with the European Academy for the Urban Environment in Berlin, a city where the concept of green roofs is now well established, as well as drawing directly on experience from Toronto and several Dutch cities.

I hope that this book will provide a useful starting point and a source of ideas on the greening of the urban environment, not only in our capital city but in towns and cities everywhere.



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The Toronto skyline from a roof-top garden

introduction

What sort of image does the word 'city' conjure up for you? To most people it suggests a hard, abrasive environment. Isolated patches of green space offer welcome relief, but these usually turn out to be sporadic refuges. Cities need not be like that...

Creating more enjoyable cities by greening them is a realistic objective. It is the concern of many politicians, planners, and environmentalists: greener cities would bring immeasurable benefits to the people who live and work in them all over the world.

But however desirable, greening the city is a complex undertaking. It touches upon transport systems, water management, air pollution, energy conservation, the recycling of waste, nature conservation and many other interconnected issues. These issues have been the subject of numerous reports, papers and books, notably the European Commission's "Green Paper on the Urban Environment" and Friends of the Earth's "Reviving the City". They are crucial matters, requiring urgent action, but they are not the subject of this book.

Building Green concentrates on one key aspect of the greening process: the use of plants on and around urban buildings. It goes without saying that this can only be part of any overall greening strategy. However, green buildings and greenspaces together define an integrated approach to plant life in cities that is central to any green programme. At the end of the first pat of this book we examine how green buildings fit into a broader based green approach to urban development and redevelopment.

Now is a particularly appropriate time to be addressing the subject of plants on buildings. Interest in the environment has never been greater. The provision of urban green space is receiving much attention both in Europe and North America. Many local authorities in Britain currently have plans for incorporating nature areas into the urban environment.

However, relatively little attention has been paid to the valuable opportunities represented by buildings and the spaces which relate to them – courtyards, terraces, balconies and so on. This is a great pity, because even in those cities relatively well endowed with green space, many areas can justifiably be regarded as deserts in biological terms. Sealed surfaces of brick, concrete and tarmac are inhospitable to all but the most opportunistic plants. Each new road, car park, office development or housing estate results in a further loss of vegetation. 'Progress equals development' is an axiom which shows no sign of being abandoned, and so we cannot pretend that the impetus of urban development is likely to slow down in the foreseeable future. Therefore

'We can make choices about the surroundings in which we live and work. Prosperity and beauty need not exclude one another.'

H.R.H. THE PRINCE OF WALES

Most cities – like Berlin – are largely grey with isolated pockets of greenery

we need appropriate development which incorporates an ecological approach to building and landscape design. This means replacing land lost beneath buildings and roads with a layer of plants on hard surfaces. By strategically adding 'green skins' in this way, it is possible to create a new network of vegetation linking roofs, walls, courtyards, streets and open spaces. This is particularly important in the city centres where vegetation may cover only about one third of the land surface, compared with 75%-95% in the outer suburbs.

It has to be stressed that growing vegetation on hard surfaces should never be viewed as an acceptable alternative to losing valuable areas of green space. Such areas are a precious commodity to be preserved at all costs. Rather, green building should be seen as something which complements a network of greenspaces, a flexible and enjoyable option which is as appropriate to existing structures as it is to new developments and rehabilitation schemes.

This book is intended to be both inspirational and practical. It is aimed primarily at developers, architects, planners, landscapers, designers and ecologists. We believe it will also be of considerable value to everyone with a serious interest in greening their own premises, whether houses, flats, shops or offices.

We outline the many human, social and natural benefits that come from using plants on buildings. There is specific, practical advice on introducing vegetation to walls, terraces, courtyards and roofs. Detailed specifications for the use of plants on buildings do not generally appear in the text, but comprehensive sources are listed in the technical information at the end of the book.

Our intention throughout has been to identify ways and means of breathing life back into our cities by re-introducing vegetation. Neither a fashionable gesture nor a cosmetic exercise, the greening of urban buildings is simply a highly rational thing to do. **Building Green** is an idea whose time has come. The task now is to make it happen.

1 the natural landscape of the city

Cities can be viewed from an entirely new, ecological perspective. Buildings offer surfaces akin to natural landforms and these can be planted following clues from nature. The skin of the city can be transformed into a living landscape.

Green Spaces alone can never be a panacea for urban society's ills, but they are clearly a very precious resource. Most city dwellers offered a choice of views would choose green areas rather than concrete piazzas and brick walls.

Green vistas are further enhanced by the natural sounds associated with them – birdsong and wind in the trees – and the result is a sense of being re-connected with the natural world.

Unfortunately, only a small number of city users have such a choice. Many cities possess too few greenspaces – and those are usually arbitrarily located. Green areas – parks, gardens and nature reserves – become relegated to isolated pockets, sometimes linked by linear walkways or derelict railway routes, but more often than not marooned in expanses of brick, concrete and tarmac.

It is clear that the fundamental structure of cities will remain unchanged for many years to come. So in the meantime, what opportunities are there for enhancing the amount of greenery in the city?

The most rewarding option is to create a network of green buildings, so introducing vegetation and its many related benefits into the actual fabric of the city. This option demands a coherent, well-researched strategy if it is to deliver the fullest benefits. In this respect, the German landscape planner Hermann Barges has suggested a valuable metaphor. He commends us to look at the city from a new perspective [1]: urban areas are likened to concrete mountains with streets like valleys; roofs of buildings correspond to alpine meadows and pastures and the walls to slopes and terraces; open spaces are like steppes and deserts; and shady courtyards resemble ravines.

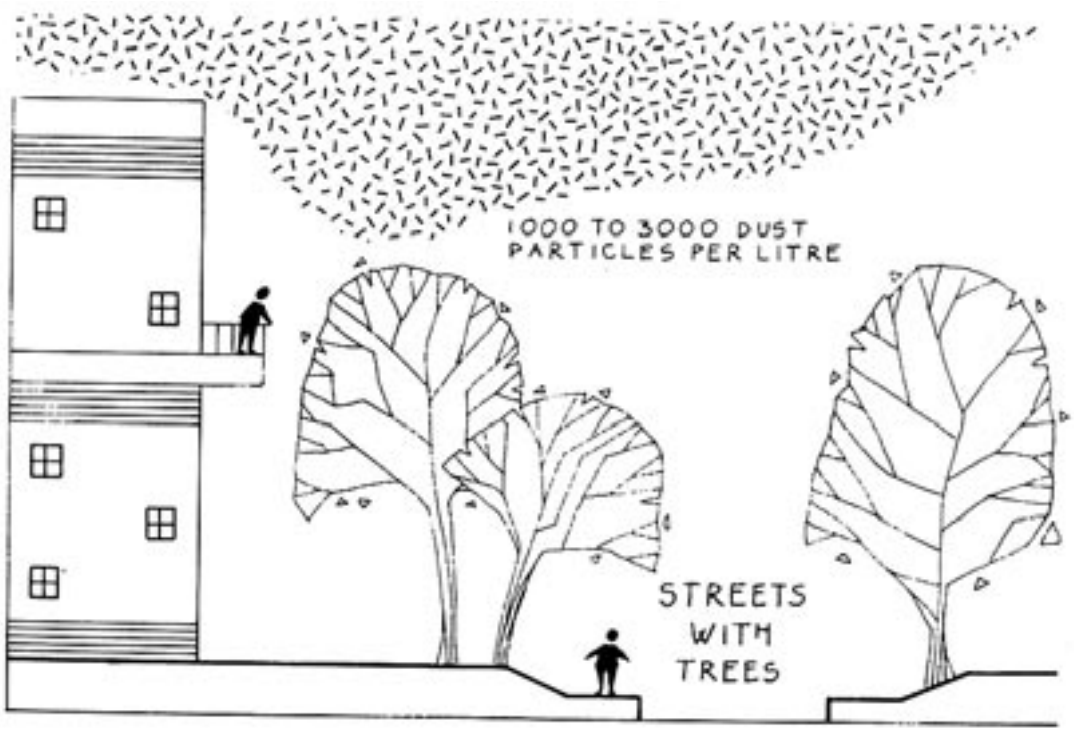
Looking at the city in this way has a practical purpose in suggesting types of plants which are most suited to each aspect of the built environment. The aim is not to create a replica of nature in the city, but to gain clues as to how best to deploy vegetation on and around urban buildings.

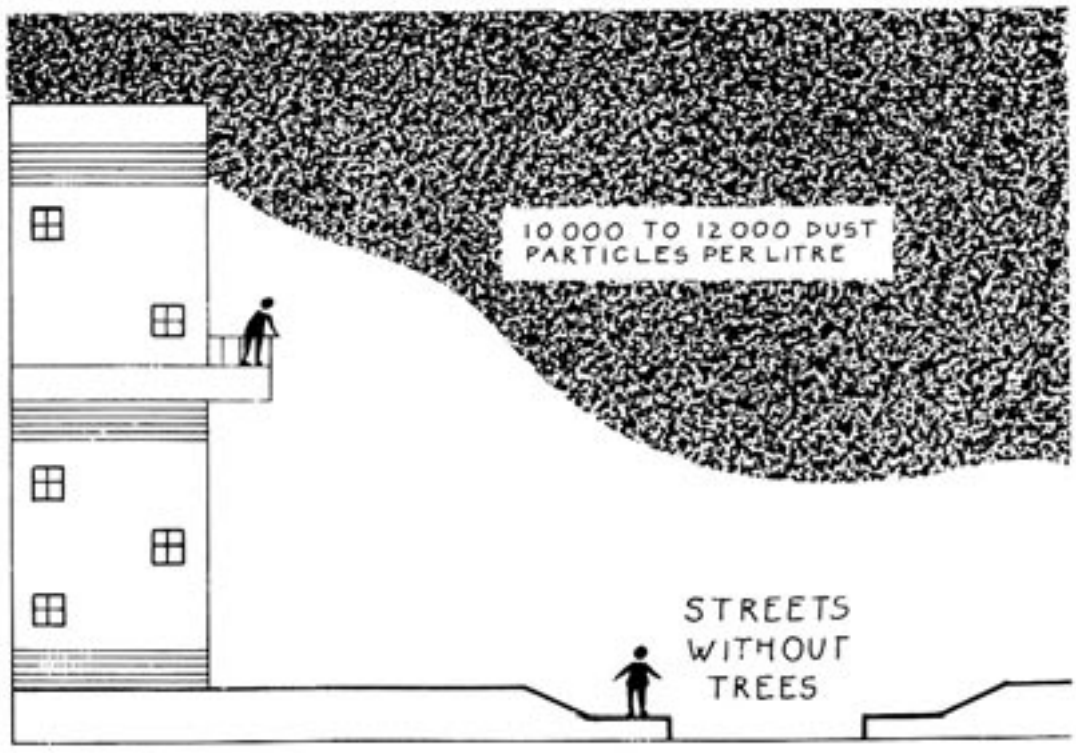
The skin of the city – its roofs, walls, streets and other hard spaces – can be transformed into a living landscape. Ecologically dead areas come alive again, becoming environmental assets in themselves as well as helping to put existing greenspaces into a framework. The sum total of all these benefits is so great that it can come as a pleasant surprise to even the most enthusiastic advocate of environmentally friendly building.

2 benefits of green cities

Quite apart from the significant psychological advantages, there are numerous other benefits that come from growing vegetation on and around buildings. Plants have a beneficial effect on city air and water and are good investments too.

Leaves can absorb a good proportion of the dust particles in urban air. A street with trees may have only 10-15% of the dust found on a similar street with no trees.





Plants help to cleanse the air of both particulate and gaseous air pollutants

Leaves account for most of the captured particles, with conifer trees performing particularly well. Research shows that trees in a parkland setting can filter out up to 85% of suspended particles. The percentage is reduced to approximately 40% in the absence of foliage on deciduous trees in winter [2]. The leaves of climbing plants provide a large surface area capable of filtering out dust, pollutants and possibly even viruses [3].

Plants improve the climate

Cities act as 'heat islands', being generally a few degrees warmer than surrounding countryside. Buildings, roads and other sealed surfaces absorb and store heat from the sun. Most hard materials conduct heat faster than wet, sandy soil [3]. Barren walls, roofs and streets also act as reflectors, absorbing some energy and redirecting a proportion to other hard surfaces [4]. Green roofs and other greenspaces contribute to the vertical mixing of air, as the temperature above them tends to be lower than that of surrounding built areas. Warmer air above hard surfaces rises and is replaced by this cooler air thus reducing the heat island effect.

Often the design of the built environment inhibits ventilation by reducing wind speed and therefore the amount of heat carried away. Meanwhile local turbulence – for instance around the base of tall buildings – is increased. The result is that pockets of air are trapped, and pollutants can remain suspended for several days. Green areas are generally cooler and windier, so introducing fresh air into the city.

The air near greenspace tends to be more humid too, as plants take in water through their roots and through the process of transpiration slowly introduce water into the surrounding air.

Cities act as 'heat islands'. The air above greenspace tends to be cooler and helps to replace warm stale air rising from hard surfaces.

Greenspaces slow down stormwater runoff

Soil and vegetation retain moisture long after brick, concrete and tarmac have dried out. Studies in Berlin have shown that on average green roofs absorb 75% or precipitation that falls on them so that immediate discharge is reduced to 25% of normal levels [5]. This means that sewers are better able to cope with runoff from streets and other hard surfaces and that risks of flooding are considerably reduced.

Greener cities exert less pressure on the wider environment. Cities which have a higher proportion of greenspace and unsealed surfaces have microclimates which are more similar to rural regions nearby. Also, by using less water through recycling schemes, green cities do not require the building of such large reservoirs in other areas.

Vegetation absorbs pollutants from rainwater

Heavy metals and nutrients in rainfall are bound in the soil instead of being discharged into groundwater or streams and rivers. Over 95% of cadmium, copper and lead can be taken out of rainwater and 16% of zinc. Nitrogen levels also fall dramatically [6].

Vegetation on buildings helps to offset the erosion of wildlife habitats

Wildlife habitats are invariably lost when open land disappears beneath built development. The effects are particularly acute in the inner city where there may be no greenspace associated with high density developments. Although additional plant life on and around buildings cannot make up for the loss of wildlife habitat, there is no doubt that here too it has a compensatory role to play.

Green buildings are good investments

People place high value on green areas. The most desirable residential neighbourhoods are those with tree-lined streets and plentiful open space. Similarly, commercial developments also can become more valuable when they incorporate green space within their boundaries. Greening buildings represents a good investment and a pleasant environment can help to attract and retain staff.

However there are additional practical advantages which can also result in financial savings. Vegetation placed directly on the surfaces of buildings protects the building shell. Extra short term capital costs are usually more than cancelled by long term savings.

Roofing materials last longer under a layer of soil and vegetation and climbers on walls protect the brickwork by absorbing wind, ultra-violet radiation and rain. Particular benefits of building green are discussed in more detail in the chapters that follow.

3 trees and buildings

As cities have grown in size and complexity, tress have come to be seen as environmental luxuries. Once they would have been a natural part of any city's culture, providing timber and food. Now they are too often viewed as decorative afterthoughts.

More trees now need to be planted in towns and cities. The objective should be to revive their role as natural constituents of the urban grain.

Cities would also benefits from wider varieties of tree species. A recent design tendency is to choose from a narrow range of species. This safe option tends to result in unimaginative design solutions. Much more adventurous choices could be made.

This chapter describes the benefits to be gained from introducing trees into the built environment – and suggests ways of dealing with problems which may be encountered.

Horse chestnut has attractive foliage and tolerates pollution and exposed sites.

BENEFITS OF TREES IN THE BUILT ENVIRONMENT

Amenity Benefits

Trees:

- introduce an element of natural scale to buildings and streets
- reflect the changing seasons and provide a psychological link with the countryside
- bring visual beauty to the built environment.

There is a popular understanding that 'added natural beauty' results in added real estate value – a fact reflected by property prices in leafy areas. This added value is hard to quantify, although attempts have been made. A survey carried out in Manchester, Connecticut, looked at residential property values in areas with trees and compared them with those in similar areas but without trees [7]. All possible variables were taken into account in the statistical analysis and the results showed that trees did contribute to property values: it was found that good tree cover added about 6% to the value of the homes. This figure compares with a contribution of between 7% and 15% to property values in a study conducted by the US Forest Service [7], and a 'gut feeling' expressed by some British developers of an enhancement of around 10%.

Roger Ulrich, a geographer at the University of Delamore has produced findings which suggest that trees can reduce costs in hospital care. In a study of patients recovering from a common type of gall bladder operation, he discovered that on average patients with a view of deciduous trees from their beds, spent almost 24 hours less in hospital.

Trees provide an excellent backdrop and improve the microclimate around the Kroller Müller museum in The Netherlands.

They also needed less nursing attention and fewer doses of expensive drugs than patients looking out onto a brick wall [8].

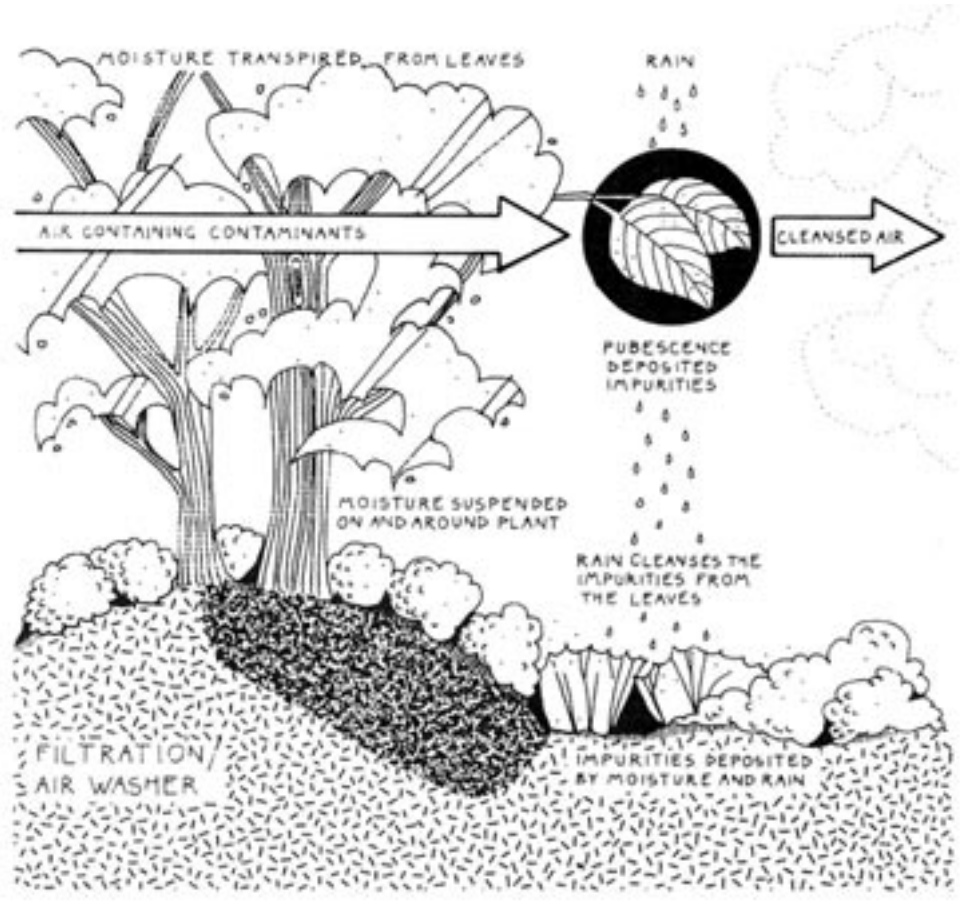
Energy Conservation

Trees and shrubs can help reduce overall energy use in buildings. The amount of energy saved depends on the building type, choice of tree species, positioning around the building and the prevailing climate.

For example, by planting deciduous trees on the west side of an exposed building:

- wind penetration can be significantly reduced
- shading provided in summer
- solar gain achieved in winter.

Savings on energy costs by the careful planting of trees can, for a conventional house over a one year period, be as much 25% [9].



Trees increase humidity in the atmosphere and absorb airborne particulates. Leaves are then cleansed by the rain.

Climate and Pollution

The pattern of urban development often serves to increase local wind velocity to the discomfort of the human population. The careful positioning of trees and shelter belts can reduce this effect, bringing with it other related benefits. These include:

- improvement of the microclimate
- reduction of wind-loading on buildings and other structures

Because of the very variable nature of city building patterns, it is hard to generalise about benefits. In open ground situations, distances of twelve times the height of a tree belt can be effectively protected from wind forces perpendicular to the belt (here effectiveness is defined as where the wind velocity remains less than 80% of the open windspeed at the same height) [10].

The shade cast by trees depends upon the species. Those with thin, light canopies intercept between 60% and 80% of sunlight; those with thick dense canopies intercept as much as 98%. Much of the radiation intercepted in this way is absorbed by the tree in transpiration and photosynthesis, although a small amount (10% - 25%) is reflected back into space. The use of deciduous trees ensures that during the winter more sunlight (40% - 70%) is allowed through to warm building surfaces and raise cold air temperatures. Solar reflection and radiation from buildings and streets is also intercepted by planting trees close to such surfaces.

Trees increase humidity in the atmosphere by releasing moisture into the air. This results in a cooling effect on the microclimate. The cooling effect of an isolated mature tree transpiring 450 litres per day from its leaves has been estimated to be equivalent to 5 average size room air conditioners running 20 hours per day [11].

Trees attenuate noise and introduce pleasant soothing sounds of their own [12]. In general, trees are most effective at reducing frequencies to which the human ear is most sensitive, although attenuation can vary from 1.5dB to 30dB per 100 metres depending on the type of vegetation [10].

Trees reduce airborne particulate matter by as much as 75%. The high surface-to-volume ratio of trees and fine hair on the surface of their bark, twigs and leaves are all important factors in filtering out such pollutants [11]. Another benefit to air quality is the amount of oxygen a tree produces during photosynthesis. A 24m tall beech tree with a crown

Planting young trees is generally the wisest choice - they are cheaper and can grow into their surroundings.

Tall London plane trees.

diameter of 15m produces enough oxygen for 10 people to breath [13]. Trees counteract visual pollution. Glare from highly reflective building materials or street lighting is reduced by the presence of trees.

Benefits to Wildlife

Wildlife benefits depend on size, and density. Trees all support insect life which in turn provides food for many different birds and even some species of bat. Usually it is the native tree species which are of the most value in this respect since they will have evolved together with animals which depend upon them.

From the design point of view, some hybrids which interbreed with native trees will offer a good compromise between visual variety and hospitality to wildlife. In addition, some non-native trees and shrubs are very successful in attracting a number of insects. A good example is buddleia, whose flowers provide an abundant source of nectar for butterflies. Sycamore too is a valuable source of food for several insect species.

For some birds, trees in the city provide valuable nesting sites. Migrant species use them as staging posts on their journeys while others use the trees planted around buildings as corridors to move from one green part of the city to another.

TECHNICAL CONSIDERATIONS

Species Choice and Size

In choosing appropriate species for a particular urban situation, a number of considerations and constraints need to be borne in mind. In some instances the aesthetic contribution that a species may make, or its relationship, in terms of size and shape, with adjacent buildings may be overriding. In others it may be the requirement of the trees to provide some environmental benefits, for example in ameliorating climate or providing shelter for wildlife.

Many situations will constrain which species can be used by virtue of prevailing soil conditions, restrictions on space, availability of sunlight or requirements for specific types of public use. Table 1 in the technical information (p82) provides a short list of some trees suitable for the urban environment, with an accent on native deciduous species to provide the greatest environmental benefits.

Many more species and varieties exist and are described in various books on trees and landscape design which are available. A selection of these is listed in Further Reading (page 107).

In planting trees close to buildings the eventual size of individual specimens is an important consideration. By choosing a variety of sizes and age classes, visual interest is increased and structural diversity provided. In many recent developments there is a tendency to plant older, and thus larger, specimens in order that ultimate design objectives are more quickly realised. Large trees require expensive techniques for ensuring that the transplant procedure is successful, and where design criteria do not dictate otherwise, smaller and younger specimens are usually a better choice: the specimen itself and the planting procedure are cheaper and the tree is given an opportunity to grow into its surroundings.

Whips can be grown around buildings in tree beds with a suitable mulch – this helps to keep tree beds weed-free. Groups of whips of a complementary variety of native species planted in close proximity, will eventually produce the most satisfactory results in ecological terms.

This technique has proved popular in Germany and Holland. In the UK it has been used to good effect in Warrington New Town and Milton Keynes.

The space allowed around the base of this tree in London, UK is adequate.

Planting

Magnificent old specimens found in cities are almost certainly relics of an age when there was little asphalt, and few pavements or underground services to interfere with growth. Today, any tree planted in an urban situation will have to cope with many stresses, and will almost certainly not reach the size or age of its country cousins. The demands of modern cities mean that root space and the amount of soil surface area left bare for water penetration and aeration of tree roots is severely restricted.

In planning for trees around a building, the interaction between the organic and the inorganic raises several important questions:

- has enough space been allowed for the tree to grow?
- how will the tree affect the building at maturity?
- will the roots start to lift up paving stones or interfere with essential services?
- will dense foliage cast shadows into offices or brush window panes?
- will the presence of a drain or soakaway result in the tree receiving too much water and becoming waterlogged?

As a rule of thumb, root space should equal crown diameter plus 1.5 metres. Large trees such as lime or oak should not be planted closer than 7 metres to the façade of a building. However, smaller trees such as birch, cherry, whitebeam, rowan or field maple can be planted closer. Another

option is to use pleached trees: species such as lime or beech can be trained and pruned to form a dense, continuous canopy – a sort of 'hedge on stilts'. This method is used to great effect in cities in Holland, France, Spain and other European countries. The formality of design is particularly suited to inner city developments.

Fruit trees can also be trained in espaliers against walls, providing visual pleasure and a source of food for wildlife. Real fruit trees – those which bear edible fruit as well as blossom – are under-utilised in city developments, and yet orchards were once an important part of city life.

The problem of surface rooting of trees is caused by soil compaction and waterlogging: where these conditions are severe, roots are likely to come to the surface. In heavily urbanized situations, large planters and wells are sometimes effective ways of managing tree roots [14].

Planters are normally erected above ground level and in many instances are used as overgrown flowerpots, providing a cheap but unattractive and ineffective alternative to good landscaping. Trees and shrubs planted at ground level as an integral part of an overall design provide a far more satisfying solution. However, large planters, when sited in heavily-used

Trees can be trained in espaliers against walls, particularly where space around buildings is minimal.

urban areas, can afford valuable protection to trees and shrubs which would, at ground level, suffer damage or abuse.

The main two causes of trees failing to take after planting are:

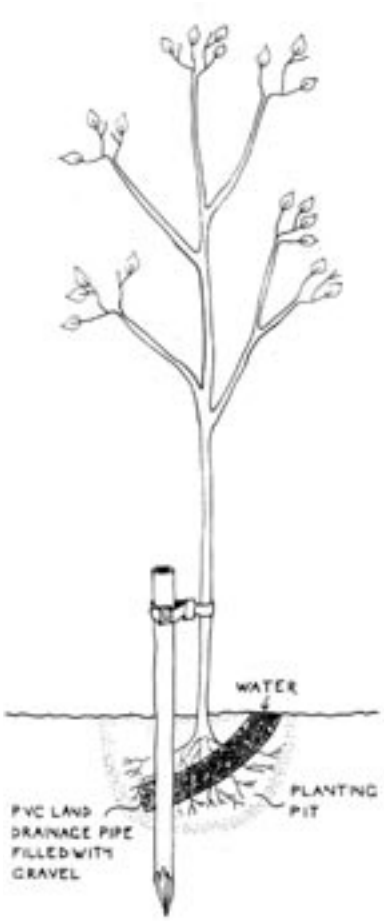
- planting the tree too deep
- filling the tree pit with humus-rich material

Tree roots need to breath and so, with a few exceptions, trees should be planted at a similar depth to their conditions in the nursery.

Humus-rich substrates should be used only at a level where they would be found in a normal soil profile – that is, no deeper than 50 cms.

Restraint should be exercised in the use of fertilizers – over-application can result in roots not penetrating beyond the tree pit owing to the concentration of nutrients there.

The tree should be planted into a volume of soil which will hold enough moisture to keep it supplied during periods of drought. Consideration must also be given to the effects of buildings on drainage and soil conditions, and this is best done early in the planning process.



A well planted tree should have a flexible stake, underground piping for irrigation and two square metres of permeable soil surrounding the trunk.

Irrigation and Aeration

A variety of methods are available to ensure that additional water, nutrients and air are able to reach the tree roots when needed. Most of these methods are based on the principle of surrounding the tree at a certain depth (30-40 cms below the surface), with some kind of perforated piping which is linked to the surface. The tree is then fed and watered as necessary via this connection.

WATER SUPPLY PROBLEMS

Helliwell recommends the following remedial action if problems with supply of water are experienced:

- maintain a water table within a small and constant distance below the base of the root system, normally within 30-40 cms
- apply water to the soil surface during dry weather
- provide soil of a better texture or greater depth than the existing soil
- if soil compaction or winter waterlogging are restricting root growth, improve the soil by cultivation and/or drainage [12]

Where possible, trees should have a minimum of 2 square metres of surrounding area permeable to water and air and protected from

compaction by cars or pedestrians. This also helps invertebrates which need friable soil or leaf litter to pupate. The most natural way of achieving this is underplanting with small shrubs, always taking into account the threat of competition for resources that these may represent. Grass can be used instead, but it is susceptible to trampling and may be shaded out after a few years.

In densely developed situations where space is at a premium and hard surfaces are common, concrete grids or steel grates can protect the soil from compaction whilst still allowing water and air to penetrate. For air exchange to be sufficient, the holes in the grid should ideally occupy 50% of the area and certainly no less than 35%. The grids should also be capable of being replaced or removed so that the tree can be given more room as it grows. Providing a large central hole for the tree to start with will defeat the object of the grid and may possibly result in the young specimen being damaged; the best strategy is to start with a small hole and increase its size as the tree gets bigger.

The tree should be planted at least 10 cms below the underside of the grid to allow for root growth. The resulting space between it and the top of the grid should be filled with washed sand, bark or 7-30mm gravel.

Experience has shown that unless this is done, the space fills up with road sweepings which, owing to their fine particles, can lead to silting up and sealing of the soil surface.

An alternative method is to lay frost-resistant perforated brick or stone sets. These are laid on a bed of sand, the perforations in the brick filled with sharp sand, and the sets arranged with a minimum of 1 cm gaps. This arrangement allows water to penetrate and encourages invertebrates to use the gaps between the bricks.

RETAINING EXISTING TREES

Major developments in the inner city areas often present opportunities for new trees and shrubs to be introduced into areas where mature specimens already exist and must remain. There are several advantages to having mature trees on a site, not least of which is their greater visual impact than younger trees. But all too often existing trees on development sites are inadequately safeguarded. Impact from machines, or indirect problems of soil compaction or root damage, can all lead to unsightly die-back of the crown or even the death of a tree. It is the oldest, most mature trees which will be least tolerant of interference. For this reason, whenever possible mature specimens should not be disturbed.

RETAINING TREES DURING THE CONSTRUCTION PROCESS

To retain a tree within a development it must be protected from damage during the construction process. The Arboricultural Association makes a number of recommendations to ensure the survival of trees in this situation.

- Remove branches likely to be disturbed by working cranes or other machinery;
- Protect the stem and the root area (from fires, dumped material, the erection of huts etc.) by the erection of stout fencing, at least 1.3 metres high;
- Inspect frequently during the period of site works to ensure that trees are not being damaged [15]

When designing building foundations care should be taken to minimize disturbance to existing trees – and to arrange services so that the water table is disturbed as little as possible. Roof drainage can be fed into the ground via soakways to maintain a supply of water to tree roots.

MANAGEMENT

Management of trees is extensively documented although sometimes a matter of great debate [16]. However most experts agree that there are basic procedures which should be followed immediately after planting if the survival of a tree is to be assured:

- small shrubs and fruit trees should be thinned by anything up to 50%.

Trees should only be planted in planters which are sufficiently large to allow for many years of growth.

- newly planted specimens should be watered well and given water as and when necessary for several years after planting. In some instances a bark mulch may promote successful growth by keeping weed species down and aiding water retention.

A long term maintenance programme generally includes:

- periodic pruning
- checking, loosening and removal of stakes and ties
- watering, usually in May and July
- weed control near base
- mulch renewal
- spraying, if necessary [13].

It is also worth remembering that when planting trees in close proximity to buildings, there will be certain legal obligations to be assumed by the owner, including the potential trespass of the tree onto neighbouring property. In all cases, designers, planners and developers should seek advice from landscape architects, horticulturists and ecologists before embarking on a planting programme.

4 courtyards

Courtyards are potential delights. They can provide green space for work or relaxation, be cultivated as wildlife habitats, or simply organised as attractive green areas to offer pleasing views from the home or office window.

New developments in the inner city can be softened and enhanced by a planted courtyard.

Courtyards can be defined as an open area surrounded by walls or buildings. They may be located within the envelope of a large building, such as an office, large home or hospital, or created by the juxtaposition of several buildings as in the case of blocks of inner city flats.

Courtyards have a long and distinguished history as places of refuge and as features of energy conscious design. Ancient cultures used courtyards in a variety of ways; as outdoor rooms for quiet contemplation; as sheltered spaces where people could assemble; as light wells; or as cool spaces surrounded by massive earth walls. Courtyards were also used as walled gardens, using plants and water to create a pleasing microclimate – a role they still fulfil.

Courtyards are best designed in tandem with surrounding buildings, as in this new housing scheme in Berlin.

And yet, by contrast, in recent times the space between buildings has been curiously neglected. As a result many buildings turn their back on potential courtyards instead of embracing them as a valuable extension of the indoor environment. All too often space between buildings is wasted, offering little more than a narrow light well which becomes a trap for rubbish and stale air.

Of course, the most satisfactory approach is usually to design the outside space alongside the rest of the scheme, using an integrated approach. In this way, a courtyard can actually lead to economies rather than extras in the overall costs [17]. But much can be achieved with existing spaces. In the 1980s the Senate of Berlin initiated a programme of 'greening backyards' which resulted in the revitalisation of 185 inner city courtyards [18]. Such projects demonstrate that even in densely built up areas there is scope for greatly increasing plant cover.

THE MICROCLIMATE OF COURTYARDS

Each country has a unique microclimate according to its size, shape and surroundings. For a courtyard to be a useful extension to a building it has to be warm and sheltered but not too hot at the height of summer. There are four factors which dictate the microclimate of a courtyard: light, wind, temperature and moisture.

Light

The amount of light which reaches the floor of a courtyard will of course be largely dependent on the height of the enclosure and the dimensions

of the open space. Courtyards formed by deep wells may be bright at top level but very dark on the ground. Permanent shade areas may be a particular feature in winter. Even in summer narrow courtyards may have a very limited period when sunshine reaches the lowest levels. Narrow courtyards can be used to great effect in hot, arid climates: the courtyard stays shaded for much of the day and at night cool air is drawn inside the building via the courtyard. In temperate regions, however, narrow courtyards have a 'basement climate' – cool, moist air tends to hang at lower levels [19]. Greening such spaces requires the use of species which will thrive in the dominant conditions.

Larger, sunnier courtyards will present very different conditions for plant and animal life. These 'sun-traps' will warm up earlier in spring, cool down later in autumn, and generally be warmer and perhaps drier than open areas nearby. Plants should be chosen accordingly.

Wind

Wind around buildings is a very variable phenomenon. Wide courtyards between tall buildings can be quite gusty as wind flow is distorted around buildings. Cold, strong winds at high level are deflected down the side of buildings causing turbulence at ground level [20]. Problems become particularly acute where gaps between buildings allow diverted air to rush through.

In narrow courtyards a different problem may arise: because of a high degree of shelter, air may be exchanged too infrequently leading to concentration of pollutants. Some experts suggest that the most advantageous size courtyard is one which is wide enough to allow free mixing of air, but not too wide – no more than the equivalent of twice the height of surrounding buildings – so ensuring that warm air masses are not lost [20].

Moisture

Small courtyards tend to be drier than an open space of similar size nearby. Walls create a drought zone of about 500mm alongside them by absorbing ground water and through creating a rain-shadow. Depending on the angle of the wind much of the rain may never reach certain areas of the ground.

A further factor is that dew seldom occurs in the close vicinity of buildings [21]. Because the ground is sheltered and tends to retain its warmth, the dew will not form. This can further add to drought problems.

A well-planted courtyard will alter the moisture situation. Plants retain moisture longer than hard surfaces and give off water vapour during evapotranspiration. As mentioned earlier, in narrow courtyards with little sun the air may remain too humid, especially in winter.

Temperature

The three factors already discussed – light, wind and moisture – all have a part to play in dictating the fourth: the temperature of the courtyard.

Generally, narrow courtyards warm up and cool down more slowly than similar areas of open space which are not surrounded by walls or buildings. For example, in the morning the air will stay cooler longer unless the courtyard is wide enough to allow sunlight to infiltrate. Conversely, in the evening the buildings transfer a considerable amount of heat into the courtyard air, keeping it warmer. On average, a narrow courtyard will be cooler in summer and milder in winter than nearby open spaces.

As mentioned earlier, larger courtyards (or those not overshadowed by high walls) will behave quite differently. They too may have a temperature which varies significantly from that of nearby open space, but they will tend to be considerably warmer in summer and slightly milder in winter.

GREENING THE COURTYARD

Planting a courtyard has a considerable effect on its microclimate. Where courtyards are too hot, plants help to lower the air temperature by providing shade and through the actions of transpiration and evaporation which draw heat from surrounding air.

Surfaces with a covering of plants heat up less, making the climate more comfortable in summer. A covering of soil and plants also helps to absorb rainwater, thus ensuring that the surface of the courtyard does not contribute to stormwater runoff problems.

Plants should be chosen to suit the type of courtyard under consideration. Narrow, dark spaces resemble ravines, gullies, or the forest floor. Ferns and other plants which thrive in low light (e.g. ivy, holly, and a variety of grasses and mosses) will do well here. Species may be chosen according to moisture and sunlight availability in the courtyard, but also with regard to attractiveness and wildlife value. Many grasses will offer cover and breeding places for certain invertebrates as well as food for some birds such as finches. More open but sheltered courtyards are particularly suitable for colourful plants which thrive in full sun. These will function as bee and butterfly gardens, supplying a rich source of nectar

The courtyard for this modern housing development in Berlin has been planted as a lush nature area.

Shady courtyards within inner city blocks can be successfully planted.

from spring to autumn. Shrubs such as buddleia, broom, lavender and gorse, and herbs such as willowherb, michaelmas daisy, soapwort, mullein and thyme all enjoy a sunny position and provide food for invertebrates.

Most courtyards will be neither totally shaded nor completely sunny and, like any garden, appropriate plants can be chosen for each aspect. For instance, low winter sun may be concentrated on a south facing wall which will act as a storage heater. Plants can be grown on the ground, directly in the soil or in pots, and trained up walls (see chapter 6) for maximum coverage throughout the courtyard.

Since all but the darkest courtyards will almost certainly be used by people, seating should be placed alongside sunny southern walls, with the provision of shaded spots – perhaps under a pergola – for when the sun is too hot. Open verandahs and other covered seating areas are also a good idea, to provide shelter from strong sun or rain.

A good example of a courtyard used to maximum effect is that belonging to the new headquarters of Greenpeace in London. The London Ecology Unit was asked to advise on appropriate plants for this small open space surrounded by walls and overlooked by office staff. The garden had to attract as much wildlife as possible whilst allowing maximum access and sitting-out space. It also had to provide a visual complement to attractively refurbished warehouse offices.

Large sunny courtyards attract bees and butterflies and provide appealing places to sit.

5 balcony gardens

Balconies and small terraces have become standard architectural features for multiple dwelling developments. The balcony garden is a natural development of the balcony's role as a link between interior and exterior environments.

Balcony gardening generally means growing plants in relatively small containers which stand on the balcony floor or are fixed to walls or railings. This sort of container gardening lends itself to other spaces too: patios, stairs, porches and roof terraces for example. The following applies to all of these locations.

BENEFITS OF BALCONY GARDENS

Balcony gardens give particular pleasure to city dwellers without gardens or to those who do not have easy access to public greenspaces. They offer an opportunity for private creativity which involves selecting suitable plants and containers, as well as overseeing the growing process. In fact looking after a balcony garden can be psychologically beneficial to any city dweller dispossessed of easy access to the countryside. Some studies even suggest that people living in high density developments are less susceptible to illness if they have a balcony or terrace garden.

Balconies provide a place for plants and an opportunity to enhance building design.

The visual benefits of plants on balconies is disproportionately high to the space needed, and with careful planning and management colour can be provided throughout the year. Viewed from the inside, plants around windows suggest high levels of vegetation; meanwhile from the outside the combined effect of plants on individual balconies can be so significant as to redefine the whole appearance of a building.

There are other advantages too. Plants provide screening from neighbours, hide ugly pipework and mask unappealing scenery. They also provide suitable conditions for some wildlife. Even smaller containers of plants attract insects; meanwhile spiders, ants and the occasional worm may be imported with the soil or plants. In turn, birds may come to feed on insects or on seeds and berries, and squirrels to feed or bury nuts for winter.

OPPORTUNITIES

Almost all buildings, new or old, present some opportunities for creating balcony-type gardens. On buildings without balconies or terraces windowboxes and other containers can be sited on window ledges or attached directly to the wall. Considerations such as the space available, sunlight, wind conditions, type of wall construction, and access for maintenance will all determine suitable design schemes. However, it is of course buildings with balconies or terraces that have the greatest scope

Creating a balcony garden can be a pleasure for city people.

for the creation of more ambitious high-rise gardens. A balcony or terrace can become a small outdoor room with climbers planted in pots and trained up walls or trellis. Small trees can be planted in containers, and pots, window boxes and hanging baskets used for planting colourful shrubs and wildflowers.

New build schemes offer the greatest scope for incorporating gardens within the framework of the buildings. Permanent raised planting beds, window boxes, and imaginative use of levels, using roofs as terraces for those living or working above, can be designed in. This ensures that garden areas are easily accessible for planting and maintenance, and that there are no structural problems from introducing heavy containers of wet soil onto flat roofs or window ledges.

All types and sizes of balcony garden can be supplemented by additional features to help attract wildlife. Nest boxes can be mounted on nearby walls (but not south-facing walls), and bird feeders can be secured onto walls or hung on brackets. Similarly, a bird table can be erected on the wall of a window, or free-standing in a terrace garden. A source of water for drinking and bathing will also be welcome and can be as simple as a shallow dish placed in a window-box. More information is given in chapter 7, Building for Birds and Bats.

SUITABLE PLANTS

A great variety of plants are suitable for growing in containers or other confined spaces. However, conditions are largely artificial and sometimes extreme: containers in south-facing positions or placed on black-topped roofs may heat up to very high temperatures in summer and water loss can be rapid. In winter, roots in smaller containers have little resistance to frost. Nutrient availability can be a problem, particularly where containers hold only small amounts of soil. Nevertheless, given adequate care and attention many plants will flourish here.

Plants should be chosen not only for their ability to thrive in confined spaces and suitability for the particular aspect, but also for their attractiveness to people and wildlife throughout the year. Vegetation with colourful flowers and fruit, followed by colourful foliage in autumn and winter, is a good choice. Trees and shrubs provide privacy screening for people and cover for birds.

Many wildflowers are suited to growing in harsh conditions and are therefore appropriate for growing in containers. Those which provide colour, nectar, pollen and seeds for insects and birds are best. Suitable species include native spring bulbs such as wild daffodil, snowdrop and

bluebell. For brilliant summer colour, cornfield annuals such as poppies, chamomile and corn marigold can be planted, or a great variety of meadow flowers such as ox-eye daisy, toadflax and harebell. Alpines, rockery plants, and those found on cliffs, such as thrift, wild thyme, stonecrops and saxifrages will thrive in minimal amounts of soil. Species choice will depend on soil type, location, and size of container. Table 2 in the technical information (page 85) gives a list of appropriate plants with information on suitable growing conditions.

Attractive foliage and flowers can set off a building.

MANAGEMENT OF BALCONY GARDENS

Careful management is the key to successful balcony gardens. The artificial growing conditions of containers necessitate frequent watering and fertilising, and it is also vital to ensure adequate drainage and shelter from strong sun and gusty winds.

Watering is the overriding concern and therefore ease of access and water supply is vital. Of course, larger amounts of substrate will hold more water, decreasing the frequency of irrigation. Mulches on the soil surface can also help. In summer, however, even large containers will need watering several times each week.

A tiny garden can provide features such as a miniature pond and wildflowers.

In residential areas, balcony gardens are generally tended by individual residents. Problems of security and privacy normally rule out any collective management arrangements. It is easy to see why watering must be able to be carried out with ease. Even then, some residents may need assistance and others convincing that the effort is worthwhile. However, most will take delight in the garden under their care and be happy to spend time and energy ensuring its success. And, balcony gardens do not require strenuous digging, constant weeding or laborious mowing and therefore will be ideally suited to many people.

Gardens in commercial situations generally benefit from a management agency. Unless individuals in offices, shops and factories show particular interest in tending 'their' balcony garden, regular servicing will need to be undertaken by gardeners, either on staff or from a specialist agency. Automatic irrigation systems can be considered for large scale projects, but even these will need to be overseen. The benefits to individuals of having plants to look upon from the offie window, and the enhancement of the attractiveness of the building and the company's image, make the cost of regular maintenance very worthwhile.

Even the smallest gardens on balconies and terraces can provide a link with the natural world. Although such gardens cannot make up for a lack of open space in a neighbourhood, they are complimentary to an open

space network. They can be installed almost anywhere, including the most densely urbanized areas.

The psychological benefits of seeing and caring for plants are well known. All houses and flats without ground-level gardens should provide built-in balconies and terraces for growing plants. These add character to a development, provide space for wildlife, and are excellent for brightening up a dreary façade. Commercial developments can benefit too, using plants to soften harsh facades and imparting an image of a caring company. The benefits of balcony gardens greatly outweigh the space and cost needed to create them.

Balconies at Broadgate create appealing points of interest.

6 green walls

Modern cities provide enormous areas of wall space, in many cases stretching high above the street. Not all of this space is appropriate for growing plants, but much of it is – certainly much more than has been utilised in recent years.

A complete covering of plants can protect a wall from sun, wind and rain.

GREEN WALLS FOR A MODERN WORLD

Green walls present a complex variety of challenges which need to be addressed carefully. Large buildings require special measures to cloak their walls with plant life. In some cases – owing to design or construction techniques – it will prove impossible.

However, on smaller buildings and at the foot of larger ones, the use of climbing plants to enhance good design (and in some cases to disguise bad design) is both feasible and desirable. An even stronger case can be made for the greening of the back sides of many modern buildings, which are frequently ugly and depressing, presenting little of visual merit.

There are also opportunities to establish plants in the joints between brick or fascia work or on specially built ledges and terraces. Here, designing with plants provides the architect with an exciting and under-utilised design dimension. In some cases, such as lower buildings with sloping roofs, climbers can be grown not only up the façade but over the rooftop to provide an alternative type of green roof.

Once again, by allowing and encouraging plants to grow on and up walls the natural environment is being extended into urban areas; the natural faces of cliff and rock slopes are simulated by brick and concrete, by ledge and window boxes.

Virginia creeper climbs along bright metal bars on this six storey appartment block in Berlin.

BENEFITS OF GREEN WALLS

There is widespread belief that plants are inimical to built structures, ripping out mortar and prising apart joints with their roots. The evidence suggests that these problems have been greatly exaggerated, except where decay has already set in and then plants can indeed accelerate the process of deterioration [22]. Certainly there is little evidence that plants damage walls. In most cases the exact opposite is true, with plant cover protecting the wall from the elements. Ancient walls still stand, despite centuries of plant growth, bearing out the view that any damage done to walls by plants is very slow indeed. Also, a layer of vegetation which protects a building from radiation may reduce thermic tensions within the structure [3].

Boston ivy sets off the grey façade of a new residential block.

Amenity Benefits

The most obvious benefit to be gained from encouraging plants to grow on walls is visual enhancement. There is also the advantage of a variety of natural scents.

In some parts of the world, civic authorities are now aware of the psychological (as well as physical) benefits which plants can bring. In 1983, the Kassel City Corporation in Germany launched a campaign encouraging people to grow climbing plants [23]. The emphasis was on community action, with the Corporation providing support in terms of expertise and, in some cases labour.

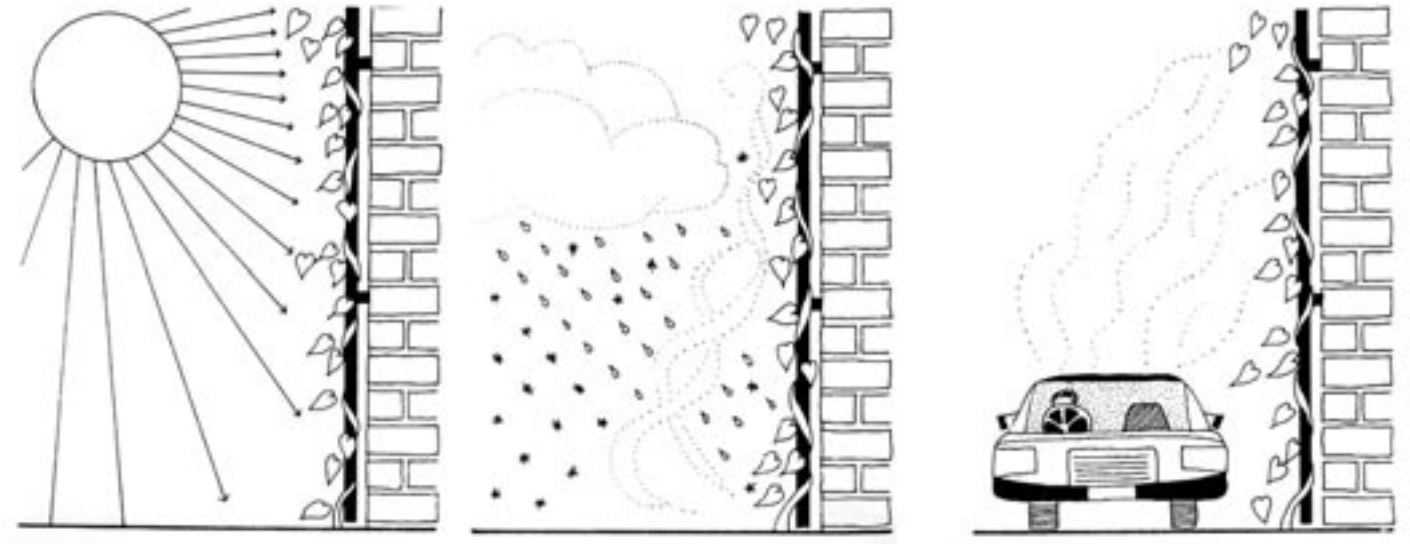
Interest subsequently spread to Munich, Berlin and Frankfurt [23] where guidelines for urban development now include proposals for roof gardens and the introduction of vegetation to façades [24]. More radical ideas have been proposed by German architect Rudolf Doernach. Many of his designs, including a chapel in Bonn, suggest that plants should be incorporated within the façade as an active building material with the ability to reproduce itself.

Energy Conservation

Vegetation on walls can assist in cooling buildings in summer and insulating them in winter.

In the summer, solar gain on the façade of a building is reduced by shading and, as many species of climbing plants raise their leaves in response to the high angle of the sun, the effect of a ventilation blind is created; cool air is drawn inwards and upwards, and warm air is vented at the top. Evaporation and transpiration provide an additional cooling force

Vegetation protects a wall from strong sun, rain or snow, and absorbs pollutants form the air.



[3]. In winter, evergreen species offer a degree of insulation by trapping a layer of air against the façade and reducing convectional heat loss [25]. An insulating effect of up to 30% has been recorded although such a high percentage is only likely when temperatures fall close to freezing [3]. Energy savings are less significant on well-insulated buildings, such as those with brick cavity walls [25].

Contrary to popular belief, façades covered with plants can also be drier – another factor which cuts heat loss by reducing conductivity: rainfall is shed by leaves onto the ground whilst the walls remain dry. This can also help to prevent the harmful effects of acid rain since carbonic acid (formed by carbon dioxide and rainwater) is one of the substances responsible for chemical weathering of stonework buildings.

Ivy is an excellent wildlife plant offering nesting sites for birds and food for insects.

Health

The leaves of climbing plants on walls provide a large surface area which is capable of filtering out dust and other pollutants. Large areas of vegetation also reduce noise levels. Low humidity levels in cities are common, and green façades can help here too. Hard surfaces of concrete and glass encourage swift runoff of rainwater into the sewage system. Plants hold water on their leaf surfaces longer than man-made materials, and through the processes of transpiration and evaporation, can add more water into the air. The result is a more pleasant climate.

Deciduous climbers such as Boston ivy insulate in summer but allow sun to warm building surfaces in winter.

Benefits to Wildlife

Green walls can provide resting and feeding places for birds, invertebrates and even small mammals. Wrens and blackbirds may be found – even shrews and voles. Watching these animals can be a source of considerable pleasure to city dwellers.

LIVING CONDITIONS ON A WALL

Even those plants rooted at the foot of the building, such as ivy or Virginia creeper, may find living on a wall arduous. Extremes of temperature and moisture make for difficult growing conditions; how difficult will depend upon the location and orientation of the building. Furthermore, in urban environments pollutants take their toll; mosses and lichens are particularly sensitive.

Plants accentuate the walls of the arena in the Broadgate development.

For those species which root into the wall itself – for example ivy-leaved toadflax, wallflower or snap dragon – conditions are even more difficult. The substrate in which they grow is made up largely of the very materials of the wall itself: brick and mortar, concrete or stone. These materials decompose at different rates under the physical and chemical effects of the weather. Other substances, not necessarily associated with the wall

Climbers on this apartment block in Chicago are a positive contribution to the streetscape.

A wire climbing frame as an attractive design.

itself, accumulate, providing the raw matrix which allows plants to become established.

At the foot of the wall debris can accumulate where it may provide the unexpected bonus of additional nutrients for climbers and even a new habitat for plants at the junction of the wall and pavement.

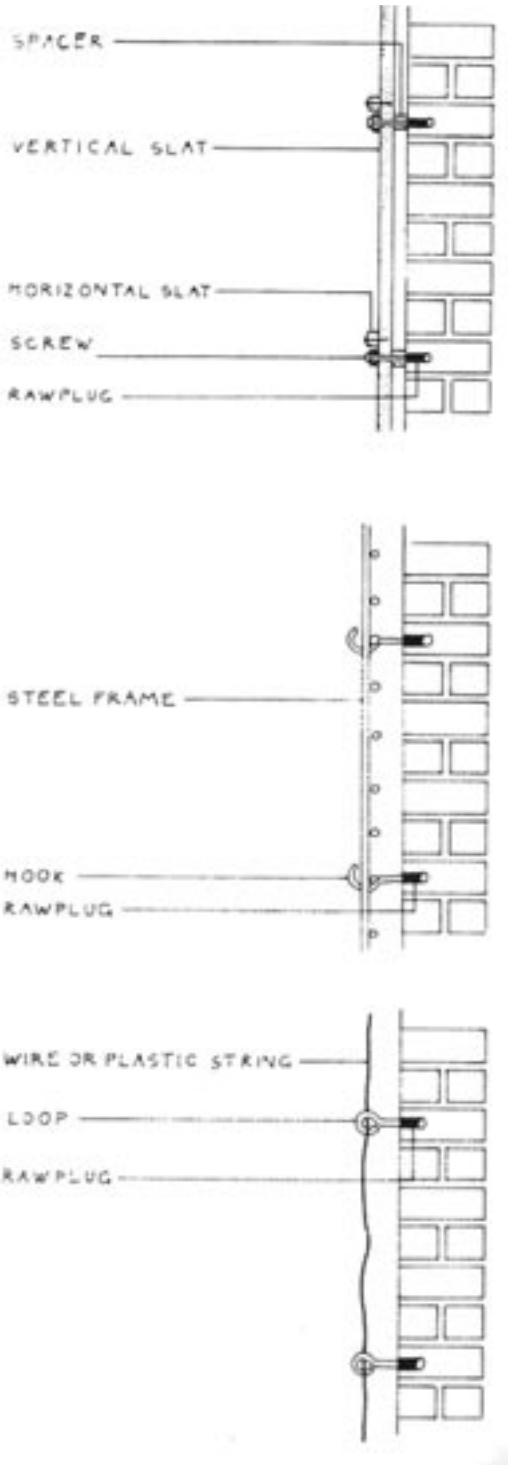
Availability of water can vary a great deal across the surface of a wall. Retaining walls with soil behind are normally well supplied with water. In other cases leaky gutters may provide temporary vertical rivulets. But most species are reliant on precipitation and the moisture-retaining properties of the wall itself for their supply. The orientation of a wall can also make a significant difference; south facing walls absorb more moisture than those facing north, and they dry out more quickly. In general, north-facing walls will therefore support a more luxuriant growth of plants.

TECHNICAL CONSIDERATIONS

As already mentioned, some plants are able to grow on walls by taking root in the substance of the wall itself. Typical of these are the small herbaceous species such as ivy-leaved toadflax, wallflower and plants such as mosses, lichens and grasses. But other species are naturally adapted to climbing up and over obstacles such as rock faces, trees and shrubs. For these to grow successfully on walls and buildings some kind of support structure is usually essential. For example, climbers such as hops support themselves by spiralling upwards around an object; they will require timber battens, trellis work, steel cables or plastic ropes. Plants which hold on with clinging roots or petioles – for example Vitas and clematis – will also benefit from a grid of thin material to which they can attach themselves.

Ivy and Virginia creeper, although able to cling directly onto walls by using adventitious roots, require a rough surface to enable them to do so. Rambling plants such as bramble and climbing rose need wide-meshed grid structures to which they can be attached and trained into place. A 50x50cm latticework of treated timber mounted on wooden posts (or an equivalent structure using cables, rope or netting) will provide an adequate support for a range of species. Whenever possible it is advisable to leave a small gap between the façade of the building and the supporting structure to maximise the effects of summer cooling and winter insulation.

Encouraging herbaceous species to grow directly into walls is rather more contentious, depending as it does upon a certain amount of



Support structures for climbers include, top: wooden trellis work; centre: steel frame, bottom: wire or plastic ropes.

deterioration in the building surface to allow them to take hold. However, there is no reason why designers could not incorporate structures into the façade where such species could be planted or allowed to take root naturally. One interesting proposal is for polypropylene cladding tiles which incorporate waterproof membranes and their own irrigation system; plants could be established on these and then hung on the outside of a building [24].

In Australia a 'mountain' wall façade has been created on the side of a large building. Shrubs grow from special containers planted at different levels on the façade. To ensure the survival of the plants and to provide an extra visual dimension, water slowly trickles down the wall and through the system [24].

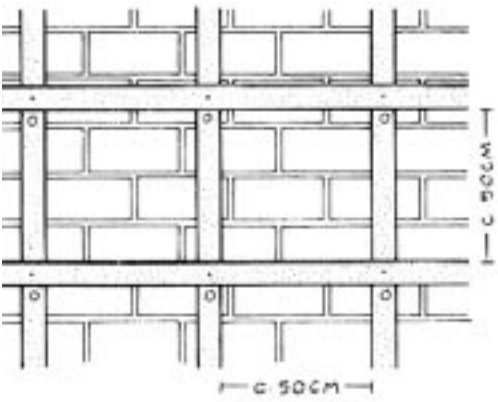
PLANTING

For climbing plants the ground should be prepared as for any tree or shrub by creating a pit and adding in some well rotted compost to the top 30cm. The plant should be positioned at least 40cm away from the wall. Where a support is used, a regular maintenance check is required to ensure that the structure is still firmly attached to the wall.

For best results, consideration must be given to the relationship between the types of plant used and the aspect of the walls where they will grow. For example, if the quantity of blossom is considered an important feature then a south facing wall is likely to give best results. In many instances the most satisfactory

Boston ivy clings directly onto a rough wall.

A combination of wooden slats and rope as a climbing frame.



A 50cm x 50cm latticework of timber is an ideal support structure. A gap should be left between the latticework and the building façade.

solution may be to use a combination of different species (annual and perennial, deciduous and evergreen, foliage and flowering, climbing and creeping) always remembering that the more vigorous species will require large amounts of wall space if they are to be combined successfully with others. A selection of plants suitable for walls is given in Table 3 (page 88).

On the south side of a building deciduous plants are the most suitable; in the summer their dense foliage shields the building from sunlight and evapotranspiration creates a cooling effect. In winter leaves are shed, allowing sunlight to reach the surface of the wall so helping to warm the interior of the building. Some of the species suitable in this situation are climbing roses, trumpet vine, jasmine, climbing bittersweet, trumpet bindweed, clematis, Dutchman's pipe, wisteria and Russian vine.

On a west-facing wall it is wise to use evergreens to protect the building from rain and provide a cushion of air to help insulation. In drier parts of the country which enjoy westerly sunshine then the suggestions for a south wall may be more appropriate. In either case, if the plants can be set away from the wall on a separate support structure so much the better. Plants which may be suitable include Dutchman's pipe, climbing bittersweet, clematis, ivy, hop, climbing hydrangea, and honeysuckle.

The native honeysuckle prefers east or west walls. Its berries are eaten by birds.

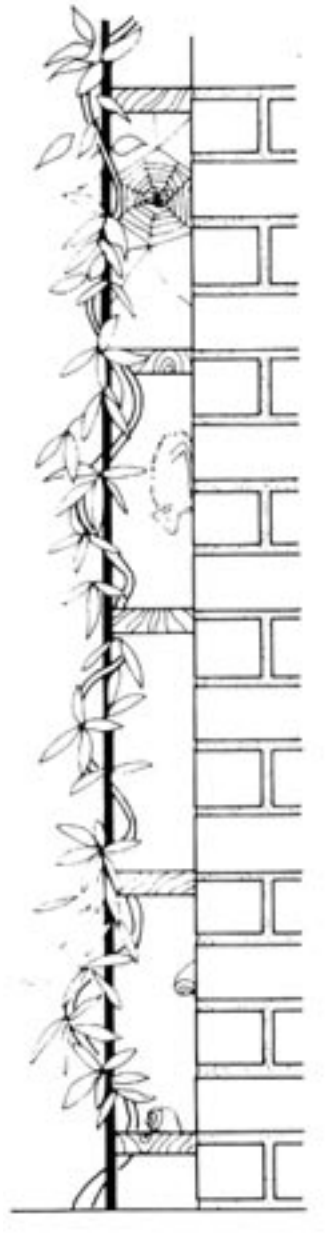
East walls may fall into either category. As a general rule, if the wall receives a fair amount of sun then it should be treated as south wall – if not it is best to use evergreens.

Evergreens, particularly ivy, are certainly the most appropriate climbing species for north facing walls which receive little direct sunlight and therefore stand to benefit most from the insulation effect of plants. Once again, thick growth on some form of structure positioned away from the wall offers valuable insulation. In experiments in Germany no air movement was detected in the space behind a 50cm thick growth of ivy [25].

North facing walls are best for supporting native herbs and wider ranges of plants. This is due to the higher moisture regime – something worth considering if a more natural appearance is required.

Further structural refinements for the space between the wall and the plants include pockets to collect leaf litter and provide nesting sites, and baffles to trap rising warm air [3].

Where an accent on native species is desired, one of the best ways of getting some idea of which species may grow best is to catalogue those



A 50cm x 50cm latticework of timber is an ideal support structure. A gap should be left between the latticework and the building façade.

already occurring in and around the locality, noting which are naturalised on walls. Of the climbers, ivy, honeysuckle, old man's beard and hop are all native species and attractive to people and wildlife. Hop is very fast-growing and can be used for a quick early effect in the first year while other species become established.

Wildlife considerations

Climbers provide nesting habitat for birds such as wrens, blackbirds, song thrushes and house sparrows. Particular species such as cotoneaster, ivy, climbing roses and some honeysuckles produce colourful berries enjoyed by birds as cold weather food. Köhler [26] has concluded from his research that climbing plants like Virginia creeper and ivy form important habitats for insects too.

Although native species are more likely to attract wildlife, some exotic species are also effective in this respect. For instance clematis provides useful nectar and seeds for birds.

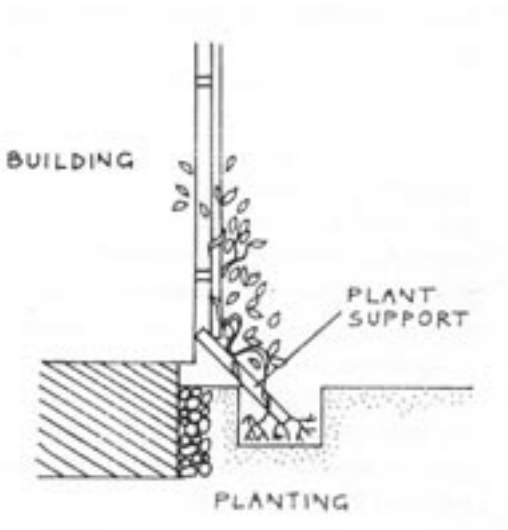
MANAGEMENT

Climbers may need radical pruning at some stage to prevent them from interfering with services such as guttering and finding their way into the building via apertures. However, this is unlikely to be a frequent occurrence, at least until a wall is fully clad; by then ivy, for example, may need to be pruned every two or three years.

Old walls, from time to time, need to undergo some structural repairs such as repointing. If possible some of the

Old Man's Beard produces nectar for insects and nesting sites and seeds for birds.

Hart's tongue fern is a beautiful plant of old walls and endangered by renovation works.



Climbers should be planted in a well-prepared pit at least 40cm away from the wall.

areas of the wall colonised by plants should be left in their original condition to provide continuity of interest and to act as a source of re-colonisation for the repaired sections. On older walls, rare species of mosses, ferns or lichens may be endangered by renovation work. Where in doubt as to the importance of the species, contact should be made with the local wildlife trust or natural history society which should be able to give advice.

Another point for consideration is the use of lime mortar which, because of its relative softness and flexibility, is a suitable medium for supporting plants. Lime mortar is particularly appropriate for garden walls although on buildings modern mortar is generally more appropriate since it ensures that plants do not penetrate too deeply.

The amount of irrigation required very much depends on the species used and the aspect of the wall. Plants growing on a south facing wall require far more water than those on a north or west facing wall. For those plants rooted into the wall, water supply is likely to depend on natural sources and the moisture-retaining quality of the substrate into which they are growing.

ALTERNATIVE GREEN WALLS

In recent years increasing interest has been shown in using plants not just as a skin but as actual structural components. Examples would be the use of plants to stabilise embankments – along roads, watercourses or adjacent to buildings.

Concrete or steel can be used to provide a skeleton of support to a wall or embankment while living plants are used to provide a natural dimension and to protect and bind exposed soil [10].

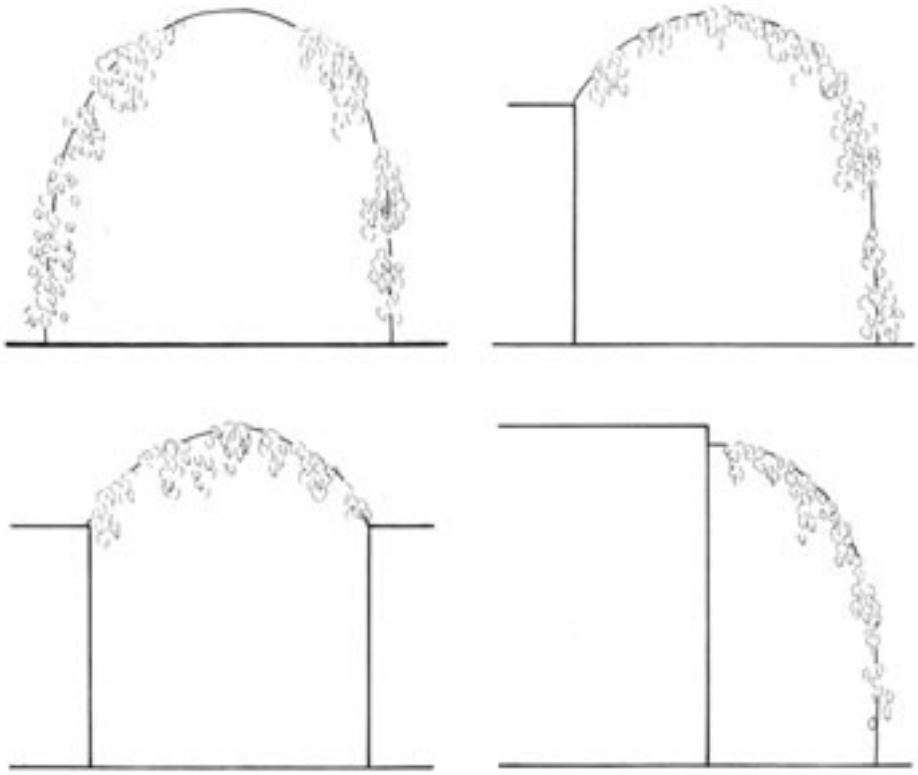
In certain circumstances living, woody material can be used as a structural component. A new concept in green walls is that of a soil bank held together with a framework of willow cuttings which sprout to form a hedge. The wall is erected in stages one metre high, with willow uprights supporting a basket weave of willow on the outside and soil inside. Cross members hold the two sides together. A second layer is established on top and so on until the desired height is achieved. An irrigation system is buried within the soil to ensure a luxuriant growth of willow, which is usually achieved within three months of planting.

The willow wall is particularly effective at absorbing noise, with a three metre wall providing nearly twice the protection of that of a simple earth bund of similar height [27]. Where noise levels are high frequency and are being emitted from a stationary source (rather than from road or rail traffic) then the effects can be even more dramatic. The willow wall also has the advantage of providing its own rather more soothing sound when the wind gently rustles the leaves.

A similar approach can be taken using steel rods of 3mm diameter welded into a mesh 75x150mm. A framework is built up which is then filled with soil and lined with turf. The result is an artificial wall resembling a Devon bank. Free-standing dry stone walls which incorporate soil and plants provide another alternative. A central cavity is filled with rubble and soil and an array of herbaceous plants can be encouraged to grow in the cracks between the stones, rooting into the soil which inevitably seeps through.

The leaves of Virginia creeper turn spectacular shades of red in Autumn.

Frames for climbing plants can stand alone, be attached to a wall, or span the space between two buildings.



A willow arbor.

Bowers, Arbours and Pergolas

These have long featured in formal gardens and landscape design, and were particularly popular in the 18th and 19th centuries as places for assignations and social gatherings. Their attraction lies in the illusion of being in the midst of nature whilst remaining close to home.

Nowadays they are less common, which is a pity since they provide many attractive landscaping options, giving form and structure to a green space as well as providing ideal locations for climbing plants. They can be used in a variety of urban situations from courtyards to terraces, as part of both commercial or residential developments.

7 building for birds and bats

The design and planning of urban renewal and new build schemes should take the needs of birds and bats into account. A wide variety of species can be attracted to nest on and in buildings, providing a great deal of enjoyment for the human inhabitants.

Many of the ideas discussed so far for greening buildings will automatically benefit birds by:

- providing food sources, either directly in the form of berries or indirectly as a result of encouraging invertebrates,
- providing cover.

This process can be taken a step further by supplying additional food sources, using feeders and bird tables attached to the outside of buildings or incorporated into their structure.

Traditional nestboxes can be incorporated into walls but should be sheltered from wind, rain and strong sun.

However, birds also need nesting places. In many locations natural nest sites will be insufficient or non-existent, so if birds are to be attracted, artificial nest sites must be provided on or around the building.

The same applies to bats, which need summer roosting sites and places to breed and to hibernate. Most species of bats are declining throughout Britain, and all are specially protected under the Wildlife and Countryside Act: it is illegal to disturb bats or their roost without consulting the statutory nature conservation agency. This includes the demolition of buildings occupied by bats.

NESTBOXES

A wide range of artificial structures have been used throughout the world to provide nest sites for a great range of birds (see page 46). They range from the familiar hole-entrance nestbox placed in gardens to attract small, hole-nesting birds, to large platforms (often old cart wheels) placed on top of chimneys by villagers in many parts of Europe to encourage nesting white storks.

Many types of nestbox can be attached to the outside of buildings. They should be sheltered from prevailing wind, rain and strong sunlight, and ideally placed on a wall facing north or east. Small, hole-entrance boxes will be used by tits, while open-fronted boxes may attract robins, pied wagtails, spotted flycatchers and, if larger boxes are used, blackbirds. Very large nestboxes will provide suitable sites for kestrels if placed on tall buildings. Artificial nests for house martins, made from papier maché or fibreglass, often attract other house martins to build natural mud nests nearby, especially if a narrow wooden ledge is attached beneath to

In many parts of Europe large platforms are placed on top of chimneys to encourage nesting white storks.

The natural mud nest of the house martin can be simulated in papier maché or fibreglass.

provide support. Similarly bat boxes can be attached to the outside of buildings. Designs for bird and bat boxes are given in the excellent guides "Nestboxes" and "Bats in the Garden". [28]

ADAPTING THE BUILDING

Buildings themselves can be regarded as artificial nest sites for certain species of birds. An urban house or office can be an artificial cliff to house martins, a cave to swifts, swallows, feral pigeons and bats, a tree with cavities to starlings and, of course, home to the ubiquitous house sparrow. More recently, kestrels have started to nest on scaffolding and tall buildings in London and elsewhere, and peregrines and merlins now do the same in several North American cities. However, in many places urban redevelopment is removing old buildings which were used by swifts and bats yet many new buildings lack suitable sites for these animals.

All of the nestboxes mentioned above can just as easily be attached to an existing building as to a new one. New buildings, however, allow for built-in nestboxes to be incorporated into the design. This may give an aesthetically more pleasing result, and offers scope to cater for a greater range of species.

Nesting areas built into the structure come in many shapes and sizes. Traditional boxes can be incorporated into walls, bricks can be removed, and gaps and ledges provided.

ALTERNATIVE WAYS TO INCORPORATE NESTING SITES INTO BUILDINGS

● open-fronted boxes (flycatchers, robins, wagtails, blackbirds)	-	design in by replacing bricks with wooden boxes
● hole-entrance boxes (tits)	-	design in, but ensure that front plate with hole is removable for cleaning
● quarter sphere (house martins)	-	place under eaves, terraces etc.
● small cavities (as open-fronted boxes)	-	create suitable gap by removing brick from façade
● gaps between roof (swifts, bats)	-	leave small gap or insert special roof tiles [29]
● purpose made bricks (bats)	-	replace ordinary brick
● ledges (kestrels)	-	design in at high level

The more obvious nesting devices can provide attractive design features by providing interest along a façade. The Swiss have produced specifications for architects wishing to design in gaps and cavities [30]. These need not be very large as small creatures such as the pipestrelle bat can squeeze through the tiniest of crevices.

Bats need minimal space under the eaves.

In addition, it is possible to construct something solely for the benefit of nesting birds. This has been done recently in Suffolk, where East Anglia's only breeding colony of Kittiwakes was threatened by the demolition of the unsafe South Pier in Lowestoft in 1988. The British Ports Authority built a new wall, with suitable nesting ledges, and the birds occupied this in the 1989 breeding season [31].

USING PLANTS

Growing plants on buildings may provide nest sites for birds. Climbing plants are particularly favoured by spotted flycatchers, and may also be used by robins and wrens. Shrubs in roof gardens or terraces may provide sufficient cover for blackbirds, song thrushes and dunnocks to nest. One of the best documented examples is the grass roof on the visitor centre at the Wildfowl and Wetland Trust reserve at Martin Mere in Lancashire. This has been home to nesting skylarks and regularly provides a suitable spot for nesting mallards.

A variety of nestboxes on display in Berlin.

When deciding which species of bird or bat to cater for in a building design, it is essential to consider which species might occur, both geographically and in terms of the surrounding habitat. For example, putting cartwheels on British chimneys is highly unlikely to attract white storks, which have not bred in Britain for centuries, and are only very rare visitors to this country.

Primary considerations are the food requirements and territory size of birds. For example, swifts are aerial feeders and travel considerable distances to forage, so any urban site is potentially suitable for swift boxes. Bats and most small birds, however, do not travel far to find food in the breeding season, and therefore need a suitable food source nearby. In practice, this will usually mean trees or bushes which attract good numbers of insects. Feeding opportunities provided by small areas of grass bring in starlings, and only a small amount of cover is required to attract songbirds such as goldfinch, blackbird and thrush. Using appropriate plants on or near buildings will encourage many more birds to inhabit even densely urbanized areas.

SOME URBAN BIRDS AND THEIR NESTING REQUIREMENTS

	Type of nest box	Dimensions (mm) (width/depth/height)	Situation
Kestrel	open fronted	300 x 500 x 300	High upon a tree or on the side of a building
Tawny owl	chimney type	200 x 200 x 800	
Swift	hole entrance	130 x 600 x 100 special design	Entrance under one end. Site under eaves or in loft.
House Martin	hole entrance cup shape	140 dia.	Site under eaves.
Wren	hole entrance	100 x 100 x 150	Site low down in thick cover
Spotted flycatcher	open fronted	150 x 100 x 100	Sit in thick ivy or honeysuckle. A missing brick in wall may provide an adequate nest site.
Robin	open fronted	100 x 100 x 150	Low down in thick thorny shrubbery.
Blue tit	hole entrance	100 x 100 x 150 entrance dia. 25	Between 2 and 5 metres off the ground
Great tit	hole entrance	130 x 130 x 200 entrance dia. 28	Between 2 and 5 metres off the ground.
Black redstart	open fronted	100 x 100 x 150	A ledge under the roof of a building

NOTE: Nest boxes should face any direction between north and south-east to avoid hot sun.
From: DuFeu, Chris. 1989. Nestboxes. BTO Guide 20, British Trust for Ornithology, Tring, Hertfordshire.

8 green roofs

Roofs present by far the most significant opportunities for the greening of buildings. Many cities have millions of square metres of unused and unattractive roofs. They represent enormous wasted opportunities for improving the quality of city life.

Every type of green roof makes a contribution to the urban environment. The largest help to cleanse the air. Smaller ones provide a source of food and shelter for birds and visual delight for city residents.

Many opportunities for creating green roofs exist in cities: tall office blocks; multi-storey or underground car parks; terraces between buildings and above basements or service areas; housing estate blocks or individual dwellings; and on earth-sheltered buildings of all kinds.

Plants on the roof at Scottish Widows HQ echo the landscape of Arthur's Seat beyond.

BENEFITS OF GREEN ROOFS

Green roofs make good sense. As well as benefits to the environment there are technical advantages for the building itself.

Amenity Benefits

One of the most attractive benefits of a green roof is its visual appeal. Green roofs come in all shapes and sizes and offer considerable creative opportunities.

For instance, in Edinburgh, the head office of Scottish Widows is located near the foot of Arthur's Seat – an extraordinary landscape of rock and moorland which stands imposingly over the city centre. The roof of the car park within the grounds cleverly incorporates a mix of heather, birch and gorse to echo the landscape.

Grass and shrubs above Cannon Street Station.

ADVANTAGES OF SPECIFYING A GREEN ROOF

Amenity
- psychological benefits of seeing greenery
- blends in with surroundings
- gardens for inhabitants of buildings
- masks ugly rooftops
- complements building forms

Ecological
- reduction of stormwater runoff
- provision of wildlife habitats
- absorption of CO_2, some air pollutants and dust
- links in city-wide networks of green space
- reduction of urban 'heat-island' effect

Technical
- protection of roof surface from ultra-violet radiation and mechanical damage
- thermal insulation
- acoustic insulation

Financial
- lower maintainance costs for roofing materials
- attractive to clients and owner (or leasee) of building facilities
- may help to win approval for planning permission

Modern office block in central Berlin with garden for staff on the roof.

Another example can be found at Laleham-on-Thames in Surrey. Here a garden centre was designed with a complete expanse of turf on the area of roof most readily seen from the main road. The roof was pitched at an angle of 10 degrees, allowing a good view of the turf from ground level.

Developers in Germany have already covered millions of square metres of roofs with vegetation.

The ability to blend in with surroundings can sometimes be a deciding factor with local planners. This is one of the most common reasons that developers specify a green roof, particularly in green belt areas or in the open countryside where it may be particularly important that a new building does not intrude. Meanwhile green roofs in the city can bring their own natural aesthetic to an aspect of urban buildings that is rarely given much visual consideration at all.

In some areas of Germany planning regulations now require the installation of a grass roof on flat-roofed industrial buildings. Such a requirement is included in Stuttgart's 1989 Law of Building Book [32]. Similar requirements may soon be in operation in Hamburg, Berlin and other German cities. There were an estimated one million square metres of low-maintenance grass roofs under construction in (West) Germany in 1989.

Visual appeal from above is an equally important benefit especially in urban areas. People living or working in high-rise buildings often look down on large expanses of ugly asphalt, tiles and slates with flat roofs usually being the worst offenders.

Green roofs are not only visually more pleasing, some also provide private gardens or communal lunchtime gathering places for those working in offices below. Space for informal recreation is at a premium in cities and roof gardens can be more secluded, less polluted and less noisy than an equivalent area at street level. If put under glass, a proportion of the green roof can be used for recreation earlier in spring and later in autumn, or even used to grow 'hot-house' crops from vegetables to flowers or indoor pot plants.

Benefits to Wildlife

Green roofs cannot be straight substitutes for wildlife habitats at ground level – many animals cannot get to the rooftop and growing conditions are not suitable for all plants. However many insects and birds will find suitable food and shelter and perhaps even a place to breed. Green roofs can go some way towards replacing lost open space beneath buildings, roads and car parks.

The spectacular International Hall, Fukuoka, Japan.

The most attractive green roofs for wildlife are those which supply an animal's four basic needs: food, cover, water and an area to breed. However even if all these requirements cannot be met a roof garden still provides another valuable link in a city-wide network of greenspaces.

Insects such as bees and butterflies can be attracted to roof gardens provided there is a good source of nectar: studies in the United States show that butterflies will visit gardens located as high as twenty storeys. The soil will provide a home to spiders, earthworms, beetles and ants. Roof vegetation is usually subjected to less disturbance than an equivalent space on the ground – an important factor to birds and insects wary of human disturbance.

Environment

Roof gardens embody many of the environmental benefits already described, for instance the improvement of the urban climate and more gradual absorption of stormwater (see page 11). The larger the green roof, the greater the environmental benefits.

Technical

Planting roofs affords technical advantages to developers, clients and people who live and work in city buildings. Chief among these is the high level of protection given to roofing materials: a layer of soil and plants keeps damaging influences away from the roof surface. A notable example is the roof garden on the Kensington High Street building original occupied by Derry and Toms department store. Installed in 1938, the roof membrane materials were examined some 50 ears later [333] and it was found that the roof surface was in excellent condition. In contrast, the average flat roof has a life expectancy of 10 to 15 years.

An extensive turf roof provides insulation for this London family house.

Perhaps the most important technical advantage of vegetation on the roof is protection from ultra-violet radiation. Planted areas heat up much less than exposed surfaces of asphalt or bitumen. Some studies show that the exposed area of a black roof can reach 80ºC when an equivalent area beneath grass is only 27ºC. The temperature difference between a gravel-covered and planted roof is less extreme but still significant: Köhler and Baier state that on average a gravel roof is 3ºC hotter in summer [34]. Reduced stresses on roofing materials mean longer practical life.

In winter erosion damage and fracture of roof surfaces by frost and ice formation can be lessened or even eradicated. One researcher found that in winter the roof surface temperature was -12ºC on a gravel roof, -5ºC on a planted roof [35].

A layer of soil and plants also protects the roof from physical damage. Recreation and maintenance activity can result in punctures or cracks, particularly when bitumic materials are softened by heat.

Green roofs can also add to the insulation value of the roof, sometimes by as much as 10% [36]. Kaiser has found that in summer the room temperature beneath a gravel roof was 30°C in contrast to 26°C under a planted roof [37]. The insulation values of different types of vegetation vary [38] and grass mixtures appear to be the most effective insulators in winter. Green roofs can also provide a degree of acoustic insulation.

Soil and plants on a roof need not weigh more than a typical gravel roof - about 80kg per square metre.

There are other positive advantages to gardens in the air. It may prove easier to provide open space on the roof than at ground level where complications may arise from toxic or impervious ground or underground pipes. Also the price of land may militate against creating open space at ground level.

Another benefit is more difficult to quantify – the financial value of planting the roof. Green roofs clearly attract interest and usually result in a positive image for those organisations that instigate them. They are attractive to planning authorities and provide added incentive to those looking to purchase or lease property.

LIVING CONDITIONS ON THE ROOF

To flourish on a roof, many plants will have to cope with harsher living conditions than those encountered on the ground. For some plants conditions will be intolerable. Others may find life on a roof amenable and they will grow quite happily. Lower concentrations of some pollutants and reduced disturbance from people are positive factors. The conditions in individual situations vary enormously and depend on combinations of local factors. The most common variables that need to be considered are wind, temperature and moisture regime.

Planted areas at Mountbatten House are stepped in terraces which give shelter from wind.

Wind

Wind speeds generally increase at higher levels. However, as any urban dweller can attest, wind speeds can also be high where the configuration of tall buildings creates a wind tunnel effect on the ground. Each situation will merit study to ascertain what wind conditions on the roof will be. Wind has a drying effect on plants and soils. It can also cause erosion of the substrate, particularly before good ground cover has been established. Strong winds can uproot or damage vegetation which has not been adequately protected.

Formal open space provided by the roof garden at Derry & Toms, Kensington, London. Built in 1938.

Solutions to wind problems are various. For new buildings, wind can be moderated by the configuration of the building; roof gardens can be provided as courtyards or terraces with other areas of the building providing shelter. This type of configuration is exemplified at Mountbatten House in Basingstoke where the attractively planted areas are stepped in deep terraces and sheltered by each successive storey.

Alternatively, protection can be provided by parapet walls on the roof top or the carefully considered placing of utilities associated with air conditioning, lift units or other building services. Hardy shrubs and hedges can be planted in such a way that they provide shelter for less robust species.

Temperature

Temperatures on the roof may vary significantly from those at ground level. Many high-level roofs will have no shelter from the sun and therefore are generally warmer by day, particularly where shielded from the wind. Scrivens reports that, as a general rule, it is common for the deeper soils of a roof garden in winter to be 5 to 10 degrees higher than those at ground level, and this aids plant growth [39].

Other variations have also been observed. In winter thin soils on the roof can freeze more easily than deeper soils on the ground. Köhler [40] shows that in mid-winter, the soil on the roof of an unheated building at the Technical University of Berlin was significantly colder than that on the ground below. On the other hand, the opposite effect takes place in summer: soil temperature can be up to 5°C higher.

Temperatures can also vary across a roof. Köhler [40] has assessed conditions for plants

- on a flat roof
- on roofs with a 12 degree slope to the north
- on roofs with a 12 degree slope to the south

Air temperature was found to be 1-5°C higher on the south side of the roof in the summer, resulting in a warmer substrate. In winter the temperature was similar across the roof irregardless of slope.

Such variations have a direct effect on plants; where temperature fluctuations are strong, vegetation adapted to cope has a better chance of survival.

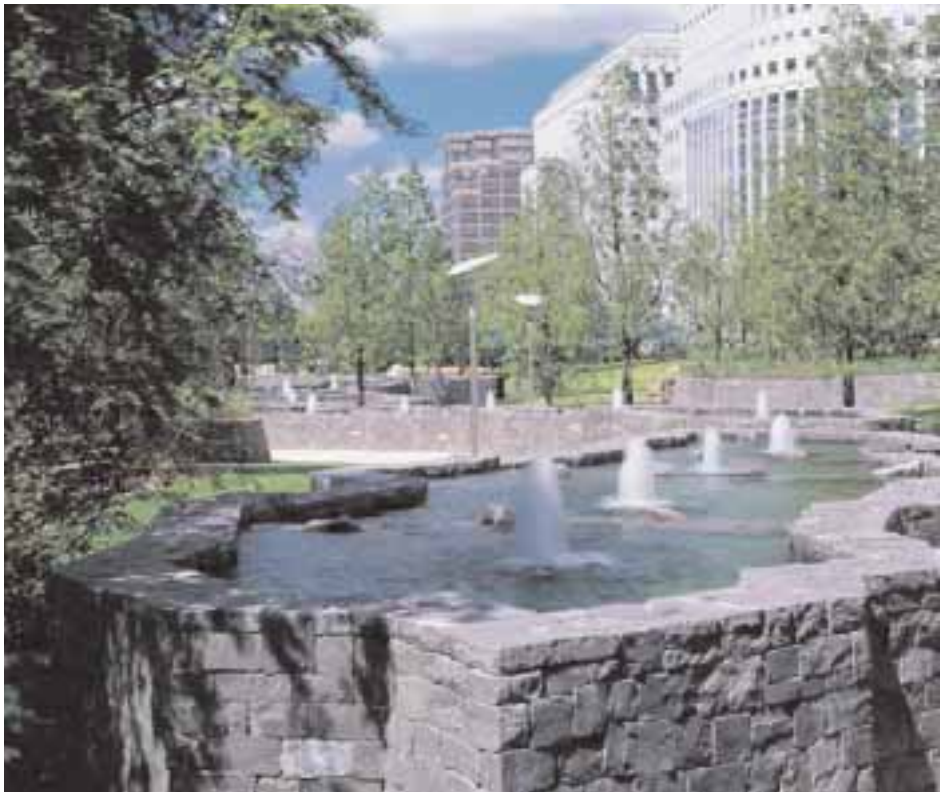
Moisture

Moisture is perhaps the most critical limiting factor for plants on roofs. Due to thin substrates and increased exposure, there is often rapid fluctuation between saturation and drought.

Water loss is a particular concern between May and September. During these months some form of artificial irrigation will probably be needed. To some extent this can be modified for extensive green roofs planted with drought resistant species (see below), or by incorporating rainwater-fed water storage sumps at roof level in the form of tanks or open pools. Even here, however, prolonged dry spells may necessitate some form of additional irrigation.

INTENSIVE AND EXTENSIVE METHODS

Methods for greening roofs can be usefully divided into two groups: intensive and extensive. These categories are commonly used to express different aims, methods and applications of green roofs. Various considerations will determine which method is best adopted.



Roof gardens above Canary Wharf underground station, London.

SOME CONSIDERATIONS FOR DESIGNING ROOF GARDENS AND GREEN ROOFS

Objectives

- nature conservation
- amenity
- informal recreation
- energy conservation
- improvement of microclimate
- gaining of planning permission
- integration within green development
- protection of roof

Site

- space available
- conditions
- aspect
- height above ground
- slope of roof
- strength of roof (load bearing)
- shelter
- distance from other green space
- wind speed and direction at roof height

Maintenance

- access to roof
- management of vegetation and facilities
- irrigation system

Costs

- substrate and plant materials
- hard landscaping
- maintenance and irrigation systems
- strengthening of structure
- equipment for erecting green roof materials (cranes etc.)
- professional fees

Intensive

Intensive green roofs, usually called 'roof gardens', are those which require intensive management. Typically, intensive roof gardens have thick growing medium, 200mm of soil or much more, an artificial watering system and a complement of plant species dominated by garden varieties. The prime objective of roof gardens is to provide open space for people; hence they usually incorporate areas of paving and seating. Well known examples in Britain include the Kensington High Street site, Mountbatten House, Scottish Widows in Edinburgh, Ready Mixed Concrete Headquarters in Thorpe, Surrey, and the garden above Cannon Street station. Roof gardens can vary. Given the appropriate substrate, irrigation, shelter and light levels, most kinds of garden can be grown: formal and informal, exotic and native, vegetable and herbaceous. All types of roof garden will be of benefit to some wildlife, however plants can be chosen specifically for this purpose (see 'Planting', page 62).

Luxurious vegetation on green roof above underground car park vent, Estepona, Spain

Although associated with high locations, roof gardens are equally applicable to other situations – for instance on top of underground car parks or in very large containers in urban plazas.

Extensive

Extensive green roofs are mainly developed for aesthetic and ecological reasons. Most aim to be self-sustaining, requiring low inputs of water, fertiliser and, in most cases, minimal maintenance. Growing mediums are normally much thinner, as little as 50mm, and plants are chose for their natural ability to survive the particular conditions associated with living on the roof. They are generally not used for recreation. Whilst gaining in popularity in continental Europe, this type of green roof is so far uncommon in Britain. Examples include the nature centre at the Wildfowl and Wetland Trust's Reserve at Martin Mere in Lancashire, and buildings at the Centre for Alternative Technology in Wales.

Formal roof garden above Cannon Street Station, London

ROOF GARDENS AND GREEN ROOFS: A COMPARISON

ROOF GARDEN INTENSIVE traditional

Deep soil, irrigation system, more favourable conditions for plants.

Advantages

- allows greater diversity of plants/habitats
- good insulation properties
- can simulate a wildlife garden 'on the ground'
- can be very attractive visually
- more diverse utilisation of roof, e.g. for growing food, as open space

Disadvantages

- greater weight loading on roof
- need for irrigation and drainage systems (greater need for energy, water, materials, etc.)
- higher cost
- more complex systems and expertise required

GREEN ROOF EXTENSIVE ecological

Thin soil, little or no irrigation, stressful conditions for plants.

Advantages

- lightweight – roof generally does not require strengthening
- suitable for large areas
- suitable for roofs from 0º - 30º slope
- low maintenance
- often no need for irrigation/ drainage system
- relatively little technical expertise needed
- often suitable for refurbishment projects
- can leave vegetation to develop spontaneously
- relatively inexpensive
- looks more natural
- easier for planning authority to demand green roof as a condition of planning permission

Disadvantages

- more limited choice of plants
- usually no access for recreation etc.
- unattractive to some, especially in winter

Because of its relatively low weight demands, the extensive method is suitable for large roofs and may be safely used on existing structures – a key point for many inner city areas where there is little scope for new development. Although this method provides less insulation value than the thicker growing mediums of roof gardens, it has the advantage of flexibility, being suitable for roofs with a slope of up to 30°. A brief comparison of roof gardens and green roofs is given opposite.

Earth-sheltering

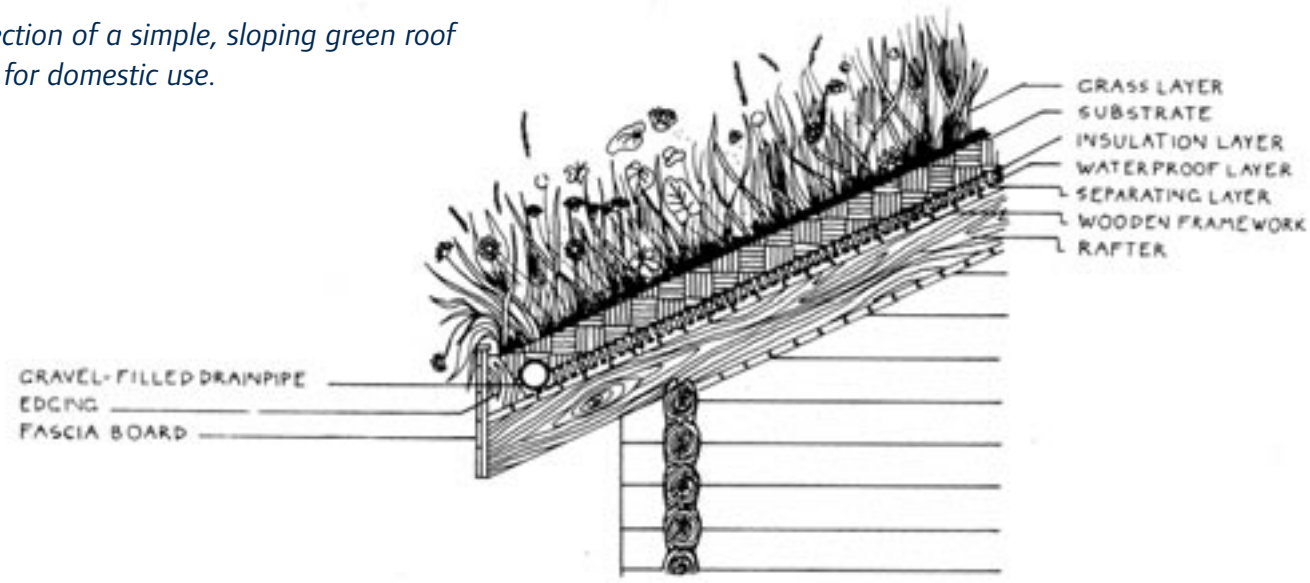
Earth-sheltered buildings are not technically green roofs but they bear many similarities to them. Although the division may seem somewhat academic, green roofs are separated by some distance (however minimal) from the ground, whereas earth-sheltered buildings are not: here the earth forms a continuous layer between the ground and the roof of the earth-sheltered building. Essentially these are structures built into the landscape.

Earth-sheltered buildings offer many of the advantages of green roofs: they blend into the surroundings, offer space for recreation, and are beneficial to wildlife and the wider environment. They are particularly beneficial in one very important respect: earth-sheltered buildings require very little energy to keep them warm due to the excellent insulating properties of the soil above. On average, running costs of an earth-sheltered building are 40 to 70 per cent of those for equivalent above-ground structures. An earth-sheltered conference centre near Monmouth in Wales uses no energy for heating and only small amounts for lighting and air circulation systems.

A striking earth-sheltered structure has been completed in Kew Gardens, London. The Sir Joseph Banks building houses an exhibition centre and is covered with grass and flower beds; it also has a small lake adjoining one side of the building. The benefits and construction of earth-sheltered buildings are not dealt with in detail here, but can be pursued elsewhere [41].

The spectacular earth-sheltered Sir Joseph Banks building in Kew Gardens in London.

Cross-section of a simple, sloping green roof suitable for domestic use.



TECHNICAL CONSIDERATIONS

Creating a successful green roof requires close liaison between many members of the building team. Aims and objectives must be clarified at an early stage, for this will have relevance to each part of the project. Particularly important aspects are:

- the load-bearing capacity of the structure
- the design of waterproofing and irrigation systems
- methods of getting soil and other necessary materials onto the roof.
- For all these reasons the designer of the green roof should be part of the design team from the outset.

Detailed technical considerations vary with each individual project. Again, the aims and the objectives of the green roof will dictate exactly what is needed. There are, however, four common aspects which need examination:

- layers for waterproofing and to facilitate drainage
- load-bearing implications
- irrigation
- maintenance costs.

A meadow has been added to the roof during the refurbishment of this inner-city housing block in Berlin.

The Upside Down Roof

Green roofs can be thought of as 'upside down roofs' where the waterproof membrane is near the bottom rather than at the top. Most roof gardens have the following layers from the bottom up: waterproof membrane, insulation, protective layers, drainage layer, filter mat and substrate. Extensive green roofs have a similar structure, but in some cases there is no need for a drainage layer

The waterproof membrane needs to have many properties in addition to its capacity to keep water from penetrating the building. Scrivens advises that this layer should be flexible, have good tensile strength, be easy and efficient to join and have relatively low adhesion to underlying materials [42]. Three coats of mastic asphalt is the common material used in Britain. For small areas, other possible materials include PVC sheeting, glass reinforced polythene liner, synthetic rubber, or bituminous materials reinforced with polyester. Particular care should be taken to ensure a good seal near air vents, chimneys etc. The suitability of the material in terms of environmental 'friendliness' should also be fully considered. A flood test at this stage is vital as repair will be difficult once vegetation is in place.

The waterproofing must be covered by a protective layer. This functions by protecting against root damage, structural movement, temperature changes and physical damage from gardening. Common materials are paving slabs or protective screeds of cement and sand. Extensive green roofs often have a layer like PVC as protection against penetration by roots. The PVC layer should be covered with felt to help anchor other layers and protect it from mechanical damage.

An insulation layer should be provided either separate from, or in conjunction with, the protective layer. In normal roof construction, insulation is provided beneath the waterproof membrane. However, in constructing a green roof the option exists to place the insulation above it; this has the advantage of keeping the whole roof structure warm and dry. Glass reinforced concrete, extruded polystyrene board or foamed glass with a sealed surface can be used. The insulation layer should be watertight. Many natural insulation materials are unsuitable, or difficult to obtain in quantity. This is unfortunate as many man made materials contain toxic substances. A partial solution is to press for much tighter emission controls on the manufacture of these toxic substances.

On top of the earth-sheltered conference centre near Monmouth, Wales – no energy is required to heat the building.

Drainage can be provided by two main methods:

- by laying the roof to a gentle fall and incorporating a layer of granular material (several centimetres thick) such as light expanded clay aggregate or pea gravel for the water to run through
- by using dual drainage and water retention layers (available from green roof system manufacturers) which act as a reservoir but allow excess water to drain away.

An even simpler method, where possible, is to allow the soil to drain naturally by pitching the roof on a minimum 10-15° slope. Certain extensive green roofs and those with taller vegetation will need a drainage layer.

Whichever system is used, drainage points will be needed. These can simply be covered holes where access to the drainage layer remains possible after the substrate and plants are in place. They need to be accessible from above for maintenance purposes and placed at regular intervals to function effectively and provide alternatives should one become blocked.

A filter later is also required to keep soil from infiltrating the drainage layer. Glass fibre mats of up to 50mm can be used, or newer materials such as polypropylene and polyethylene fibre mats. On roofs with a slope of more than 20º, timbers or other suitable materials will need to be laid across the roof to stop substrate and plants from sliding down. If grass turf is used this should be laid across the ridge.

Growing Medium

The growing medium used can vary considerably in accordance with many factors, such as the type of plants and the proposed method of irrigation. Soil depth can be as little as 10mm or over 2000mm. Generally shallow depths of 200mm or less are suitable only for extensive green roofs. Greater depths are appropriate for intensive roof gardens where a variety of trees, shrubs, herbaceous plants and grasses are likely to be grown.

An appropriate growing medium for intensive roof gardens is good quality topsoil.

IDEAL PROPERTIES OF SOIL FOR ROOF GARDENS

- good moisture retaining capabilities
- good water permeability
- good air retention
- good nutrient status
- an excellent rooting medium
- good plant anchorage properties
- minimal organic decay
- minimal shrinking
- resistance to rot and frost

	depth/mm
• grass	200-250
• herbaceous plants and shrubs	500-600
• trees	800-1300

To improve water retention and soil structure, other materials can be added – either organic materials such as various peat substitutes (see page 60) or inorganic materials such as perlite or vermiculite.

Scrivens warns that soil structure can be damaged in transportation or by over-mixing with other materials [42]. Soil should be handled carefully at all times and organic and inorganic materials should be added in discrete bands or nodules instead of being thoroughly mixed in. Caution is also needed to ensure that soils remain sufficiently heavy to provide good anchorage for plants, retain water, hold nutrients and are not susceptible to high wind speeds. High organic matter content in a substrate can lead to considerable settling over time.

Suggested soil depths given above may be substantially reduced in practice. With a good irrigation system, appropriate nutrients, sensitive management and judicious use of drought resistant plants, a roof garden can be developed on as little as 100-300mm of soil. For example, Mounbatten House has soil from 225 – 300mm, Kingston Hospital uses 100-400mm, and Cannon Street Station 200mm.

Appropriate substrates for extensive green roofs (overleaf) share many of the same properties as those for intensive roof gardens. The substrate should have good water storage capacity, not be easily eroded, and have good permeability for air and water. However, poor and relatively thin soils are best: these will encourage wildflowers which are tolerant of poor substrates, and help them to compete with more vigorous species which prefer richer soils.

This ideal soil will be composed of 60-70% pore volume, 30-40% firm substance, and incorporate 35-45% water and 15-25% air. The pH should be slightly acidic, with a value of about 6 [43]. Soils which are too rich can be mixed with a proportion of sand. Care should also be taken to use sterile soil if possible – without living plant fragments and with as few seeds as practicable. Heavy soils can be lightened by the addition of a proportion of lightweight clay granules.

Drainage points at Mountbatten House are easily accessible for routine maintenance.

APPROPRIATE SUBSTRATES FOR EXTENSIVE GREEN ROOFS COMPOSITION

Ideal soil will have:

• firm substance	30-40%
• pore volume	60-70%
of which	
water	35-45%
air	15-25%

Typical materials include mixture of:

- sterile topsoil
- subsoil
- sand
- clay granules
- gravel (16-32mm)
- clinker (crushed brick, concrete etc.)
- peat substitutes (bark, leaf mould, coir etc.)

Ideal characteristics include:

- moisture retaining
- low but adequate nutrient status
- large proportion of porous material
- lightweight
- peat-free
- free of living seeds and plant fragments as far as possible

DEPTH	**mm**
• self-established vegetation and moss	10-20
• succulents and other low rock plants e.g. Sedum, Sempervivium, Alyssum, Thymus	30-50
• grass and herbaceous	
• wildflowers	50-200

NOTE: Growing medium will build up as vegetation dies back each year, forming humus and increasing nutrient status.

'Roof gardens are a fascinating confirmation that in a man-made world we still seek a green place in which to live and work.'

JANET JACK
LANDSCAPE ARCHITECT

Appropriate substrates for extensive greening of roofs have been researched at the Bavarian Institute for Civiculture and Horticulture in Veishochheim, Germany. Dr Kölb and his team of researchers have tested over 50 different mixtures and identified several which are particularly suitable for use on roofs [38]. These include:

- 50% garden compost + 50% clay granules
- 60% clay granules (4-8mm) + 25% clay granules (<4mm) + 10% Vermiculite + 5% calcium bentonite
- 100% Hygromix (German premixed substrate)

Kölb also suggests a mulch of 20mm of brick, rock or lava grit (2-5mm) on the surface to help deter unwanted plants, especially aggressive weeds or tree seedlings. The mulch is also useful for reducing water loss by evaporation from the substrate. It is also good practice to water the substrate several times before planting to encourage settling, this is particularly important for substrates with substantial organic content.

Generally, no one substrate is suitable for all sites. An appropriate mixture should be chosen with reference to climate, location, and species that will be planted. Availability and cost of materials are other factors to consider. Topsoil should be avoided as it tends to be infested with weed seeds.

Although the ideal substrate is more complex, even pure sand may be used. This has been successfully employed on green roofs in Berlin. About 100mm of sand is laid on the appropriate layers of waterproofing, insulation and felts, and then soaked. Next, chopped pieces of stonecrop are sprinkled over the surface and covered with loosely woven Hessian. The sand is kept moist for a few weeks whilst the stonecrop takes root, thereafter it is self-sustaining.

Use of materials already available on site is good practice, for both ecological and economic reasons. Substrates such as sand and gravel, or even crushed rubble, brickwaste and concrete, may all be used to supplement organic materials used on the roof. This enables re-use of materials which would otherwise require disposal, so reducing transport costs, landfill requirements and production of new materials.

Although the substrate for green roofs should be relatively poor, it needs to have an adequate level of nutrients for plant growth. The nutrient levels will probably increase in time, as vegetation dies back each winter eventually to form a layer of humus. However this process is much slower than mineralization on turf or meadows at ground level where conditions are normally damper.

100mm of sand provides the substrate for a simple green roof of stonecrops. Hessian prevents erosion until plant cover is established.

Colourful stonecrops cover the roof of the Chicago Centre for Green Technology.

Dust and rainfall absorbed by roof vegetation will contain various minerals which will also slowly increase the nutrient levels of the soil. The choice material will depend on the type of green roof envisaged and plants to be used. A predominance of common garden species may benefit from peat substitutes rich in nutrients (e.g. compost and manure). Plants appropriate for extensive green roofs favour poor soils, so substances that improve the soil structure without enriching it will be best (e.g. bark, leaf mould, perlite).

Load on the Roof

Every roof has a particular load-bearing capacity. Adding vegetation and all the associated layers of waterproofing and insulation will add considerable weight. In some cases the roof will already be sufficiently strong, in others the roof will need strengthening.

With new buildings, conventional calculations should be made to ensure that the structure will withstand the weight of both dead loads and live loads. Dead loads include all of the materials permanently in place on the roof, such as layers of vegetation, insulation, waterproofing and substrate in a saturated state. Live loads include the weight of people and maintenance machinery.

LOADING ASSOCIATED WITH GREEN ROOFS

For each centimetre in depth, saturated	kg/m2
• topsoil	16-20
• sand	20-22
• gravel	16-18
• standard soil	7-9
• aerated clay (diameter 8-16mm)	3
• turf	5

Typical weights of a variety of green roofs	kg/m2
• special light-weight green roof e.g. using foam system	25-30
• Bauder system for extensive green roof on gravel	80-150
• typical extensive green roof on gravel	80-150

In refurbishment projects, it is generally simplest to incorporate an extensive green roof on thin substrate, which can weigh little more than the original covering of gravel or asphalt.

Typical weights can be attributed to substrates used on a roof. To this must be added the weight of waterproofing, heat insulation and drainage layer (if used). Felts and other materials used as filters and protective layers are usually very lightweight, however their weight should still be added into the calculation. Loads associated with trees, hard landscaping, large numbers of visitors and even heavy snow falls should also be taken into account.

The Technical University of Berlin is studing growth of stonecrops under a variety of simulated roof conditions.

PLANTING

The final layer on a roof is, of course, the plants. Appropriate species for planting on roofs include a vast array of native and traditional garden plants. The choice for intensive roof gardens is wider than that for extensive green roofs where the thin soils and absence of irrigation systems mean that a much narrower range of species can be used.

Plants should be chosen both for their ability to thrive in the particular conditions of growing on a roof (see 'Living Conditions on the Roof' above), and for their suitability for attracting wildlife. Native species which are adapted to the local climate and conditions, may require less maintenance and prove better able to provide the food needed by wildlife. The Nature Conservancy Council (English Nature) states that 'low maintenance wild plant gardens on roof tops in the UK could make an important contribution to the survival of Britain's native plants – including rare plant species' [47].

Creeping thyme in flower on the roof of Scottish Widows in Edinburgh.

Intensive Method

Roof gardens with suitable depths of soil can incorporate all of the usual features of a wildlife garden as found on the ground: trees and shrubs, flower beds, lawns and meadows and a pond.

Trees and shrubs are particularly valuable to birds, offering food, cover, song posts and nesting sites. When choosing trees and shrubs, look for species which provide flower for feeding insects in the spring, and seeds, fruits or nuts to feed birds later in the year. Hedges are valuable for providing windbreaks and shelter for other plants. Often a trellis or screen can be erected first to assist in training trees and shrubs in this formation.

	WILDLIFE BASICS
Food:	grow plants which are good sources of nectar and produce edible nuts, seeds or berries. When necessary, supplement natural food sources with nuts, seeds, lumps of suet or cheese.
Water:	make a pond, or alternatively provide an old sink or shallow waterproof dishes.
Cover:	aim to supply areas for wildlife to feed, hide, mate and breed. Provide some areas of dense cover of shrubs and trees (where soil depths allow), tall grass, piles of leaves, logs and stones.
Breeding Areas:	provide vegetation that gives protection from the elements and freedom from disturbance. Add bird boxes, bat boxes, and other artificial breeding sites.

When planting flower beds choose wildflowers or garden varieties rich in nectar and pollen to attract bees, hoverflies and butterflies. By careful selection it should be possible to provide colourful flowers from spring to autumn, providing food for insects for many months of the year. Shady areas in the flower border or between shrubberies may be suited to ground cover plants. These should again be chosen for their food-providing flowers and for their fruits and provision of dense cover.

Succulent plants can be grown in commercial nurseries for use on roofs.

Lawns need not be simple rye-grass sward – they can contain attractive flowers. Specialist seed suppliers can provide suitable mixtures of meadow plants, or individual species for introducing into specific areas (see List of Suppliers page 95). Another possibility is to grow a herbal lawn of chamomile and thyme.

Ponds provide another wildlife habitat, as well as water for birds to bathe in and drink. A great variety of plants and animals are at home in an aquatic environment and can increase the amenity and wildlife interest of the roof. In certain circumstances it may be possible to encourage water-loving insects and amphibia – for example, where the roof is continuous with the ground.

Extensive Method

As noted, the thinner soils of extensive green roofs support mainly low vegetation – trees and shrubs are generally inappropriate. Certain herbaceous plants, succulents, grasses and mosses are best. Tolerance to the roof climate and appeal to wildlife should be the criteria.

Through studies of spontaneous vegetation on unplanned green roofs, a picture of suitable plants begins to emerge. For instance many roofs covered with a layer of gravel or tiles will eventually become colonised by mosses, grasses and certain drought-resistant herbs. Prinz [44] particularly favours mosses because they can easily cover large areas, store moisture, survive drought, add little weight to the roof, have minimal nutrient requirements, display a good tolerance of pH levels and are tolerant of a range of light levels.

Given the right conditions, moss will naturally colonise undisturbed roofs.

Trillitzsch [45] describes a study of an old factory roof (constructed in 1910) of approximately 500 sq.m. The original 40mm layer of gravel laid on top of the roof had grown to a 60-70mm mixed layer of gravel and humus almost completely covered by moss. In shaded areas trees such as willow, alder and ash colonised and established themselves by spreading their roots over a wide area. Trillitzsch found that a similar green roof could be established by covering a roof with 50mm of gravel plus 20mm of garden soil and planting with pieces of moss at 150mm centres. After four years the coverage of vegetation was almost continuous.

Other types of plants have also been frequently observed on undisturbed roofs. Plants of the stonecrop family and several grasses may self-seed. Stonecrops are particularly suitable, being succulent and therefore drought-resistant, and naturally found on rocks and walls, sand and gravel. They are also particularly attractive and therefore well suited to areas of the roof visible from ground level. Grasses such as fescues, bromes and meadow-grass are also common. Criteria for choosing appropriate species are given on page 67 and appropriate species for planting on green roofs on page 91.

Generally, the most favourable time to plant is between October and March for most of England, Wales and Ireland, or from April to June in colder areas, to avoid frost damage.

Different planting strategies can be used on roofs in accordance with the angel of inclination. Flat roofs are the least prone to erosion and therefore can be sown with suitable seed or planted with young plants grown in 4cm compressed earth pots, at a density of 20 to 25 individuals per square metre. If turf is used, this need only be placed along the roof edges, with perhaps a few sods in the middle of the roof to act as a seed source. Turves can be interspersed with seeded areas, and small areas of bare soil left to be colonised naturally. On flat roofs with a drainage layer, more turf can be used to help stabilise soil. In general, flat roofs tend to have a more diverse sward with a richer variety of plants than angled roofs. For this reason flat roofs usually attract more insect life.

On steeper roofs of 8 or 10º and above, the use of turf is recommended. Vegetation needs to be close-knit and strongly rooted to help prevent erosion; therefore grasses are preferable to herbs, which are used in a secondary role. Strips of turf about 130 cm in length are placed across the ridge and down the sloping sides of the roof.

If there are some small gaps in the coverage of turf, young specimens of herbs such as stonecrop and houseleek can be planted in. Some herbs will colonise naturally over time, particularly those that are not heavily dependent upon moisture – those that prefer wetter conditions will tend to remain at the bottom edges of the roof where soil water is retained longer. Such strongly-rooted plants are particularly useful here for helping to prevent erosion as well. As an additional measure, it is also useful to sow a seed mixture of grasses that prefer dry conditions across the whole of the roof on top of the turf; this helps to ensure that any gaps, either existing initially or created with small areas of turf which do not flourish, will be filled.

In some situations it may be possible to use turf from wasteland areas. Particularly suitable is turf from threatened sites – those designated for destruction through development for instance – and that which is covered with low-growing ruderal vegetation.

Green roofs require very little maintenance – perhaps just an annual removal of invasive plants.

CHOOSING APPROPIATE PLANTS FOR EXTENSIVE GREEN ROOFS

Growth Habit

- low growing – generally less than 60cm
- establish a dense root layer
- capable of regenerating after periods of stress
- able to form resilient, permanent cover
- strongly rooted – particularly for steeply angled roofs
- drought resistant characteristics such as thick protection layers, a strong system of veins, and good water storage capacity
- some plants that will grow quickly are needed to help stabilize the soil (where turf is not used)

Cultivation

- tolerant of thin soils
- compete well on nutrient-poor soils
- prefer free-draining soils
- tolerant of drought
- survive periods of waterlogging
- enjoy, or at least tolerant of, a sunny aspect

Typical Natural Habitats

- wasteground
- gravel and sand pits
- walls and other hard surfaces
- dry grassland
- heathland
- rocky outcrops

Other Considerations

- appropriate species will vary in accordance with the angle, position and height of the roof
- species should also be tolerant of prevailing climatic conditions
- visually attractive with wealth of blooms, good colour and scent, and a blend of low and taller plants, deciduous and evergreen
- predominance of native species for their value to wildlife
- maintenance free
- use of young plants, seed or turf depending on roof

'I always think that it is somewhat tragic that when you contemplate the view of any city from a high-rise building that the possibility of re-creating the ground level site at the top of a building is generally squandered.'

NORMAN FOSTER

Many plants which are attractive to wildlife are also beneficial to the wider environment: they don't need fertilisers, are less susceptible to pest attack and drought and may require less management. Plants suitable for use on extensive green roofs should require very little maintenance, being

Turf is particularly appropriate on sloping roofs.

self-sustaining. Using naturalistic vegetation is particularly desirable if costs need to be kept to a minimum.

ESTABLISHING VEGETATION ON AN EXISTING ROOF

Whether or not an existing roof is suitable for greening depends on the existing load bearing capacity, how well the roof has been sealed or waterproofed, the roof angle, and method of drainage. Of these the key factor is roof loading. Once this has been established as adequate to take the additional load associated with soil, plant and protective layers (100-200 kg. per sq.m. on a typical extensive green roof), planning a green roof can begin. A step-by-step guide to establishing vegetation on an existing roof is given overleaf.

THE VALUE OF GREEN ROOFS FOR FAUNA

Muller [46] studied the vegetation of ten grass roofs, from two to five years old, to investigate invertebrate populations. He found that the typical roof fauna consisted of highly mobile species. Organisms preferring moist conditions were absent and conditions did not favour temperature-sensitive species such as earthworms.

Wildlife will also vary with many other factors. Initially, invertebrates will colonise rapidly if brought in with the substrate used on the roof. Colonisation is also aided if the green roof is directly connected to the ground, as in earth sheltered buildings.

STEP-BY-STEP GUIDE TO GREENING AN EXISTING ROOF

1. DESIGNING

Planning and design

- contact local planning authority if necessary
- contact experts as needed
- calculate
  - loadbearing capacity
  - angle and aspect of roof
  - area of roof
  - strength and durability of existing waterproofing
- draw roof to scale, including various extensions, ducts, chimneys etc.
- make planting plan, including consideration of sunlight, sheltered areas, areas visible from ground level
- select roof seals, drainage method, and possible subsidence preventions for roofs > 20°
- calculate soil and plant needs

Preparation

- identify possible sites for obtaining 'threatened' turf
- obtain quotes for materials, and professional and contractors fees where necessary
- order materials

2. INSTALLING

Setting up the framework

- position clamps and connectors
- install timbers at eaves and batons to prevent soil slippage
- construct border drainage

Sealing the roof

- clean the roof
- prepare all technical fittings
- lay first layer of protection foil and seal all edges
- lay second layer of protective fleece
- weigh down with stones

Putting in a drainage layer

(for flat roofs 0°-5°)

- install drain plates
- cover with fleece layer
- install clay layer for 0° roof
- cover with filter layer
- check border drainage

3. GREENING

Laying the soil

- mix materials (topsoil, sand, clay aggregate etc.)
- lift soil to roof (using soil bags, hoists, cranes as necessary)
- lay even depth of soil and rake to smooth out surface

Planting

- collect turves and purchase plants
- roll out turf perpendicular to ridge
- bed in additional plants
- sow with wildflower seed mix for dry conditions, rake in
- water well
- plant self-clinging climbers at base of chimneys, ducts etc. to cover vertical surfaces

Maintenance

- water well for initial few weeks, then water only during periods of severe drought
- remove tree seedlings occasionally

Choosing plants that will tolerate drought reduces dependence on irrigation.

Generally roofs that are a considerable distance from ground level will have a poorer fauna due to difficulties in dispersal. Nevertheless examples of animals found at high level include bees on the 23rd floor, and, in New York, squirrels and birds including woodpeckers, goldfinches and blue jays on the 19th floor [47]. The numbers and types of birds and insects seen will vary in accordance with available green space around the building – an office block in a city centre with no parkland nearby will have correspondingly poor fauna associated with it.

One of the best documented examples of how a green roof is used by birds, is located at the Wildfowl and Wetlands Trust Centre at Martin Mere in Lancashire. The green roof on top of the visitors' centre was constructed in 1975 using a double layer of turf – one grass-side down, and the other grass-side up. Turf cut from marshy areas within the centre's grounds was used, with a layer of wire netting sandwiched between the turf. The wire was laid in a continuous piece over the ridge of the roof, which stopps the upper layer from slipping. Mallards, skylarks and various finches and thrushes have all used the green roof. Mallards regularly breed on the roof, although most other species have not nested, perhaps due to the disturbance from the occupants in the rooms below.

The type of plants grown is highly significant for some animals. As on the ground, plants which provide nectar, fruit, seeds and nuts are best. Structural diversity is also vital: areas sheltered from disturbance by wind, rain and people provide the seclusion needed for feeding or roosting. Providing water, even if only a very small amount, will greatly benefit wildlife. For instance wagtails can often be seen searching for dead invertebrates in puddles on roofs in autumn and winter.

MANAGEMENT OF GREEN ROOFS

The need for maintenance on green roofs varies widely: some extensive green roofs will require very little maintenance, perhaps just occasional watering during severe drought and removal of tree seedlings. Kolb [38] estimates that time needed for removal of unwanted plants and tree seedlings on an extensive roof should be about eight minutes per square metre per year. For roof gardens on deeper soil, maintenance required will reflect the original choice of plants for the garden and the aims and objectives of establishment.

Irrigation

Artificial irrigation is vital for intensive roof gardens, particularly those where plants have not been chosen for tolerance to drought. Such high technology landscapes will do best with high tech solutions: built-in irrigation systems electronically controlled. A more environmentally-

friendly approach is to store water on-site for use in irrigation. Water can be stored in a tank from surface water run-off as at Mountbatten House in Basingstoke. Water is therefore recycled rather than allowed to run off site into the sewage system. Easy access to an irrigation source is needed for every green roof, even if only for initial watering or during periods of severe drought.

One way to reduce dependence on irrigation is to choose plants that will tolerate arid conditions; these can be specified for either intensive or extensive roof gardens. Many plants have growth forms and other means of protection for surviving prolonged dry spells. Succulents are well known for this as are mosses which lie dormant as necessary. Many grasses will bounce back after long periods without rain, as shown by extreme conditions during the summers of 1976 and 1990 in Britain. Also suitable are herbaceous plants and shrubs which occur naturally on sandy and gravelly soils such as in lowland heaths, dry grasslands, or on artificial substrates such as brick rubble and other waste ground. Examples include shrubs such as gorse and buddleia and herbs such as rosebay willowherb, evening primrose and a variety of alpines.

Köhler [40] found that where moisture is very limited, plants will generally have low growth forms and a high root to shoot ratio. Plants may stop growing in summer until rain returns in the autumn. Generally, for extensive green roofs irrigation is unnecessary unless there is a very prolonged dry spell. Whichever species are planted they should be given a thorough initial soak and watered regularly for a few weeks to aid establishment.

Maintenance of Vegetation

As with irrigation, plant maintenance will depend on the species chosen and design objectives. A low-maintenance landscape is best achieved through a naturalistic approach for example, grassland areas can be managed as hay meadows, cutting once a year and removing the clippings or composting them elsewhere on the roof. Some grass roofs require very little maintenance. The grass on the visitors' centre at Martin Mere is allowed to grow and die back naturally each year and it is not mown.

The only management is occasional pulling of invasive plants such as ragwort and thistle. The turf is not watered and may die back and look yellow during dry summer periods, but it soon turns green again in the autumn. Wildflowers occurring spontaneously in the sward are allowed to flourish, and fallen leaves left to provide habitats for various birds and

Flower-rich meadows prefer nutrient-poor soil – as demonstrated on a roof at the Chelsea Flower Show.

insects. This represents a flexible approach to natural changes in species composition over time.

The need for fertilisers is reduced by this approach. Flower-rich meadows thrive on nutrient-poor soil whereas traditional lawns require periodic additions of fertiliser. The drought-tolerant herbs and shrubs mentioned above will also grow well without such additives. Incorporation of composts could be considered where extra nutrients are required for certain species. In this case, a holistic approach with on-site composting designed in, may be the best course.

COSTS

The cost of creating a green roof must be weighed against the many benefits discussed above. Capital costs of developing an intensive roof garden will be considerable: there will be a need for 200mm or more soil on the roof, various drainage and protective layers and perhaps an irrigation system. Load bearing structures may need to be enhanced for reasons already discussed. However, if planned from the outset roof gardens may be included in the design of a building at little or

ESTIMATED COST OF ESTABLISHING AN EXTENSIVE GREEN ROOF

	per sq.m.
● 2 fleece layers	£3
● root protection mats	£5
● waterproof seal	£5
● soil mixture	£4
● plants and seeds	£2

TOTAL £19 per sq.m. plus incidentals (sealant, clamps and connections)

Optional Additions:	**per sq.m.**
● heat insulation	£10
● drainage layer	£3.50
● timbers to prevent slippage	
● professional/contractors fees	

From: Hauser in Lebendigem Grun (Buildings with a living green cover), Mehl and Werk (1987).

no extra capital cost. Brownlie cites the example of the Willis, Faber & Dumas building in Ipswich where the developers made savings on structural elements of the building. This in turn paid for the development of the garden [47].

Costs for creating an extensive green roof are generally much less than those for an equivalent area of intensive roof garden. Some estimates suggest that costs could be reduced by 50% or even as much as 80%, particularly as green roofs usually do not need extra structural reinforcement [47]. The much smaller depths of soil, usually less than 150mm, normally mean that loadings are equivalent to that needed for a flat roof covered with gravel chippings. An irrigation system is not normally needed.

The simplest green roofs cost about £20 (1987) per square metre for DIY enthusiasts, or approximately twice that sum where further layers (insulation and drainage) and fees are added in. This accords roughly with an estimate in Berlin (1990) that each square metre of green roof established professionally cost approximately £50 to provide. In the developer's terms, this would mean that a very modest additional rental of 3/4 pence per square foot would need to be levied on a seven storey building. In some cases, providing a green roof will be little more expensive than a traditional three-layer bitumen and gravel roof, particularly where a green roof is specified from the initial sketch design phase. However, using a system such as that supplied by Erisco Bauder, costs about three times as much as an average flat roof.

On both types of green roof one of the significant costs is the hauling of the soil onto the roof. Even to create a small green roof only a few storeys up, a crane will be needed and hire costs may be considerable.

Maintenance costs vary in accordance with the objectives of the green roof. Formal gardens with demanding species will require a lot of watering, weeding, fertilising and clipping. Less formal and more naturalistic gardens will need specialist but less intensive maintenance, resulting in lower costs.

All of these costs need to be weighted not only against the benefits of green roofs but should be viewed in relation to the total contract sum. Köhler and Schmidt [6] cite the example of a roof garden for a new administration building for the Chancellor of Germany, costing approximately DM 115,000 (£38,000) – a modest 0.1% of the total contract price of 115 million DM.

The Willis Faber Dumas building by Fosters Associates includes roof-top open-space for staff at no extra cost.

9 green buildings: a vital part of sustainable cities

The techniques and approaches discussed in this book will be most effective when undertaken within the context of larger initiatives – neighbourhood schemes, large scale new developments and green strategies for entire cities.

Wetland area surrounding housing in Malmö, Sweden.

In Britain and elsewhere, the subject of greening buildings has so far been very much undervalued. As we have seen, greening buildings brings a wealth of practical and psychological advantages to towns and cities, improving ventilation, unsealing hard surfaces, providing shelter and insulation, sustaining wildlife and otherwise helping to offset the many unhealthy and dehumanising effects of high density urban environments.

These are not pipe dreams – they are real, measurable benefits which have already been achieved in some parts of the world by enlightened planners, developers, architects – and particularly communities. The clear lesson to be drawn from their achievements is that green buildings are at their most effective as an integral part of a broader green scheme.

However, it is also important to remember that the greening of buildings is an intrinsically valuable thing to do; as such it is relevant to many types of building projects. It represents a valuable focus and a practical starting point for everyone- both individuals and members of the relevant building professions – who may otherwise feel powerless to take action until comprehensive environmental policies are in place at every level. Even where the physical advantages of individual efforts are small, the psychological and inspirational benefits of action should not be underestimated. Also, experience has shown that what starts out as a relatively small initiative can sometimes be the seed for concerted neighbourhood action; this in turn can have wider effects.

Sustainable urban drainage system in Malmö, Sweden

Sustainable development requires the consideration of a whole host of interconnected elements – the reduction of energy and water consumption, minimising waste and pollution, the use of environmentally friendly materials, and providing efficient public transport. Green space, including the greening of buildings, is just one piece of the jigsaw – a vital piece that concerns us here.

To ensure that an urban renewal or new development scheme maximises the provision of green space, a number of principles can usefully be employed. Not every principle will apply to each building project, but the list should give valuable guidance.

A few examples will illustrate how these principles can be applied in practice.

At Block 103 in Berlin a 'vertical swamp' cleanses greywater for re-use.

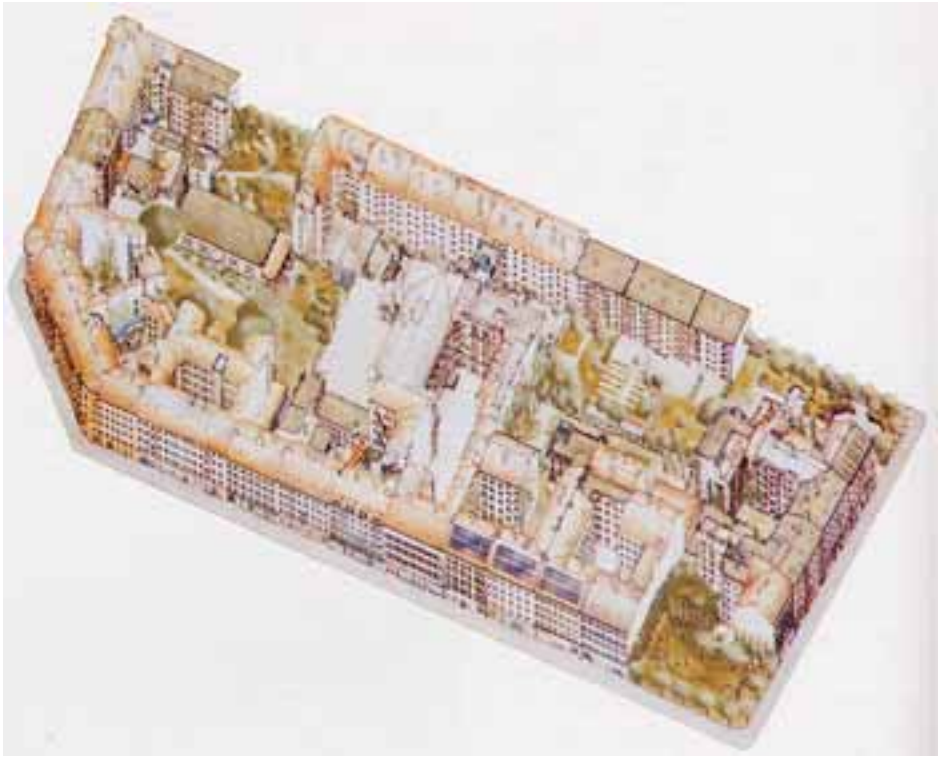
MAKING IT HAPPEN

Block 103, Kreuzberg, Berlin

The renaissance of this inner city district provides an illuminating demonstration of how green developments can grow from unpromising beginnings.

Despite some very local circumstances, Kreuzberg had embodied many of the classic symptoms of urban degeneration. Once a mixed residential/business district, it became gradually isolated and its businesses were moved out to make way for a proposed autobahn which, in the end, was not built due to the continuing presence of the Berlin wall. Eventually squatters moved in to the various tenement blocks including Block 103. After much negotiation with the local authorities, squatters and residents teamed up with a non-profit making company to establish an imaginative new style of tenancy. They inaugurated a framework of pilot projects in energy generation, water and refuse recycling, the use of environmentally sensitive building materials – and greening.

Nearly 40 per cent of Block 103's roofs have now been planted, bringing a variety of benefits, including a beneficial increase in humidity and improved insulation



Plan for the ecological refurbishment of Block 103 in Berlin

Many façades have been planted with climbers, and plants are grown on balconies and terraces. An innovative project on one building is the creation of a 'vertical swamp' by fixing rows of swamp grasses in planters down the side of the façade; water is released in measured amounts into the top planter and then, through a system of pipes and drains, is filtered through successive layers of grasses. Upon reaching ground level the cleansed water can be re-used.

PRINCIPLES OF SUSTAINABLE DEVELOPMENT: GREENSPACE

1. Make the best use of what's already there

- identify those areas that it is important to retain
- retain and enhance:
  - valuable wildlife habitats
  - other green space valued by the local community
  - large areas of green space beneficial to the microclimate
- make the best use of existing natural landforms in planning and design

2. Maximise opportunities for new planting

- plant before building where possible
- use vegetation as buffers for buildings against wind and rain
- seek to replace any green areas lost with an equivalent amount of green space within the development site
- plant on and between buildings
- create a variety of greenspaces from formal parks to city farms, community gardens and nature parks
- link green areas by green pathways and waterways

3. Minimise sealed surfaces

- use paving systems which incorporate vegetation
- use plants as alternatives to hard landscaping for fences, barriers, walls etc

4. Use vegetation for filtering and cleaning water

- create wetlands with reedbeds
- consider 'vertical swamps' on façades (water is filtered as it trickles down through vegetation and a series of pipes and drains)

5. Plan for long-term management of green areas

- decide objectives, management agency and funding

6. Community involvement

- involve end-users fully in the planning and management of green areas.

Block 103 in central Berlin is a showpiece for the use of natural vegetation alongside paths and entrances.

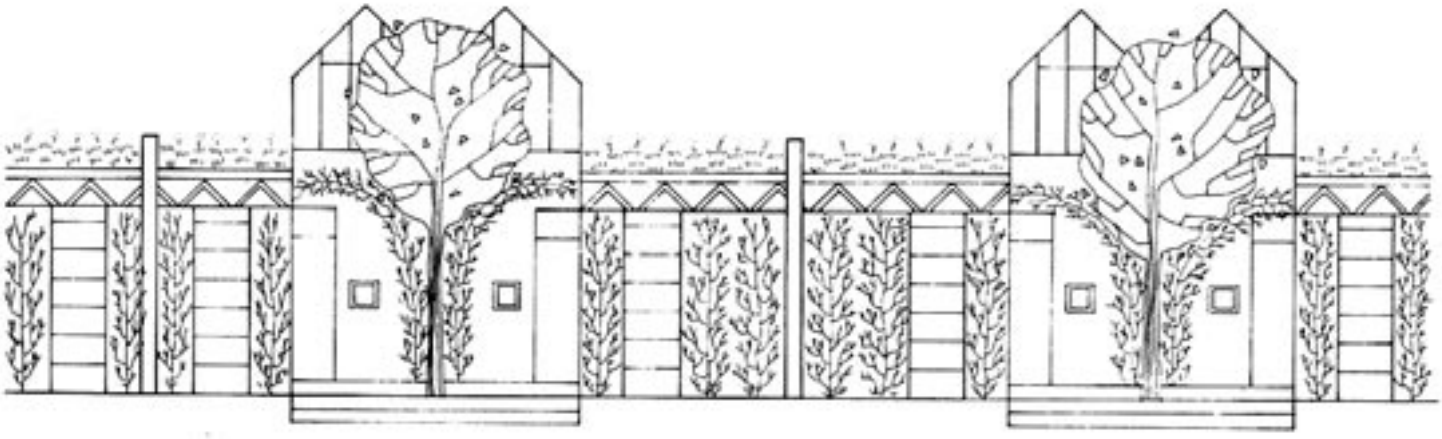
Detail of the 'vertical swamp' at Block 103 showing the system of pipes and planters in successive layers.

Courtyards have been planted with trees, shrubs and climbers to improve the microclimate. New community gardens have been created with a 100 metre long wetland area to filter and cleanse water for re-use. At Block 103 the greening of buildings takes its natural place in a radical new approach to urban regeneration and high density living. It is an example of ecological urban renewal that could be replicated in many inner city areas.

Torsted West, Horsens, Denmark

Torsted West is an 80 hectare district within the town of Horsens, Denmark. It is the site of a bold initiative in creating urban communities to a new set of principles founded on the concept of a Healthy City.

Torsted West is the product of an enlightened local and national government committed to promoting the physical, mental and material



A model green development would include green roofs, green walls and generous planting around buildings.

well being of its citizens. The town council has from the start pursued a policy of consultation, debate and involvement of local people.

The development illustrates how ecology and nature may be integrated into town planning. Valuable areas of woodland, wetland and meadow have been retained, and new greenspaces created. Green areas infiltrate deeply into built development and total area of hard surfaces is minimized.

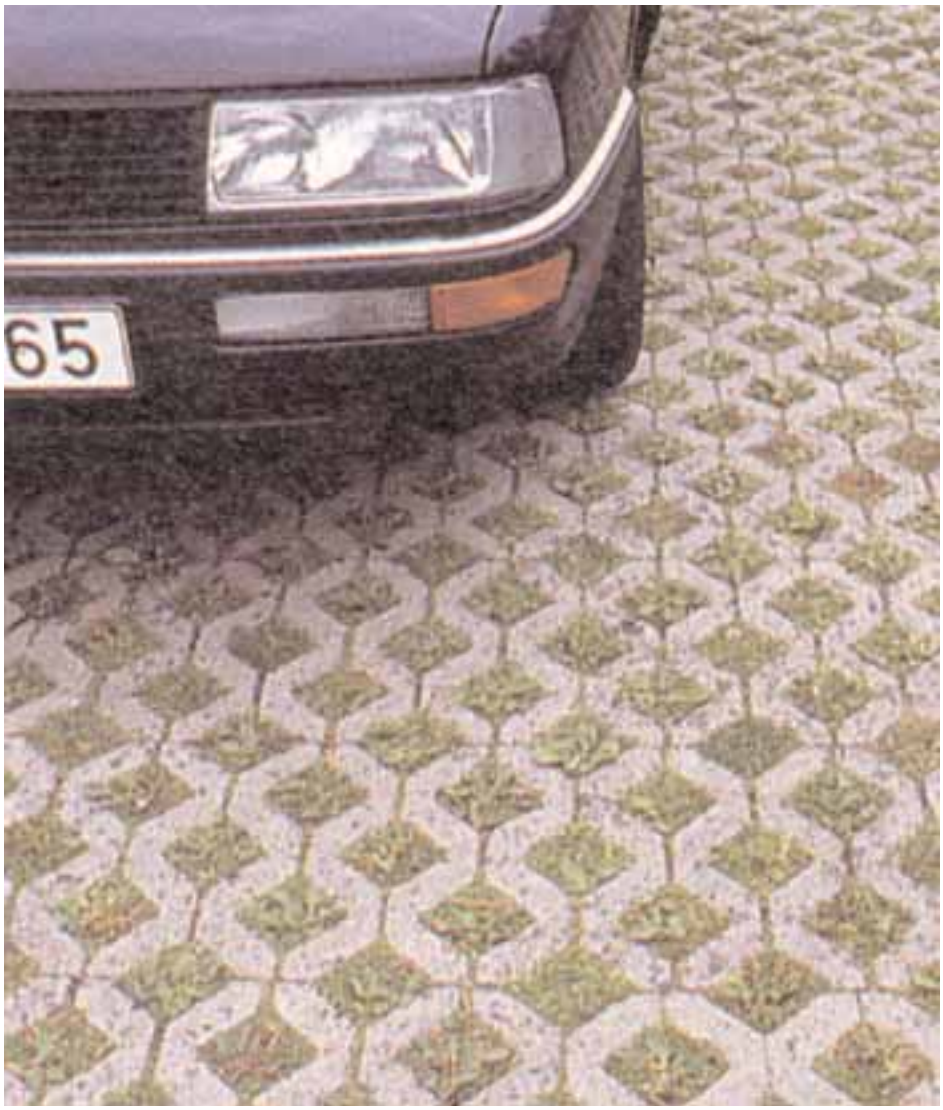
In addition to its excellent plans for nature, Torsted West will prove a valuable test bed for developing new building methods, healthy materials and new energy and water installations.

Plan for the new green development at Torsted West in Horsens, Denmark.

The Torsted initiative exemplifies many admirable and inspirational attitudes: ecological commitment, political will, a willingness to consult and an understanding that its efforts have national and international significance.

The successful establishment of schemes like Block 103 and Torsted West are highly significant. They demonstrate that innovative solutions to environmental problems can deliver very positive results. They are pioneering developments which should one day be standard practice.

With examples like these and many others now emerging, there is a growing catalogue of visible, working solutions to the gradual achievement of sustainable cities. Clearly, there is something that individuals and members of the relevant building professions can do. People have already done it. We hope that this book will play its part in encouraging others to do as much, and more.



10 conclusion

In the previous chapters we have attempted to demonstrate the value of re-introducing vegetation to the surfaces of urban buildings and their related spaces. We have suggested that, far from being a radical or fashionable solution, this is simply the re-interpretation of an approach with a long and distinguished history.

Before the full benefits of green buildings could be scientifically proven, the principle was already accepted and practised in cities all over the world. Only in the relatively recent past – in our haste to pursue progress through relentless development – have we lost sight of the many advantages that green buildings can bring. Ironically, it is when we need them most that they seem to have been forgotten. The results of such a short-sighted approach are there for all to see: noise, pollution, congestion and serious erosion of the quality of city life.

Of course it would be absurd to suggest that the introduction of vegetation on inner city buildings will magically solve all of our urban ills. Complex problems demand complex solutions. Green building is most effective as part of an integrated green approach to cities.

Such an approach demands a much closer cooperation between architects, ecologists, developers and green planners than has so far taken place. Without that partnership – and the will to change things – urban greenery risks stagnation in its present role as a sporadic amenity or 'clip-on' design accessory.

Developers, planners and building professionals have it within their power to influence the future development of our cities for the good; if they do it in an informed way, it is hard to see who will not benefit from the exercise. But if they fail to grasp the opportunity presented by a new spirit of green awareness, future generations may find it hard to forgive them.

Whilst the greening of buildings will work most effectively when harnessed to a wider green approach, it is equally true that every scheme helps. Anyone who instinctively feels that introducing vegetation to the surface of a building or a courtyard is a pleasurable and positive thing to do, will be making a valuable contribution to the quality of city life. This book is intended to help those people and to encourage others. It also seeks to offer a practical blueprint for the next major step towards the attainment of that most worthwhile goal – healthy cities that are sustainable and enjoyable.

TECHNICAL INFORMATION

The next 16 pages give additional technical information on which plants to use where, lists of suppliers and organisations, and sources of further reading.

Although not exhaustive, the plant lists demonstrate suitable types of species for use on and around buildings. Many have been chosen for their attractiveness to wildlife in addition to their suitability for particular locations.

Please note that the inclusion of a supplier or organisation does not constitute a particular recommendation.

TABLE 1:
A Selection of Trees Suitable for Urban Situations

NAME	SITUATION	GROWING CONDITIONS	FEATURES	HEIGHT	SPREAD	COMMENTS
Ash *Fraxinus excelsior*	Cold and exposed sites. Withstands smoke. Keep away from buildings.	Grows best on rich deep soils.	Graceful and decorative. Casts a light shade. Hardy.	40m	28m	Native tree. Seeds attractive to birds and small animals.
False Acacia *Robinia pseudoacaia*	Paved courtyards, streets. Smoke resistant.	Light well drained soill.Full sun.	Hardy. Open, light attractive foliage and flowers. Shallow roots. Brittle branches.	25m	6m	
Field Maple *Acer compestre*	Tolerates smoke and fumes. Exposed and shady sites.	Prefers heavy soils.	Small scale. Interesting leaf shape and good autumn colour.	15m		Native tree. Flowers attractive to insects.
Hawthorn *Crataegus monogyna*	Street, park development schemes.	Any well drained soil.	Rapid in spread, slow in height. All year round interest, flowers and fruit. Long lived.	14m	8m	Native tree, good for wildlife. C. oxyacantha 'Paul's Scarlet' – better shape for close proximity to buildings.
Holly *Ilex aquifolium*	Suitable for understorey planting and hedges. Withstands smoke and wind.	Well drained soil. Sun or shade.	Evergreen. Winter colour.	20m	8m	Native tree, good for wildlife. 'Fastigiata' grown as amenity variety.
Hornbeam *Carpinus betulus*	Cold, exposed sites. Streets and shelter belts.	Any soil in sun or shade. Grows well on clay.	All year round interest, flowers, leaves, fruit. Good autumn colour.	25m	8m	Native tree. Fruit for birds.
Horse Chestnut *Aesculus hippocastanum*	Tolerates pollution. Parks. Withstands cold, exposed sites although prefers sunny locations.	Prefers loam, but tolerates sand, clay and chalk provided not too dry.	Attractive foliage and flowers. Fast growing.	35m	27m	Conkers in autumn.
Lime *Tilia x euchlora*	Parks and open spaces. Requires large space. Groups and avenues.	Deep moist soils preferred.	Fresh green leaves, tallow in autumn. Long-lived – tolerates pruning.	40m	20m	This particular variety does not sucker or attract aphids which drop honeydew.
London Plane *Patanus hybrida x acerifolia*	Street tree. Tolerates polluted atmosphere, cold winds.	Compacted soil. Deep well-drained soils.	Large leaves, dappled bark, globular seeds remain all year. Decorative and elegant. Fast growing.	30m	25m	Fallen leaves are tough and can make pavements slippery.

NAME	SITUATION	GROWING CONDITIONS	FEATURES	HEIGHT	SPREAD	COMMENTS
Norway Maple *Acer platanoides*	Streets and parks. Tolerates polluted atmosphere.	Prefers well-drained sandy loam.	Flowers in March. Good autumn colour.	26m	20m	
Oak *Quercus robur*	Parks. Specimen trees or in avenues. Not suitable for tight situations as deep rooted, needs large space.	Deep moist loams.	Light shade. Interesting leaves, acorns. Very long-lived.	35m	36m	Native tree, excellent for wildlife.
Rowan *Sorbus aucuparia*	Good for small spaces.	Chalky or acid peaty soils.	Attractive pinnate leaves. Winter berries. White flowers in spring.	20m		Native tree. Berries eaten by birds.
Silver Birch *Betula pendula*	Suitable for planting near buildings in limited space.	Moist or dry soils, preferably acid. Needs plenty of light.	Slender branches. Light leaves and attractive bark. Spring catkins. Quick growth. Short-lived (60-80 years).	25m	17m	Native tree. Good for wildlife.
Tree of Heaven *Ailanthus altissima*	Urban squares and streets. Smoke resistant. Should not be grown in confined space.	Grows on poor soils. Prefers sunny position.	Foliage emerges bright red in mid-June. Sheds leaves early.	26m	19m	Limited use as shade species as late in leaf and early to shed.
Whitebeam *Sorbus aria*	Streets, restricted sites near buildings.	Any well-drained soils, particularly chalk.	Upright, wind resistant. Attractive foliage and fruit.	12m	9m	Native tree. Berries eaten by birds
Wild Cherry *Prunus avium*	Parks, open spaces, streets	Deep well-drained sols. Lime or good loam.	Attractive blossom, bark and autumn colour. Short-lived.	28m	18m	Native tree, good for wildlife. Roots can lift pavements.

TABLE 2: A Selection of Plants Suitable for Containers on Balcony or Terrace

	SOIL	A ANNUAL B BIENNIAL P PERENNIAL E EVERGREEN	HEIGHT cms	FLOWERING PERIOD	BUTTERFLY NECTAR	BEE NECTAR /POLLEN
SUNNY ASPECT						
CULINARY HERBS						
Chamomile *Chamaemelum nobile*	Well-drained low fertility	P	10-30	June-Aug		
Chives *Allium schoenoprasum*	Fertile, moist	P-Bulb	30	Spring		✓
Lavender *Lavendula vera*	Dry preferably	E	40-60	Summer	✓	✓
Marjoram *Origanum vulgare*	Well drained	P	40-50	Summer	✓	✓
Sage *Salina officinalis*	Well drained	P	60	Summer		✓
Sweet Basil *Ocinum basilicum*	Good	A	20	Summer		✓
Thyme *Thymus vulgaris*	Well drained	P	15-20	Summer	✓	✓
ROCKERY/ALPINES						
Biting Stonecrop *Sedum acre*	Poor, dry	P	2-10	June-July		✓
Common Rock Rose *Helianthemum nummularium*	Poor, alkaline	P	5-30	May-Sept	✓	✓
Heathers *Erica spp.*	Acid	P	Various	All seasons	✓	✓
Maiden Pink *Dianthus deltoides*	Well drained	P	15-45	June-Sept		✓
Purple Saxifrage *Saxifraga oppositifolia*	Poor, acid	P	Creeping	March-May		✓
Rock Cinquefoil *Potentilla rupestris*	Well drained	P	20-50	May-June	✓	
Thrift *Armeria Maritima*	Most	P	10-20	April-May	✓	✓
Wallflower *Cheiranthus cheiri*	Well drained	P	20-60	April	✓	✓
Wild Thyme *Thymus praecox*	Most	P	Creeping	June-July	✓	✓

	SOIL	A ANNUAL B BIENNIAL P PERENNIAL E EVERGREEN	HEIGHT cms	FLOWERING PERIOD	BUTTERFLY NECTAR	BEE NECTAR /POLLEN
CORNFIELD ANNUALS						
Corn Buttercup *Ranunculus arvensis*	Well drained	A	15-50	May-July	✓	
Corncockle *Agrostemma githago*	Most	A	30-120	June-Aug	✓	✓
Cornflower *Centaurea cyanus*	Fertile	A	20-100	June-Aug	✓	✓
Corn Marigold *Chrysanthemum segetum*	Most, but prefers light	A	20-50	June-Sept	✓	
Poppy *Papaver rhoeas*	Most, fertile	A	20-60	June-Aug		✓
MEADOW FLOWERS						
Daisy *Bellis perennis*	Fertile	P	7-15	Mar-Oct	✓	
Hardheads *Centaurea nigra*	Fairly fertile	P	30-60	June-Sept	✓	✓
Harebell *Campanula rotundifolia*	Most, but prefers poor	P	15-40	July-Sept	✓	✓
Soapwort *Saponaria officinalis*	Fertile	P	30-60	June-Sept	✓	✓
Common Toadflax *Linaria vulgaris*	Most	P	30-80	July-Oct	✓	✓
Tormentil *Potentilla erecta*	Most, likes acid	P	5-50	May-Oct	✓	✓
SHADY ASPECT						
CREEPING PLANTS						
Germander Speedwell *Veronica chamaedrys*	Most	P	Creeping	Mar-June		
Ivy *Hedera helix*	Most	E	Creeping	Sept-Nov	✓	✓
Periwinkle *Vinca major*	Most	E	25/Spreading	May-Sept		
WOODLAND/HEDGEROW						
Bugle *Ajuga reptans*	Most, prefers acid	A	10-40	Apr-Sept		✓
Common Dog Violet *Viola riviniana*	Most moist	Semi-E	10	May-Aug	✓	

	SOIL	A ANNUAL B BIENNIAL P PERENNIAL E EVERGREEN	HEIGHT cms	FLOWERING PERIOD	BUTTERFLY NECTAR	BEE NECTAR /POLLEN
Ground Ivy *Glechoma hederacea*	Fertile, moist	P	10-30	Mar-May		✓
Herb Robert *Geranium robertiarnum*	Most, likes acid	A	10-40	April-Sept		✓
Lesser Celandine *Ranunculus ficaria*	Moist, neutral	P	8-20	Mar-May	✓	✓
Lily of the Valley *Convallaria majalis*	Moist	P	20	April-May		✓
Lungwort *Pulmonaria officinalis*	Most	P	30	April-May		✓
Primrose *Primula Vulgaris*	Most	P	8-15	Mar-June	✓	
Snowdrop *Galanthus nivalis*	Rich, moist	P-Bulb	15-20	Jan-Mar		✓
Wild Daffodil *Narcissus pseudonarcissus*	Moist, fertile	P	20-25	Mar-Apr	✓	✓
Wood Anemone *Anemone nemorosa*	Most	P	15	Mar-Apr		✓

Main Source: Wildlife Gardening: A Practical Handbook, Fran Hill, Derbyshire Wildlife Trust

TABLE 3: A Selection of Plants Suitable for Walls

	D DECIDUOUS E EVERGREEN A ANNUAL	ASPECT N E S W bold = preferred light = tolerated	MAX HT (mtrs)	GROWTH RATE	SOIL	NATIVE /EXOTIC
SELF-CLINGING CLIMBERS (Generally no support needed. May need support on very smooth walls.)						
Ivy *Hedera helix*	E	**N** E S W *Excellent wildlife plant. Good nesting site for robins and wrens, and hibernating butterflies – esp. brimstone. Nectar and pollen for bees and hoverflies.*	30	Slow	Most, rich	N
Virginia Creeper *Parthenocissus quinquefolia*	D	N **E** S W *Useful for nesting birds if grown on a trellis. Provides nectar and pollen for bees. May attract nesting spotted flycatcher.*	15	Average	Any	E
Boston Ivy *Parthenocissus tricuspidata*	D	N **E** S W	15	Fast	Any	E
Climbing Hydrangea *Hydrangea petiolaris*	D	**N E W** *Good for nesting birds and produces nectar for bees and other insects.*	15	Average	Moist, loamy	E
Euonymus *Euonymus fortunei vars.*	E	**N** E W	5	Slow	Any	E
TWINING CLIMBERS **(Suport needed. Thin steel wires, roughened plastic lines or timber battens running vertically will suffice for some species. Others will need a good network of wire or wooden trellis-work.)**						
Russian Vine *Polygonum bauldschianicum*	D	N E **S** W *Good for nesting birds.*	30	Fast	Any moist	E
Honeysuckle (Woodbine) *Lonicera periclymenum*	D	**E** S **W** *Must be kept bushy for nesting birds. Excellent for insects, especially moths, due to nightscented flowers. Bark from older stems used by nesting birds. Berries eaten by birds.*	5	Average	Good loam	N
Honeysuckle (others) *Lonicera spp.*	Mainly D Some E	N **E** S **W** *Several varieties are useful nectar and seed plants.* *Evergreen honeysuckly trained up a trellis makes a good bird roosting site.*	6	Average	Good rich	E
Old Man's Beard *Clematis vitalba*	D	E S W *Seeds for birds. Nesting sites. Nectar for insects.*	10	Fast	Prefers alkaline	N

	D DECIDUOUS E EVERGREEN A ANNUAL	**ASPECT N E S W bold = preferred light = tolerated**	**MAX HT (mtrs)**	**GROWTH RATE**	**SOIL**	**NATIVE /EXOTIC**
Clematis (others)						
Clematis spp.	Mainly D					
	Some E	**E** **W**	10	Fast	Various	E
	Useful nectar and/or seed providers. Useful for nesting sites if trained thickly on a trellis.					
Common Hop						
Humulus lupulus	D	**E** S **W**	6	Fast	Rich moist	N
	Good for bees.					
Dutchman's Pipe						
Aristolochia spp.	D	**N** S **W**	10	Average	Most	E
Jasmine						
Jasminum officinale	D	**E** **W**	9	Fast	Well-drained	E
	Night-scented, attracting moths and other night-flying insects.					
Vine						
Vitis spp.	D	E **S** W	20	Average/fast	Rich, loamy, moist	E
	Provides fruit for birds and nectar and pollen for bees.					
Wisteria						
Wisteria spp.	D	E **S** **W**	18	Average	Rich, moist, loam	E
	Excellent nectar and pollen for bees. Can be used by nesting.					
Trumpet Vine						
Capsis radicans	D	E **S** **W**	12	Slow	Rich, well-drained	E
Passion Flower						
Passiflora caerulea	D	E **S** **W**	8	Fast	Any	E
	Nectar and pollen for bees.					
Sweet Pea						
Lathyrus odoratus	A	**S** W	2	Fast	Rich, well-drained with chalk	E
Nasturtium						
Tropaeolum spp.	Mainly A	E **S** W	2	Fast	Poor	E
	Nectar/pollen for bees and beetles. Seeds eaten by birds and small mammals. Food plant of small and large white butterflies.					
RAMBLING SHRUBS						
(Not true climbers but can be trained on wide meshed grid structures or by tying to wall.)						
Bramble						
Rubus fruiticosus	E	N E S W		Average	Most, but likes acid	N
	Provides pollen for bees and nectar for bees and butterflies. Berries for birds and small mammals, Night-scented and attracts moths.					
Winter Jasmine						
Jasminum nudiflorum	D	N **S** W	5	Average	Most	E

	D DECIDUOUS E EVERGREEN A ANNUAL	**ASPECT N E S W bold = preferred light = tolerated**	**MAX HT (mtrs)**	**GROWTH RATE**	**SOIL**	**NATIVE /EXOTIC**
Dogrose *Rosa canina*	D	E **S** W	3	Average	Good, cultivated	N
	Night-scented for moths. Nectar for insects, rosehips for birds and small mammals. Good nesting cover for birds.					
Climbing rose *Rosa spp.*	D	E **S** W	5	Average	Most	E
	Excellent nectar for bees. Nesting sites for birds.					
Forsythia *Forsythia suspensa*	D	N E **S** W	4	Average	Most	E
	Nesting sites for birds, as above.					
Cotoneaster *Cotoneaster spp.*	Mainly D Some E	**N E**	3-6	Slow	Any	E
	Thick growth may be used by nesting blackbirds and tbrushes. Berries for birds, especially blackbirds and small mammals. Nectar and pollen for bees.					
Firethorn *eg Pyracantha atalantiodes*	E	**E** S W	5	Slow	Most, esp. fertile, well drained	E
	Good for nesting birds e.g. thrushes, and provides nectar and pollen for bees and berries for birds, particularly blackbirds.					
WALL FRUITS (Can be trained to cover walls through espalier technique.)						
Apple, cherry, quince, pear, currant, gooseberry, apricot, fig, grape, peaches etc.	Various	Various	3	Slow	Various	N E
	Strong branches can provide good nest sites. Fruit eaten by birds and insects. Nectar and pollen for bees.					

TABLE 4: A Selection of Plants Suitable for Extensive Green Roofs

NAME	HT (cm)	CULTILVATION SOIL	S/Ps/Sh	NATURAL HABITAT /WILDLIFE NOTES
HERBS				
ROCK PLANTS				
White Stonecrop *Sedum album*	5-10	Poor, dry, well-drained, prefers alkaline	S	Rocky places, walls and sea cliffs Attracts bees
Biting Stonecrop *Sedum acre*	2-10	Poor, dry, well-drained, acid or alkaline	S	Rocky and sandy places, dry grassland, dunes, beaches, walls, railway tracks. Attracts bees
Reflexed Stonecrop *Sedum reflexum*	5-10	Poor, dry, well-drained	S	Walls, rocks, dry banks Attracts bees
Tasteless Stonecrop *Sedum sexangulare*	5	Poor, dry, well-drained	S	Old walls. Attracts bees
Hen-and-chickens Houseleek *Jovibarba sobolifera*	5	Well-drained, prefers acid	S	Sandy and grassy places
Common Houseleek *Sempervivum tectorum*	10	Well-drained	S	Grassy and rocky places, screes, walls and roofs
Wild Thyme *Thymus serpyllum*	20	Poor, well-drained, prefers alkaline	S	Sandy heaths, dry grassland. Attracts bees and provides nectar for butterflies
Common Wild Thyme *Thymus drucei*	20	Poor, well-drained, prefers alkaline	S	Dry grassland, heaths, dunes, rocks Nectar for bees and butterflies
Chives *Allium schoenoprasum*	20-30	Loamy, neutral to alkaline	S/Ps	Grassy and rocky places, limestone Attracts bees
Golden Alyssum *Alyssum saxatile*	10	Well-drained	S	Rocky habitats, walls and embankments. Attracts bees and provides nectar for butterflies
Snow-in-Summer *Cerastium tormentosum*	10-20	Well-drained	S	Grassy and rocky places, banks and walls
Mountain Alison *Alyssum montanum*	5-15	Well-drained	S	Rocky places and gravels

NAME	HT CM	CUTILVATION SOIL	S/Ps/Sh	NATURAL HABITAT /WILDLIFE NOTES
Mountain Avens *Dryas octopetula*	5-20	Well-drained, poor, alkaline	S	Limestone or basic rocks
Purple Saxifrage *Saxigraga oppositifolia*	5-10	Well-drained, poor, alkaline	S/Ps	Rocks and cliffs, often limestone Attracts bees
Meadow Saxifrage *Saxifraga granulata*	5-30	Well-drained, neutral or alkaline	S	Meadows, road verges, rocky places
Common Rockrose *Helianthemum nummularium*	5-30	Well-drained, poor, alkaline	S	Dry meadows, banks and rocky habitats Nectar for bees and butterflies
Red Valerian *Centranthus ruber*	30-80	Well-drained, poor, neutral to alkaline	S	Old walls, cliffs, rocks wasteland Nectar for bees and butterflies
Lavender *Lavendula augustifolia*	50	Well-drained, alkaline	S	Rocky slopes Nectar for bees and butterflies
ROCK/GRASSLAND PLANTS				
Hoary Cinquefoil *Potentilla argentea*	10-40	Well-drained	S/Ps	Dry, sandy grasslands and rocky/stony places. Nectar for bees and butterflies
Thrift *Armeria maritima*	10-20	Most. Well-drained, slightly acid to alkaline	S/Ps	Cliffs, salt marshes, mountain ledges, dry grassland. Nectar for bees and butterflies
Sheep's-bit *Jasione Montana*	5-30	Well-drained, acid, sandy, stony	S/Ps	Cliffs, dry grasslands, heaths, dunes Nectar for bees and butterflies
Bloody Cranesbill *Geranium sanguineum*	10-40	Well-drained, alkaline	S/Ps	Dry rocky or sandy places, grassland and open woods. Nectar for bees
Fine-leaved Sandwort *Minuartia hybrida*	5-20	Well-drained, sandy	S	Walls, dry stony grassland
Wall Germander *Teucrium chamaedrys*	10-20	Well-drained	S/Ps	Chalk grassland, walls, rocky places
Toadflax *Linaria vulgaris*	30-80	Most well-drained, neutral to alkaline	S/Ps	Fields, rocky and waste places. Nectar for bees and butterflies
Mouse-ear Hawkeed *Hieracium pilosella*	5-20	Well-drained	S	Grassland, heaths, wasteland and rock outcrops/scree. Nectar for bees and butterflies

NAME	HT CM	CUTILVATION SOIL	S/Ps/Sh	NATURAL HABITAT /WILDLIFE NOTES
Common Centaury Centaurium erythraea	10-40	Well-drained, dry	Ps	Roadsides, wasteground, rock outcrops and cliffs
Wild Carrot *Daucus carota*	30-60	Well-drained, dry, alkaline	S	Grassland, roadsides, rock outcrops and cliffs. Attracts a variety of insects
GRASSLAND PLANTS				
Yellow Chamomile *Anthemis tinctoria*	50	Well-drained	S	Arable land, roadsides, wasteland Nectar for bees
Thyme-leaved Sandwort *Arenari serpyllifolia*	3-20	Well-drained, alkaline	S	Arable land, wasteland, chalk, grassland
Maiden Pink *Dianthus deltoides*	10-50	Well-drained	S	Dry grassland
Mullein *Verbascum thapsus*	30-200	Mostly well-drained	S	Wasteland, dry banks Nectar for bees. Mullein moth caterpillar feeds on leaves.
Common furnitory *Fumaria officinalis*	20	Well-drained, moderately acidic to alkaline	S	Arable fields, esp. on chalk and sand, wasteground
Perforate St John's Wort *Hypericum perforatum*	30-90	Most well-drained, neutral to alkaline	S/Ps	Roadsides, hedgebanks, grassland, esp. on chalk and sand Nectar for bees and butterflies
Common Mallow *Malva sylvestris*	45-90	Well-drained, dry	Ps	Roadsides, wasteground, hedgebanks Nectar for bees and butterflies. Food for painted lady caterpillar
Yarrow *Achillea millefolium*	10-50	Well-drained	S/Ps	Roadsides, grassland Nectar for bees and butterflies.
Wild Mignonette *Reseda lutea*	30-75	Well-drained, alkaline	S	Wasteland, grassland Nectar for bees and butterflies
Bird's-foot Trefoil *Lotus corniculatus*	10-40	Most well-drained, except very acid	S	Grassland, roadsides Nectar for bees and butterflies. Food for various moth and butterfly caterpillars.

NAME	HT CM	CUTILVATION SOIL	S/Ps/Sh	NATURAL HABITAT /WILDLIFE NOTES
Bladder Campion *Silene vulgaris*	25-90	Well-drained	S/Ps	Roadsides, open ground, hedgebanks, esp. on chalk and sand Nectar for butterflies
GRASSES/SEDGES				
Common Bent *Agrostis capillaris*	10-70	Poor, dry, acid, sands to clay	S/Ps/Sh	Dry acid grasslands, wasteground, heath
Creeping Bent *Agrostis stolonifera*	8-40	Most. Light or heavy, dry or wet	S/Ps	Widespread. Grassland, roadsides, cliffs, wasteland
Upright Brome *Bromus erectus*	40-100	Well-drained, alkaline	S	Wasteland, roadsides, chalk grassland
Sheep's Fescue *Festuca ovina*	5-60	Well-drained, poor, acid to alkaline	S/Ps	Dry grassland
Red Fescue *Festuca rubra*	20-60	Well-drained, chalky, gravelly or sandy soils	S/Ps	Dry grassland, roadsides and wasteground
Yorkshire Fog *Holcus lanatus*	20-100	Most	S/Ps	Rough grassland, wasteland Caterpillar food plant for skipper butterflies
Smooth Meadow-grass *Poa pratensis*	10-90	Well-drained, sandy, gravelly and loamy	S/Ps	Meadows, roadsides, walls, wasteland Caterpillar food plant for meadow brown and gatekeeper butterflies
Crested Dog's-tail *Cynsurus cristatus*	15-75	Well-drained, esp. chalk	S/Ps	Grassland on acid and basic soils
Yellow Oat-grass *Trisetum flavescens*	20-50	Well-drained	S/Ps	Widespread in meadows and grasslands, esp. calcareous
Annual Meadow-grass *Poa annua*	5-30	Most	S/Ps/Sh	Bare and disturbed ground

NOTES: S=sun Ps=partial sun Sh=shade. Not all the plants listed are native to Britain, and in addition some have very limited natural distributions. Absence of entry under "wildlife notes" does not imply absence of value to wildlife.

SUPPLIERS

Tree Guards and Grilles

Cu-Phosco
Charles House
Furlong Way
Lower Road
Great Amwell
Ware
Herts. SG13 GTA
(0920) 462272

Cast Iron Services Ltd.
Albany Court
Blenheim Rd. Industrial Estate
Ashbourne
Derbyshire
DE6 1HA
(0335) 300234

Furnitubes International Ltd
Seager Building
Bookmill Rd.
London SE8 4HL
(081) 694 9333

Mustang Metal Products
Mustang House
28 Carr Road
Nelson
Lancasshire BB9 7JS
(0282) 601020

Planters

Heritage Timber Landscape and Streetscape Designs
Waterway Cottage
10 Dark Lane
Whittle le Woods
Chorley
Lancashire PR6 8AE
(02572) 67700
Supply components such as planter boxes, earth retaining systems, paving blocks etc. in British hardwoods and selectively treated softwoods.

Green Walls and Fencing

BRC Spencer
Lichfield Road
Stafford ST17 4NN
(0785) 57777
Suppliers of Devon banks - metal frames for covering with turf for use as hedging.

C.D. Brown (Ladscaping) Ltd.
Udimore Farm
Chapel Lane
Ightham
Sevenoaks
Kent TN15 9AQ
(0732) 884286
Suppliers of willow wall – a natural sound barrier system invented and developed in Holland.

The English Basket Ltd
The Willows
Curload
Stoke St. Gregory
nr Taunton
Somerset
TA3 6JP
(0823) 698 418
Grow and sell willow for fencing. Also make fencing, arbours and bowers.

Farmer Foster Ltd.
Albion Works
Ropery Road
Gainsborough
Lincolnshire
(0427) 810 231
Suppliers of heavy duty plant support.

Green Wall Sound Barriers Ltd.
Surrey house
39/41 High Street
Newmarket
Suffolk CB8 8NA
(0638) 668196
A natural sound and visual barrier constructed from living willow shoots.

Trellisworks
West Head Nursery
Clay Lane
Fishbourne
Chichester PO19 3J9
(0243) 778566
A comprehensive selection of trellises.

Roof systems

Enterprise Plants
Unit 102
Cannon Workshops
West India Dock
London E14
(071) 987 5753
Design and install green roofs

Erisco Bauder Ltd
Broughton House
Broughton Road
Ipswich
Suffolk IP1 3QS
(0473) 257671
Suppliers of waterproofing, insulation materials and complete green roof systems

Euroroof Ltd
Denton Drive
Northwich
Cheshire CW9 7LU
(0606) 48222
Supply necessary roof membranes and complete green roof systems.

Isola-Platon Ltd.
175a High Street
Beckenham
Kent BR3 1AH
(081) 658 0187
Norwegian waterproofing systems for earth covered roofs.

MSP
19 Clarendon Road
Hornsey
London N8 0DD
(081) 881 0505
Supply waterproof membranes for roof gardens

Re Natur
Ch. Ross Weg 24
2355 Ruhwinkel-
Wankendorf
Germany
(04323) 6001
Suppliers of green roof systems with an emphasis on ecological principles.

Soprema ULK Ltd
Soprema House
Queens Square
Adeyfield
Hemel Hampstead
Herts HP2 4ER
Design and supply systems for roof gardens

Paving

ECC Building Products Ltd
Holland Ward
Ashborne
Derby DE6 3ET
(0332) 629291
Supply many types of paving, including some which allow 85% surface area for grass.

Grass Concrete Ltd.
Walker House
22 Bond street
Wakefield
West Yorkshire
WF1 2QP
(0924) 374818
Large choice of grass/concrete units.

Marshalls Mono Ltd.
Brier Lodge
Southowram
Halifax
HX3 9SY
(0422) 366666
Offer a variety of grass/concrete paving types.

Bird and Bat Boxes

ACO Polymer Products Ltd.
Hitchen Road
Shefford
Bedfordshire SG17 5JS
(0426) 816666
Suppliers of nestboxes made of polymerised concrete to insert into brick walls.

Redland Roof Tiles
Technical Department
Castle Court
41 London Road
Reigate
Surrey RH2 0SJ
(0737) 233733
Supply adaptations of block-end ridge tiles for use a nest-boxes.

Trees

Bambers Nursery and Garden Centre
Lynn Road
Walton
Nr Wisbeck
Cambridge
PE13 7DA
(0945) 585946
Large variety of tree species.

Boningale Nurseries
Holyhead Road
Albrighton
nr. Wolverhampton WV7 3AU
(0902) 374991
Trees supplied for commercial contractors.

Bridgemere Garden World
Bridgemere
Nantwich
Cheshire
CW5 7QB
(0936) 5264
Trees from whips to heavy standards. Also fruit trees.

BTCV Trees and Shrubs
The Old Estate Yard
Newton St Loe
Bath
Avon BA2 9BR
(0225) 874018
Native trees and shrubs – generally younger specimens.

Kingsfield Tree Nursery
Winsham
Broadenham Lane
Nr Chard
Somerset TA20 4JF
(0460) 30697
Specialist in native plants, including broadleaf trees and shrubs from seedling to standards.

Limit's Field
The Prospect
Long Preston
nr Skipton
North Yorkshire
BD23 4QH
(0729) 840 206
Organically grown trees, shrubs and hedging. Exclusively native species.

Climbers

John Beach (Nursery) Ltd
9 Grange Gardens
Wellesbourne
Warwicks CV35 9RK
(0926) 624 173
Suppliers of climbers, including clematis, wisteria, jasmine, honeysuckle etc.

J. Bradshaw & Son
Bushyfields Nursery
Herne Common
Herne Bay
Kent CT6 7LJ
(0227) 375415
Climbers including roses, honeysuckle, wisteria and jasmine

Deacon's Nursery
Moorview
Godshill
Isle of Wight
PO38 3HW
(0983) 840750/522243
Suppliers of trained fruit trees.

Read's Nursery
Hales Hall
Loddon
Norfolk
NR14 6QW
For hardy climbers

Stone House Cottage Nursery
Stone
nr Kidderminster
Hereford
Worcester DY10 4BG
(0562) 69902
For a range of hardy climbers.

Treasures of Tenbury Ltd
Burford
Tenbury Wells
Worcestershire WR15 8HQ
(0584) 810777
A wide selection of clematis and other climbers.

Alpine/Rockery Plants

Castle Alpines
Castle Road
Wootton
Woodstock
Oxon. OX20 1EG
(0993) 812162
Suppliers of alpines and rock plants.

J. Cunnington
Engleberg Nursery
Bull Lane
Brookman's Park
Hatfield
Herts. AL9 7AX
(0707) 58161
Suppliers of alpines and rock plants.

Mansfield Nurseries
Eastwood Rise
Eastwood
Leigh-on-Sea
Essex SS9 5DA
(0702) 525410
1400 varieties of alpines and rock plants.

Trenear Nurseries
Chantry Land
New Road
Chequers Lane
Eversley Cross
Hants
RG27 0NX
(0734) 732 300
Rock plant, heathers and ground cover plants.

Wildflower and Herbs

John Chambers Wildflower Seeds
15 College St.
Irthlingborough
Wellingborough
Northants NN9 5TU
(0933) 652 562
Supplier of a large variety of wildflower seeds.

Emorsgate Seeds
Terrington Court
Popes Lane
Terrington
St Clement
King's Lynn
Norfolk PE34 4NT
(0553) 829028
Seeds for wildflowers and meadows.

Landlife Wildflowers Ltd.
The Old Police Station
Lark Lane
Liverpool L17 8UU
(051) 782 7011
Suppliers of wildflower seeds and plants

Mommersteeg International
Station Road
Finedon
Wellingborough
Northants NN9 5NT
(0933) 680 891
Supplier of wildflower seeds.

Naturescape
Little Orchard
Main Street
Whatton in the Vale
Nottinghamshire
NG13 9EP
(0949) 51045
Wildflower plans and seeds supplied.

Ruth Thompson
Oak Cottage Herb Garden
Nesscliffe
Shropshire SY4 1DB
(074338) 262
Specialist suppliers of herbs.

Suffolk Herbs
Monks Herb
Pantlings Lane
Kelvedon
Essex CO5 9PG
(0376) 572 456
supplier of herbs and wildflowers.

Substrates

Cowpact
PO Box 595
Adstock
Buckingham MK18 2RE
(0296) 713 838
Manufacturers of peat substitutes.

Melcourt Industries Ltd.
8 Bells House
Tetbury
Glos. GL8 8JG
For peat substitutes.

Uza-Frenly Organic Products
Stallard Common
Great Elingham
Attleborough
Norfolk NR17 1LJ
(0953) 456487
Peat free products including mulch and soil conditioners.

Wessex Horticultural Products
South Newton
Salisbury
Wiltshire SP2 0QW
(0722) 742500
Peat free products.

USEFUL ORGANISATIONS

Arboricultural Association
Ampfield House
Ampfield
Romsey
Hants SO51 9PA
(0794) 68717
Carry out aboricultural education, research and advisory work. Publish journal and booklets, and organise seminars.

Association of Community Technical Aid Centres
The Royal Institution
Colquitt Street
Liverpool L1 4DE
(051) 708 7607
ACTAC is a national network of over 60 centres providing low cost professional technical aid services (e.g. architects, planners, landscape surveyors) for a wide range of built and natural environment community projects.

Association of Environment Conscious Builders
Windlake House
The Pump Field
Coaley
Gloucestershire
GL11 5DX
The Association publishes a directory of products and services and aims to encourage environmentally friendly building.

The Bat Conservation Trust
C/o The Conservation Foundation
Lowther Lodge
1 Kensington Gore
London SW7 2AR
(071) 240 0933

British Butterfly Conservation Society
Tudor House
Quorn
Loughborough
Leicestershire LE12 8AD
(0509) 412870

The British Earth Sheltering Association
Caer Llan Berm House
Lydart
Monmouth
Gwent NP5 4JJ
The Association publishes a quarterly newsletter The British Earth Sheltering Association Journal.

British Ecological Society
Burlington House
Piccadilly
London W1V 0LQ
(071) 434 2541
Encourages the study of ecology as a science by publishing original research in its journals, and organising scientific meetings and symposia.

British Trust for Conservation Volunteers
36 St. Mary's Street
Wallingford
Oxfordshire OX10 0EU
(0491) 39766
BTCV is the leading organisation for practical conservation projects ranging from planting trees to cleaning polluted ponds. The Trust will undertake work on a commercial basis.

British Trust for Ornithology
The Nunnery
Nunnery Place
Thetford
Norfolk IP24 2PU
(0842) 750050

Building Research Advisory Service
Building Research Establishment
Bucknalls Lane
Garston
Watford WD2 7JR
(0923) 894040

Bund fur Umwelt und Naturschutz Deutschland (BUND)
Im Rheingarten 7
Postafach 300220
D-5300 Bonn 3
Germany
(010 49 228) 400970
German nature conservation organisation which publishes useful books and pamphlets on using vegetation on buildings.

The Civic Trust
17 Carlton House Terrace
London SW1Y 5AW
(071) 930 0914
Aims to stimulate action for environmental improvement and to foster high standards of planning, design, restoration and new building.

Countryside Council for Wales
Plas Penrhos
Fford Penrhos
Bangor
Gwynedd LL57 2LQ
(0248) 370 444
National government agency for nature conservation in Wales.

English Nature
Northminster House
Peterborough PE1 1UA
(0733) 40345
Government organisation for nature conservation. Provides advice on urban nature and publishes relevant publications.

Environmental Design Association
c/o 20 High Street
Stroud
Gloucestershire GI5 1AS
(0453) 765575
Aims to promote environmentally friendly products and building design, and the research, evaluation and setting of standards for ecological products.

The European Academy of the Urban Environment
Bismarckallee 46-48
D-1000 Berlin 33
Germany
(010 49 30) 8959990

Fauna and Flora Preservation Society
1 Kensington Gore
London
SW7 2AR
(071) 823 8899

Flat Roofing Contractors Advisory Board
Field House
Gower Road
Haywards Heath
West Sussex
RH16 4PL
(0444) 440027

Friends of the Earth Cities for People Campaign
26-28 Underwood Street
London N1 7JQ
(071) 490 1555
Publishes literature on creating more liveable cities. Also campaigns for more environmentally sound systems for transport, energy, recycling etc.

Green Roof Associates
9 St Mark's Rise
London E8 2NJ
(0712) 254 56
Advice on greening roofs and all aspects of the built environment.

The Groundwork Foundation
85-87 Cronwall St
Birmingham B3 3BY
(02100 236 8565
Umbrella body for a network of Groundwork Trusts nationally. Promotes environmental action in towns and cities or on the urban fringe. Aims to create partnerships between public, private and voluntary agencies working to improve the environment.

The Henry Doubleday Research Association
Ryton-on-Dunsmore
Coventry CV8 3LG
(0203) 303517
The national centre for organic gardening. Supplies information on peat substitutes, organic fertlizers etc.

Institute of Ecology and Environmental Management
36 Kingfisher Court
Hambridge Road
Newbury
Berkshire RG14 5SJ
(0635) 37715
The professional institute for ecologists and environmental managers.

Landlife
The Old Police Station
80 Lark Lane
Liverpool
L17 8UU
(051) 728 7011
Advice on greening urban areas and sales of wildflowers.

Landscape Institute
6-7 Barnard Mews
Clapham
London SW11 1QU
(071) 738 9166
The professional institute for landscape architects and managers.

London Ecology Centre
45 Shelton Street
London WC2H 9HJ
(071) 379 4324
A focal point in London, promoting education and awareness of ecological activities and issues. Also provides information service on green office management, and displays exhibitions.

National Centre for Alternative Technology
Llwyngwern Quarry
Machynlleth
Powys
SY20 9AZ
(0654) 702400
Research and demonstration areas on alternative technologies and sustainable lifestyles. Several buildings incorporate turf roofs.

Netherlands Society for the Protection of Birds
Driebergseweg 16c
3708 JB Zeist
The Netherlands
Organisation which promotes the protection and welfare of birds in the Netherlands. Roof tiles for swift nests available.

Royal Entomological Society
41 Queens Gate
London SW7
(071) 584 8361

Royal Horticultural Society
80 Vincent Square
London SW1P 2PE
(071) 834 4333
Aims to promote horticulture research and gives advice on plant identification and garden design. Produces variety of publications and holds a large collection of reference material.

Royal Institute of British Architects (RIBA)
66 Portland Place
London W1N 4AD
(071) 580 5533

Royal Society for Nature Conservation
(The Wildlife Trusts Partnership)
The Green
Witham Park
Waterside South
Lincoln
Lincolnshire
LN5 7JR
(0552) 544400
Aims to increase public awareness of nature conservation. Acts as umbrella body for urban wildlife trusts.

Royal Society for the Protection of Birds
The Lodge
Sandy
Bedfordshire
SG19 2DL
(0767) 680551
Conservation body for birds and the environment.

Royal Town Planning Institute
25 Portland Place
London W1N 4BE
(071) 636 9107

School Garden Company
PO Box 49
Spalding
Lincolnshire
PE11 1NZ
(0775) 769518
Produce publications and give advice on wildlife gardening, including gardening for bats.

Scottish Natural Heritage
12 Hope Terrace
Edinburgh EH9 2AS
National government agency for nature conservation in Scotland.

Technical Landscapes Ltd
Fawkham Green
Fawkham, near Longfield
Kent DA3 8NL
(0474) 874875
Landscape design consultants specialising in planting the built environment.

Town and Country Planning Association
17 Carlton House Terrace
London SW1Y 5AS
(071) 930 8903
The Association is concerned with all aspects of town planning. It aims to improve the environment through effective planning, public participation and sustainable development.

The Tree Council
35 Belgrave Square
London SW1X 8QN
(071) 235 8854
Further the maintenance and improvement of the environment through the planting and care of trees.

Trust for Urban Ecology
P.O. Box 514
London SE16 1AS
(071) 237 9165
Carry our research on urban ecology and run several nature areas as demonstration sites.

Urban Wildlife Trust
Unit 213
Jubilee Trades Centre
130 Pershore Street
Birmingham B5 6ND
(021) 666 7474
Promote urban nature conservation throughout Britain. Run an educational centre build on environmental principles.

World Wide Fund for Nature
Panda House
Wayside Park
Godalaming
Surrey GU7 1XR
(0483) 426444

Vincent Wildlife Trust
10 Lovate Lane
London
EC3R 8DT
(071) 283 2089
Produces a publication on bats in buildings.

REFERENCES

The Natural Landscape of the City

1 Barges H. 1986. The City Green: Green Vision 2. Architects Journal 6(183), 5 Feb. 1986, pp. 40-42

Benefits of Greener Cities

2 Lohmann, G. 1990. The Effect of Trees on Air Pollution. Urban Forests, Issue 33, p. 11.

3 Doernach, R. 1979. Uber den Nutzungen von Biotektonischen Grunsystemen. (On the Use of Biotectural Systems). Garten und Landschaft 89(6), pp. 452-457.

4 Brown, M. 1983. Design of Planting and paved Areas and their Role in the City. In City Landscape. Eds. A.B. Grove and R.W. Cresswell, pp. 87-124. The University press, Cambridge.

5 Köhler, M. 1989a. Okologische Untersuchungen an Extensiven Dachbergrunung (Ecological Analysis of Extensive Green Roofs). Poster zu Verhandlung der Gesellschaft fur Okologie (Essen 1988) band XVIII, pp. 249-255.

6 Köhler, M and Schmidt, M. 1990. The Importance of Roofs Covered with Vegetation for Urban ecology – Biotic Factors. Unpublished paper. 16pp.

Trees and Buildings

7 Morales, D.J. 1980. The Contribution of Trees to Residential Property Value. Journal of Arboriculture 6(11), pp. 301-302.

8 Ulrich, R.S. 1984. View Through a Window May Influence Recovery from Surgery. Science, Vol 224, April 27, pp. 420-421.

9 Heisler, G.M. 1985. Energy Saving With Trees, Journal of Arboriculture 12(5), pp. 113-125.

10 Coppin, M.J. and Richards, I.G. 1990. Use of Vegetation in Civil Engineering. Construction Industry research and Information Association, Butterworths, London.

11 Pitt, D., Soergell, K., and Zube, E. 1979. Trees in the City. In Nature in Cities, Ed. Ian Laurie, John Wiley & Sons, Chichester, pp. 205-230.

12 Helliwell, D.R. 1983. Tree Growth and Changes in Soil Moisture: 2. Effects

of Building and Development on Soil Moisture. Arboricultural Journal 7, pp. 96-100.

13 Brookes, J. and Thompson, M. 1984. Designing with Plants 2: The Function of Plants. Architects Journal, 2 May 1984.

14 Wagar, J.A. 1985. Reducing Surface Rooting Trees with Control planters and Wells. Journal of Arboriculture 11, pp. 165-171.

15 Arboricultural Association 1985. Trees on Development Sites. Arboricultural Association, Romsey.

16 See for example: Clouston, B. and Stansfield, K. (eds.) 1981. Trees in Towns. Maintenance and Management. Architectural press, London; and Hibberd, B.G. (ed.) 1989. Urban Forestry in Practice. Forestry Commission Handbook 5, HMSO, London.

Courtyards

17 Beazley, E. 1990. Sun, Shade and Shelter. Landscape Design. No. 194. October 1990, pp. 23-26.

18 Köhler, M. 1989b. Bergrunungspotential von Grunderzeitbauten in Berlin (West). (The Green Potential of Buildings from the Beginning of the 20th century in Berlin (West). Landschaft und Stadt 21(2), pp. 56-62.

19 Fezer, F. 1990. Climatic Change After Regeneration in the Oldest Quarter of Heidelberg, Landscape and Urban Planning 19, pp. 47-54.

20 Property Services Agency 1988. Energy Saving Through Landscape Planning: Volume 1 – The Background. PSA Directorate of Architectural Services, London

21 Beazley, E. 1990c. Sun, Shade and Shelter – the Forgotten Art of Planning with the Microclimate in Mind: Part Three. Landscape Design No. 196, December 1990/January 1991, pp. 41-43

Green Walls

22 Woodell, S. 1979. The Flora of Walls and Pavings. In Nature in Cities, Ed. Ian Laurie, pp. 135-157

23 Witter, G. 1986. A Campaign for Climbing Plants in the City. Anthos 1, pp. 29-34.

24 Sitta, V. 1983. A Living Epidermis for the City. Landscape Australia 4 (83), pp. 277-286.

25 Baumann, I.R. 1986. The Constructural Importance of Climbing Plants. Anthos 1, pp. 22-28.

26 Köhler, M. 1988. Besiedlung von Kletterpflanzan durch Insekten und Spinnen in Berlin (West). (Colonisation of Climbing Plants by Insects and Spiders in Berlin). Zeitschrift fur Angewandte Zoologie. (German Journal for Applied Zoology), 75(2), pp. 195-202.

27 Brochures on Green Walls from: Green Walls Sound Barriers Ltd, Surrey House, 34/41 High Street, Newmarket, Suffolk, CB8 8NA and C.D Brown (landscaping) Ltd., Udimore Farm, Chapel Lane, Igtham, Sevenoaks, Kent, TB15 9AQ.

Building for Birds and Bats

28 De Feu, C. 1989. . BTO Guide 20, British Trust for Ornithology, The Nunnery, Nunnery Place, Thetford, Norfolk IP24 2PU. Thompson, S 1989. Bats in the Garden. School Garden Company, P.O. Box 49, Spalding, Lincolnshire PE11 1NZ.

29 Special roof tiles available from Hans Peeters, Netherlands Society for the Protection of Birds, Driebergseweg Ibe, 3708 JB Zeist, The Netherlands.

30 Further information from World Wide Fund for Nature Suisse, Case Postale 2995, 1211 Geneve 2, Switzerland.

31 Brown, B.J. 1990. Lowestoft Kittiwake Wall. BTO News 169, pp. 4-5.

Green Roofs

32 Baugesetzbuch (BBAUG) 1989. 19. Auglage DTV. (Quoted in Köhler, M. and Schmidt, M. 1990.)

33 Scrivens, S. 1980-1982. Series of case studies of roof gardens in the Architects Journal including Gateway House (2.3.80), Arundel Great Court (9.4.80), Derry and Toms (15.10.80), Uetilhof (10.2.82), Harvey's Store and Kensington Hospital (24.2.82). See also articles on Construction (27.2.80) and Irrigation (12.3.80. and 19.3.80).).

34 Köhler, M and Baier, B. 1989. Okologische Untersuchungen an neueren Berliner Grasdachern. (Ecological Analysis of Recent Green Roofs in Berlin.) Das Gartenamt 38, pp. 302-306.

35 Kolb, W., Schwarz, T. and Trunk, M R. 1983. Zur Begrunung von Kiesdachern, (Planting of Roofs with a Voering of Gravel). Zeitschrift fur Vegetationstechnik No. 6, October-December 1983.

36 Gotze, H. 1988. das Grundach aus Abdichtungstechnischer Sicht (Roof Planting from a Constructional Viewpoint). Garten und Landschaft 98(10), pp. 52-55.

37 Kaiser, H. 1981. An Attempt at Low-cost Roof Planting, Garten und Landschaft 91(1), pp. 30-33.

38 Kölb, W. 1986. New Habitats on the Roof – Possibilities for the Provision of Extensive Vedure. Anthos 1, pp. 4-10.

39 Scrivens, S. Undated. Urban Landscape. Unpublished report. Contact: Technical Landscapes Ltd, Fawkham Green, Fawkham, Dartford, Kent DA3 8NL.

40 Köhler, M. 1990. The Living Conditions of Plants on the Roofs of Buildings – A Preliminary Report. In Urban Ecology Ed. H. Sukopp, pp. 33-45.

41 Contact the British Earth Sheltering Association, Caer Llan Berm House, Lydant, Monmouth, Gwent NP5 4JJ.

42 Scrivens S. 1989a. Urban Landscape. Paper given to "Greening the Cities: The Role of the Developer". Seminar organised by Midland Environment Ltd., Aston Science Park, Love Lane, Birmingham, 18 January 1989.

43 Mehl, U. and Werk, K. 1987. Hauser in Lebendigen Grun – Fassaden und Dacher mit Pflanzen Gestalten. (Buildings with a Living Green Cover Using Plants to Create Green Facades and Roofs). Falken-Verlag GmbH, 6373 Niederhausen, Germany.

44 Prinz, P. 1981. The Biological Activation of the Urban Structure. Garten und Landschaft 91(1), pp. 23-29.

45 Trillitzsch, F. 1979. Some Thoughts on the Subject of Roof Gardens, Garden und Landscaft 89(6), pp. 447-451.

46 Müller, D.U. 1989. Zur Flora und Fauna auf Grasdachern. (The Value of Grass Roofs for Fauna). Garten und Landschaft 99(1), pp. 21-25.

47 Brownlie, S. 1990. Roof Gardens – A review. Urban Wildlife Now No. 7, Nature Conservancy Council (now English Nature), Peterborough. Also see: Dove, L.E. 1987. Urban Refuges I: High-rise Wildlife Gardens. Urban Wildlife Managers Notebook 14. Urban Wildlife News. (3-4). National Institute for Urban Wildlife, 10921 trotting Ridge Way, Columbia, MD 21044, USA.

FURTHER READING

Akroyd, T. 1986. Trees and the Law. Arboricultural Journal 10, pp. 233-240.

Avon Wildlife Consultants Ltd. Undated. Hospital Wildlife Gardens. Published by UK2000 and RSNCD. Available from: The Royal Society for Nature Conservation.

Bachtler, R. 1988. Der Baum in Stradtraum (Urban Spaces – Places for Trees). Garten und Landschaft 98(7), pp. 25-29.

Badeja, A. 1982. Verwaltungsgebaude mit Naturnaher Umgebung (Office Building with Natural Surroundings). Garten und Landschaft 92(7), pp. 529-534.

Badeja, P.J.E. 1986. The Provision of Vendure on the Credit Suisse Administrative Building "Uetilhof", Zurich. Anthos 1, pp. 11-16

Baines, C. 1985. How to Make a Wildlife Garden. Elm Tree Books, London.

Baines, C. and Smart, J. 1991. A Guide to Habitat Creation 2nd Ed. Packard publishing, Chichester.

Bartholmai, G. 1984. Pflanzengagengepasste Kletterhilfen (Climber Supports matched to Plant Material). Garten und Landschaft 94(11), pp. 49-54.

Baumann, R. 1983. Begrunte Architektur: Bauen und Gestalten mit Kletterpflanzen. Verlag Callwey, Munchen. 244 pp.

Beazley, E. 1990. Sun, Shade and Shelter near Buildings: Part Two. Landscape Design No. 195, November 1990, pp. 14-17.

Blauermel, G. 1983. If Trees are to Survive in City Streets. Garten und Landschaft 3/83, pp. 185-195.

Bornkamm, R., Bartfelder, F. and Köhler, M. 1989. Verbunde Hof-Fassaden und Dachbegrunung (Combined Courtyard, Façade and Roof Greening). Kurzberichte aus der Bauforschung Mai 1989, Bericht Nr. 73, pp. 321-324.

Chambers, J. 1987. Wild Flower Garden. Elm Tree Books, London.

Chandler, J. 1987. Urban Renewal in Sympathy with Nature. London

Environmental Bulletin 4(4), pp. 5-8.

Clouston, B. (Ed.) 1977. Landscape and Design with Plants. Heinemann, London.

Doernach, R. and Heid, G. 1982. Das Naturhaus. Wolfgang Kruger Verlag. 96pp.

Doernach, R. 1985. Naturwerkstaff. Wolfgang Kruger Verlag. 96pp.

Doernach, R. 1986. Naturlich Bauen. WolfgangKruger Verlag. 96pp.

Dove, L.E. 1987. Urban Refuges I: High-rise wildlife gardens. Urban Wildlife Managers Notebook 14. Supplement to Urban Wildlife News, 10921 Trotting Ridge Way, Columbia, MD 21044, USA. Available from National Institute for Urban Wildlife, 10921.

Erisco-Bauder. Undated. Erisco-Bauder Green Roof Systems, 32pg booklet. Available from: Erisco-Bauder Ltd., Broughton House, Broughton Road, Ipswitch, Suffolk IP1 3Q5.

Ernst, W. 1988. Planted Roofs, Facades and Interiors. Garten und Landschaft 98(10) pp. 49-51.

Evans, H. 1985. The Patio Garden. Guild Publishing, London.

Fisch, R. and Giseke, U. 1987. The Treatment of Open Space at the International Building Exhibition (IBA), Berlin. Anthos 3, pp. 12-16.

Friends of the Earth and Business Design Group 1990. The Good Wood Manual. Friends of the Earth, London.

Gilbert, O. 1989. The Ecology of Urban Habitats, Chapman and Hall.

Grützmacher, B. 1984. Grass-covered Congress Centre in Torshaven. Garten und Landschaft 94, pp. 34-36.

Guntenspergen, G. and Stearns, F. 1982. comment on N.A. Richards Diversity and Stability in a Street Tree Population. Urban Ecology 7, pp. 173.

Hahn, E. 1989. Ecological Urban Restriction: Urban Environmental Problems and Environmental Strategies in Different Social Systems. Unpublished report available from: WZB-Wizzenschaftszentrum Berlin fur Socialforschung, Reichpietschufer 50, 1000 Berlin 30, Germany.

Helliwell, D.R. 1983. Energy Saving with Trees. Journal of Arboriculture 12(5), PP. 113-125.

Hempel, V. 1984. Is Ecology only a Feature? Garten und Landschaft 94(10), pp. 39-44.

Hessisches Ministerium fur Umwelt und Reaktorsicherhei, undated. Hessen Wird Grun: An Hausern, auf Dachern, in Hofen. Available from: Hessisches Ministerium fur Umwelt und Reaktorsicherheit, Referat Presse- und Offentlichkeeitsarbeit, Dostojewkistrasse 8, 6200 Weisbaden, Germany.

Hill, F. 1988. Wildlife gardening: a practical handbook. Derbyshire Wildlife Trust, Elvaston Castle, Derby DE7 3EP.

Holdsworth, B. 1990. Architecture for the New Age. Environment Now, May 1990, pp. 12-15.

Hutson, A.M. undated. Bats in Houses. Fauna & Flora Preservation Society, 79-83 North Street, Brighton, East Sussex BN1 1ZA.

International Bee Research Association 1981. Garden Plants valuable to Bees. Available from: International Bee Research Association, Hill House, Gerrards Cross, Bucks. SL9 0NR.

Johaentges, K. 1986. Shared Adventure. Architects Journal 10 September 1986, pp. 36-49.

Johnson, J. 1988. Regionalism and Invention. Landscape Architecture April-May 1988, pp. 59-63.

Johnston, J. 1990. Nature Areas for City People. London Ecology Unit Ecology Handbook 14. Available from: London Ecology Unit, Bedford House, 125 Camden High Street, London NW1 7JR.

Keble Martin, W. 1982. The New Concise British Flora in Colour. Michael Joseph/Ebury Press.

Laurie, I.C. (ed.) 1979. Nature in Cities. John Wiley & Sons, Chicester.

Leicester City Wildlife Project 1990. Greening Business Promises: A feasibility study for nature conservation groups. Available from: The Wildlife Trusts Partnership, The Green, Witham Park, Lincoln LN5 7JR.

Milchert, J. 1982. Balconies – the Garden Rooms of the City. Garten und Landschaft 92(12), pp. 937-939.

Ministeriums fur Umwelt Baden-Wurttemberg 1988. Besser leben mit der Natur (5 leaflets on "living better with nature"). Available from: Ministeriums for Umwelt, Baden-Wurttemberg.

Minke, G. and Witter, G. 1983. Hauser mit Grubem Pelz. Ein Handbuch Zur Hausbegrunung. Fricke Verlag. Frankfurt. 126pp.

Pearson, D. 1989. The Natural House Book, Conran Octopus, London 287pp.

Pryke, J.F.S. 1979. Trees and Buildings. Arboricultural Journal, April 1979. pp.388-396.

Richards, N.A. 1983. Diversity and Stability in a Street Tree Population, Urban Ecology 7, pp. 159-171

Robertson, C. (ed.) 1990. Landscape Specification 1990: The Sourcebook. Landscape Promotions, 3 Blackburn Road, London NW6 1RZ.

Saville, D. 1982. Walled Gardens: their planting and design. B.T. Batsford, London.

Schneider-Wessling, E. 1988. Nature and Architecture. Garten und Landschaft 98(10), pp. 28-32.

Schroeder, H.W. and Cannon, W.N. 1987. Visual Quality of Residential Streets: Both street and yard trees make a difference. Journal of Arboriculture 13, pp. 236-239.

Scrivens, S. 1982. Design Guide: Roof Gardens. Architects Journal, 17 March 1982, pp. 73-87.

Scrivens, S. 1989. Landscape Update: 3 Urban Planning, Architects Journal. 15 February 1989.

Scrivens, S. 1989. Urban Landscape. Paper given to "Greening the Cities: The Role of the Developer". Seminar organised by Midland Environment Ltd., Aston Science Park, Love Lane, Birmingham, 18 January 1989.

Snow, B and D. 1988. Birds and Berries. Butler and Tanner Ltd., London

Stephens, D.H. 1976. Water Storage Roofs. The Architect, December 1976, pp. 77-81.

S.T.E.R.N. 1989. Step by Step – Careful Urban Renewal in Kreuzberg, Berlin. International Bauausstellung Berlin (IBA) 1987. Available from S.T.E.R.N., Kopenickerstr. 154, D-1000, Berlin, Germany.

Stevenson, V. 1985. The Wild Garden. Windward, Leicester.

Stirrat, R. 1985. The Place of Trees in Towns: A planner's view, Arboricultural Journal 9, pp. 201-205.

Thompson, S. 1989. Bats in the Garden. School Garden Company, P.O. Box 49, Spalding, Lincolnshire PE11 1NZ.

Turner, T. 1985. Surface Water Drainage and Management. Landscape Design, Oct. 1985, pp. 43-45.

Villager, J. 1986, Green Roofs and Walls – a necessity in the city. Anthos 1, pp.1-3.

West Sussex County Council 1972. Tree Planting in Urban Areas. West Sussex County Council, Chichester.

Whiston-Spirn, A 1984. The Granite Garden. Basic Books Inc., New York.

Winkler, A. 1989. Nature in the Design Process. Anthos, March 1989, pp. 29-33.

Wood, A.D.B. 1965. Terrace and Courtyard Garden: for Modern Homes W.H. and L. Collingridge Ltd., London

World Meteorological Organisation. Undated. Climate, Urbanization and Man. World climate programme, WMO, Geneva.

WWF Suisse. Undated. Place a la Nature: La Maison des Animaux, WWF Suisse. Leaflet.

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ngôn ngữ của bạn, hãy gọi điện theo số hoặc
liên lạc với địa chỉ dưới đây.

Greek

Αν θα θέλατε ένα αντίγραφο του παρόντος εγγράφου στη γλώσσα σας, παρακαλώ να τηλεφωνήσετε στον αριθμό ή να επικοινωνήσετε στην παρακάτω διεύθυνση.

Turkish

Bu brosürü Türkçe olarak edinmek
için lütfen asagidaki numaraya
telefon edin ya da adrese basvurun.

Punjabi

ਜੇ ਤੁਹਾਨੂੰ ਇਸ ਦਸਤਾਵੇਜ਼ ਦੀ ਕਾਪੀ ਤੁਹਾਡੀ ਆਪਣੀ ਭਾਸ਼ਾ
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तो कृपया निम्नलिखित नम्बर पर फोन करें अथवा दिये
गये पता पर सम्पर्क करें

Bengali

আপনি যদি আপনার ভাষায় এই দলিলের প্রতিলিপি
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যা ঠিকানায় আমাদের সঙ্গে যোগাযোগ করুন।

Urdu

اگر آپ اِس دستاویز کی نقل اپنی زبان میں چاہتے
ہیں تو براہِ کرم نیچے دیئے گئے نمبر پر فون کریں
یا دیئے گئے پتے پر رابطہ قائم کریں۔

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