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Building Resilience in Urban Settlements Through Green Roof Retrofit

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1.0 Introduction

The 'challenge of achieving sustainable development in the 21st century [will] be won or lost in the world's urban areas' (Newton and Bai, 2008: 4) and a major issue is the contribution that the built environment makes to greenhouse gas (GHG) emissions and global warming. Typically each year 1–2% of new buildings are added to the total stock; it follows that informed decision-making in respect of sustainable adaptation of existing stock is critical to deliver emissions reductions. Within cities, local government authorities are encouraging building adaptation to lower building-related energy consumption and associated GHG emissions. Examples include San Francisco in the USA and Melbourne in Australia. For example, the City of Melbourne aims to retrofit 1200 commercial central business district (CBD) properties before 2020 as part of their strategy to become carbon neutral (Lorenz and Lützkendorf, 2008). Office property contributes around 12% of all Australian GHG emissions and adaptation of this stock is a vital part of the policy (Garnaut, 2008). Whilst Australian cities date from the early 19th century, the concepts of adaptation and evolution of buildings and suburbs are not as well developed or entrenched as in other continents like Europe. However, the issue of the sustainable adaptation of existing stock is a universal problem, which increasing numbers of local and state

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governments will endeavour to address within the short to medium term. In most developed countries we now spend more on building adaptation than we do on new construction. Clearly there is a need for greater knowledge and awareness of what happens to commercial buildings over time.

There are a range of definitions for 'urban resilience', and a marked lack of agreement as to what the concept means. However, there is an underlying meaning which covers the ability to bounce back from external shocks, and Meerow's et al's (2016: 39) definition provides a comprehensive and up to date focus: 'Urban resilience refers to the ability of an urban system….to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current of future adaptive capacity'. Green roofs therefore not only offer an important element in developing urban resilience across a range of scales (building, neighbourhood and city), but also in helping create adaptive capacity to deal with future environmental disturbances, both of which are key themes explored throughout this book.

This book is intended to make a significant contribution to our understanding of best practice in sustainable adaptations to existing commercial buildings in respect of green roof retrofit by offering new knowledge-based theoretical and practical insights, and models grounded in results of empirical research conducted within eight collaborative construction project team settings in Australia, the UK and Brazil (see Section 1.6 below). The results clearly demonstrate that the new models can assist with informed decision-making in adaptations that challenge some of the prevailing solutions based on empirical approaches, which do not appreciate and accommodate the sustainability dimension. Hence, the studies collectively offer guidance towards a balanced approach to decision-making in respect of green roof retrofit that incorporates sustainable and optimal approaches towards effective management of sustainable adaptation of existing commercial buildings; from strategic policy-making level to individual building level.

1.1 Background and Context: Green Infrastructure

Green infrastructure (GI) is a term used to describe all green and blue spaces in and around our towns and cities, and as such is very much a collective term embracing parks, gardens, agricultural fields, hedges, trees, woodland, green roofs, green walls, rivers and ponds (RTPI, 2013). The concept evolved for thinking in the USA and the 'greenway' movement, which highlighted the importance of using networks to manage green space and achieve multiple aims and objectives (Roe and Mell, 2013). In the North American context, therefore, GI was originally based around conservationist principles, and in Europe it has evolved into a holistic and cross-cutting agenda. In the UK, GI principles have now flowed into a range of policy, practice and guidance for built environment professionals. In England, national planning policy (through the National Planning Policy Framework, NPPF) (Communities and Local Government, 2012) places an emphasis on local planning authorities to plan strategically for networks of green infrastructure, and to take account of the benefits of GI in reducing the risks posed

Table 1.1 Examples of GI assets (TCPA, 2012)

Natural and semi-natural rural and urban green spaces	Including woodland and scrub, grassland (e.g., downland and meadow), heath and moor, wetlands, open and running water, brownfield sites, bare rock habitats (e.g., cliffs and quarries), coasts, beaches and community forests.
Parks and gardens	Urban parks, country and regional parks, formal and private gardens, institutional grounds (e.g., at schools and hospitals).
Amenity green space	Informal recreation spaces, play areas, outdoor sports facilities, housing green spaces, domestic gardens, community gardens, roof gardens, village greens, commons, living roofs and walls, hedges, civic spaces, highway trees and verges.
Allotments, city farms, orchards, suburban and rural farmland	
Cemeteries and churchyards	
Green corridors	Rivers and canals (including their banks), road verges and rail embankments, cycling routes and rights of way.
Sites selected for their substantive nature conservation value	Sites of Special Scientific Interest and Local Sites (Local Wildlife Sites and Local Geological Sites); Nature Reserves (statutory and non-statutory).
Green space designations	Selected for historic significance, beauty, recreation, wildlife or tranquillity.
Archaeological and historic sites	
Functional green space	Such as sustainable drainage schemes (SuDS) and flood storage areas.
Built structures	Green (or living) roofs and walls, bird and bat boxes, roost sites within existing and new-build developments.

by climate change. The NPPF defines GI as: ‘a network of multi-functional green space, urban and rural, which is capable of delivering a wide range of environmental and quality of life benefits for local communities’ (Communities and Local Government, 2012: 52). Similarly, the UK’s natural environment white paper (HM Government, 2011) offers explicit support for green infrastructure as an effective tool in managing environmental risks such as flooding and heatwaves.

GI is seen very much as a multi-functional asset therefore and so relates to making the best use of land to provide a range of valuable goods and services (see Table 1.1). GI is also underpinned by the concept of ‘ecosystem services’, which are provided by the range of GI assets. Work by the UK National Ecosystems Assessment, for example, includes the following as key ecosystem services:

- Supporting services – those necessary for all other ecosystem services such as soil formation and photosynthesis.

- Provisioning services – such as food, fibre and fuel.
- Regulating services – including air quality and climate.
- Cultural services – such as recreational activities and wellbeing, aesthetic values and sense of place.

By thinking in this way about assets and services, it requires us to think more closely about the overall costs and benefits of GI as a service-producing infrastructure (UKGBC, 2015). One of the key attractions of GI is its multi-functionality, or its ability to perform several functions and provide several benefits on the same spatial area (EC, 2012). These functions can be environmental, such as conserving biodiversity or adapting to climate change, social, such as providing water drainage or green space, and economic, such as jobs creation or increasing property prices for owners.

As the European Commission (EC, 2012) suggests, a good example of this multi-functionality is provided by the urban GI of a green roof, which reduces stormwater runoff and the pollutant load of the water, but also helps reduce the urban heat effect, improves the insulation of the building and provides increased biodiversity habitat for a range of species. Thus it is this multi-functionality of GI that sets it apart from the majority of its 'grey' counterparts, which tend to be designed to perform one function, such as transport or drainage without contributing to the broader environmental, social and economic context (Naumann *et al*., 2011; EC, 2012). In this way GI has the potential to offer 'no regrets' solutions by dealing with a range of important problems and producing the maximum number of cost-effective benefits.

GI has a wide range of health and wellbeing and environmental benefits, through improved mental wellbeing and better physical activity, as well as reduced exposure to pollution and high urban temperatures (POST, 2013). Although in the UK some local authorities (such as Birmingham, London, Manchester and Plymouth) have developed GI strategies, this is variable, and with the exception of SuDS, new GI is not *required* by national legislation. In Australia, the adoption of GI is at state and city level and varies between states and cities. Plans and strategies have been made and adopted, only to be amended and moved to other agencies. As such, no coherent national policy exists currently.

1.1.1 Green Roofs

Green roofs are an important and growing element of GI. Green roofs have existed throughout history. Some of the earliest examples include the Hanging Gardens of Babylon in 500BC (Figure 1.1), the ziggurats of Mesopotamia and early Roman architecture (Berardi *et al*., 2014). Early Viking housing and mediaeval buildings also employed green roofs, with the technique also popular during the settling of the American west and in the vernacular tradition of Scandinavia. During the 20th century Le Corbusier also included them in his five points of modern architecture before the technology gained a real foothold in Germany (from the 1880s), then latterly in France and Switzerland (Magill *et al*., 2011; Berardi *et al*., 2014). In comparison, the UK is a relatively recent innovator in green roofs (although the

Figure 1.1 The mythical Hanging Gardens of Babylon.
Source: Wikimedia.

technology was used to camouflage airfield buildings during World War II) with some good examples in London (St James Tube Station), Manchester (Metropolitan University), Edinburgh (Royal Bank of Scotland) and Cardiff (Interpretation Centre).

1.2 Extensive and Intensive Systems

Green roofs (also known as vegetation or living roofs) are an example of a 'no regrets' adaptation measure that can serve multiple societal goals (Mees *et al*., 2013). For example, they can offer a number of improved public ecosystem services (or benefits), such as increased biodiversity, improved air quality and mitigation of the urban heat island effect, as well as having the ability to harvest rainwater and reduce surface runoff. Similarly, they offer additional private benefits to property owners through improved energy savings, thermal comfort and aesthetics, and can potentially increase property values.

1.3 Valuing Green Infrastructure and Wider Economic Benefits

There are clearly a range of benefits that green infrastructure can bring to bear in adapting to, and mitigating for, climate change. Often these may be indirect, through reduced flooding risk, which can increase property values

Table 1.2 Potential benefits of green infrastructure in a retail centre (NRDC, 2013)

Green infrastructure improvements	40,000 sq. ft green roof with 90% green coverage 50 strategically planted medium-sized trees Bioswales and rain gardens that manage an inch of runoff from 2000 sq. ft adjacent impervious area 72,000 sq. ft permeable pavement parking lot Cisterns to capture runoff from 5000 sq. ft of roof area and use for irrigation
Building assumptions	Area: 40,000 sq. ft One storey with 40,000 sq. ft roof Lot area: 128,000 sq. ft Permeable area: 5000 sq. ft (covered in turf) Number of storeys: 15 Annual rent: $17 per sq. ft Annual retail sales: $2.182m per store
Potential benefits	Energy savings (reduced demand for heating/cooling): $3560 p.a. Avoided costs for conventional roof replacement: $607,750 NPV over 40 years Tax credit: $100,000 for installation Increased retail sales: $1.2m p.a. Stormwater fee reduction: $14,020 p.a. (with projected 6% increase) Total benefits (over 40 years) > $24,202,000
Non-quantified benefits	Water conservation (increase in net benefits) Increased property value (significant increase in net benefits) Reduced infrastructure costs (possible increase) Reduced crime (possible increase) Improved health and employee satisfaction (increase in net benefits) Reduced flooding costs (uncertain impacts)

(Molla, 2015), or perhaps contributing to, for example, a higher sustainability assessment rating through BREAAM[1] or LEED[2] (Berardi *et al.*, 2014). Perhaps key to understanding how cities could create real change in the built environment to bring about more sustainable outcomes is the commercial property sector, comprising offices, retail and industrial properties. Theoretically, at least, GI (including green roofs) could help increase property values, sales, save energy and increase workplace productivity. Research by NDRC (2013) highlights how, in an office building, the total present value of benefits can approach $2m and in a retail centre, $24m (with $23m of this in increased sales). In the case of the retail centre, present value benefits were calculated over a 40-year period using a 6% discount rate, and projected inflationary rates with the location assumed as being Philadelphia (Table 1.2).

GI can, in a general sense, also reduce lifecycle costs associated with private property improvements. Green roofs do not need to be replaced as

[1] Building Research Establishment Environmental Assessment Methodology.
[2] Leadership in Energy and Environmental Design.

frequently as conventional roofs – they are typically considered to have a life expectancy of at least 40 years, compared with 20 years for a conventional roof. For example, in a midsize retail building (with a 40,000 sq. ft roof), a green roof could avoid a net present value of over $600,000 in roof replacement costs over 40 years; a medium-sized office building, with a roof half that size, could save over $270,000. In some instances, green roofs can also reduce air conditioning system capital costs by allowing for use of a smaller heating, ventilation and air conditioning (HVAC) system.

1.4 Measures of Greenness in Cities and the Growing Market for Green Roofs

The Inter-American Development Bank (2014) suggest that Latin American and Caribbean cities need to measure and benchmark the amount of green space within their boundaries. A key indicator is suggested as being the amount of green space (in hectares) per 100,000 inhabitants, with a green rating as >50 ha, orange as 20–50 ha and red as <20 ha. Similarly, the World Health Organisation (WHO) has suggested that every city should have a minimum of 9 m^2 of green space per person. An 'optimal' amount would sit between 10 and 15 m^2 per person. Indeed, one of the greenest cities in the world is thought to be Curitiba in Brazil, with 52 m^2 per person, followed by Rotterdam and New York (Karayannis, 2014).

This increasing focus on green space and its role within a specific measure of urban sustainability has come at a time when there has also been an increasing focus on how cities can become more self-sufficient in terms of food production. Urban agriculture, which focuses on the development of localised food systems within and close to urban areas, has been a frequent feature of sustainable thinking in many cities (Hui, 2011). This is not surprising, given that cities occupy only 2% of the global land surface but consume 75% of the world's resources (Giradet, 2008), although by the same token cities can also be relatively efficient in terms of per capita consumption and emissions. There are many examples of what has been termed 'zero acreage farming' (Z farming), which implies the non-use of land/acreage, and which is a subset of the wider term 'urban agriculture' (Specht *et al*., 2013; Thomaier *et al*., 2014). Examples include open rooftop farms, rooftop greenhouses, productive façades and indoor farming. Clearly, green roofs which produce food are a key example of this growing phenomenon.

1.5 A Growing Global Market for Green Roofs

In contrast to other markets such as photovoltaics (PVs) or biofuels, the growth of green roofs and green walls (building-integrated vegetation, BIV) is often driven by city-level actions rather than national policies. Green roofs tend therefore to be driven by building code requirements and mandates or financial incentives (or both).

Previous estimates (Ranade, 2013) suggest that the green roof market globally will be $7bn, comprising a $2bn market for suppliers of polymetric materials and the balance for vegetation, installation and operations. This reflects falling costs, and also the use of incentives and regulation. By 2017, costs for green roof installation are expected to be cut by 28%, from an average of $38 per sq. ft in 2012 to $23 per sq. ft in 2017. Green wall growth is expected to be $680m by 2017. Europe has led the growth of the green roof market over the last 20 years: for example, Germany has 86 million m^2 of green roofs out of a total of 104 million m^2 and already 10% of flat roofs are green. Similar growth levels have occurred in Switzerland, where for example in Basel 70% of its green roof target has been met. Despite this, there is considerable opportunity for green roof growth in other European cities, such as London and Copenhagen. Wilkinson and Reed (2009) estimated that 15% of commercial office roofs in the Melbourne CBD could be retrofitted as green roofs. Despite this growth, the sector faces key challenges. Generally speaking, most green roofs globally have used sedum or drought-friendly irrigation, but green thinking is moving towards greater diversity in species – with payback periods of 30 years.

1.6 Overview of the Structure of the Book

As this chapter and the book as a whole emphasises, roofs can fulfil a multitude of objectives: attracting biodiversity, improving thermal performance, attenuating stormwater runoff, mitigating the urban heat island, providing space for urban food production, providing space for social interaction and engagement, and possibly space for the reintroduction of endangered species of flora and fauna. In most climates, therefore, green roofs can make a positive contribution to building resilience to climate change and help to arrest the speed of that change.

Furthermore, in addition to the primary reason for the retrofit, other benefits co-exist. For example, a green roof retrofit in northern Europe for improving thermal performance and saving energy not only results in less GHG emissions but also attracts biodiversity, reduces stormwater runoff, mitigates the urban heat island, and could provide space for the reintroduction of endangered species of local flora and fauna. Where access is provided, the roof could also provide space for urban food production and/or space for social interaction and engagement. These multiple benefits make it an attractive option.

In Chapter 2, structural issues are taken into account by Renato Castiglia Feitosa and Sara Wilkinson. Retrofit of the existing stock of buildings is vital, as only 1–2% is added annually to the total stock of buildings, and around 87% of the buildings that we will have by 2050 are already built (Kelly, 2009). With regard to green roofs, the overriding issue is one of structural capacity to accommodate the additional loads that a retrofit brings. This chapter considers the technical and engineering considerations that stakeholders need to consider when evaluating green roof retrofit potential. For example, existing structure, load-bearing capacity, access, power and water supply, orientation, exposure to sunlight and overshadowing, and occupational health and safety. In short, how to determine what type of green roof is suited to the structure.

Issues of urban heat islands are raised in Chapter 3 by Paul Osmond and Matthias Irger. The global climate change and the urban heat island (UHI) phenomenon – whereby cities absorb and release more heat than the surrounding countryside – carry growing potential to make urban life at particular times and places an exercise in low-grade misery. The mitigating role of urban vegetation and green spaces, reflective materials and strategies for reducing the release of heat from human activities like transport and air conditioning are increasingly well understood. Green roofs have also been widely recognised as playing a part in UHI mitigation. This chapter reviews the literature around the microclimatic effects of green roof retrofitting and presents a model based on detailed remote-sensing data for metropolitan Sydney, Australia. We apply this model to explore the effects of installing extensive green roofs on 100% and 50% of rooftops across the variety of urban form typologies which characterise Sydney's built environment. The results suggest a modest but real reduction in heat island effects.

Thermal performance is the focus of Sara Wilkinson and Renato Castiglia Feitosa in Chapter 4. Green areas have diminished in big cities and with increasing temperatures, deterioration of air quality is a common result. Consequently, there is a rise in air pollution and GHG emissions, the costs of air conditioning, and mortality and heat-related illness. Due to the lack of space in urban areas, green roof retrofit is a feasible alternative to this problem. Green roofs improve the insulating qualities of buildings, attenuating heat exchange through inadequately insulated and poorly sealed roof structures. After a review of the literature, this chapter reports an experiment on two small-scale metal roofs in Sydney (Australia) and Rio de Janeiro (Brazil) to assess the thermal performance of portable green roof modules. In each site, two identical roofs, one covered with modular lightweight trays planted with succulents and the other not, had their internal temperature recorded simultaneously and compared. Green roofs were showed to attenuate housing temperatures, indicating that green roof retrofitting could lower the cooling energy demand considerably.

In Chapter 5, Jessica Lamond, David Proverbs and Sara Wilkinson describe research demonstrating the assessment of whether to retrofit with green roofs as a means of attenuating stormwater runoff. The problem of pluvial flooding in terms of financial costs and the impact on our urban settlements is the starting point for a discussion on the potential of retrofitted green roofs as a mitigating measure. A range of technical specifications for stormwater roofs, and critical issues to consider in retrofit of existing buildings, are evaluated. Theoretical frameworks of the distributed benefits of green roofs are presented, and a methodology to estimate the potential for stormwater attenuation of green roof retrofit at the city-scale level is described in detail. The chapter reports on recent empirical research undertaken in two cities with very different climatic conditions: Melbourne, Australia and Newcastle, UK, at city-scale level. Having examined the city-scale level, a second illustrative case study at an individual building scale outlines stormwater performance and the assessment process in Portland, Oregon. The chapter concludes by describing how the stormwater effectiveness of green roofs may be limited in certain conditions by the availability of suitable buildings and the source of floodwater. A summary of the potential benefits of green roof retrofit for stormwater attenuation is made.

The focus of Chapter 6 is the changes to biodiversity associated with green roof retrofit and based on work by Tanya Latty, an entomologist. Green roof retrofits have the potential to increase urban biodiversity by providing animal habitats within highly urbanised areas. Indeed, many municipalities explicitly list 'benefits to biodiversity' as part of the rationale for building or retrofitting green roofs. But do green roofs actually increase animal biodiversity? Although green roofs can provide food sources for bats and birds, there is little evidence that the presence of green roofs actually increases bird or bat populations; in at least one case, green roofs appear to act as an ecological trap, attracting birds to build nests in habitats that cannot support their offspring. In contrast, green roofs support a wide variety of invertebrate species, but at levels that are usually below those of other urban green spaces such as parks or bushland fragments. Nevertheless, green roofs may play a role in urban conservation by creating corridors through urban areas, effectively connecting otherwise isolated populations. Future retrofits can increase invertebrate biodiversity by providing structurally complex habitats, providing a mixture of pollen and nectar-producing plants, and by using diverse substrates.

Plant survival and green roof installation/maintenance costs will long remain prime considerations in planting choices for green roofs, and this is covered in Chapter 7 by Tijana Blanusa, Madalena Vaz Monteiro, Sarah Kemp and Ross Cameron. If low levels of funding, lack of horticultural knowledge/experience and the need for reduced maintenance limit the options, then developing a roof with succulents and grasses might be a way to introduce some ecosystem benefits. However, in scenarios where a semi-extensive substrate depth can be afforded and an investment in sustainable irrigation (recycled rainwater, greywater) is possible, considering and using a wider range of low-growing perennial species with light-coloured leaves, higher leaf area indices (LAIs) and evapotranspiration (ETp) rates would likely provide more benefits. The total direct cost of roof installation may well be higher in that case but the argument in support of a more diverse plant choice should be linked to the direct and indirect savings and benefits which this planting produces over and above the simple extensive green roof. These benefits include building insulation and temperature reduction, localised air cooling effects, greater rainfall capture, more pollutant capture per square metre, greater biodiversity support, etc.

In Chapter 8, John Blair and Paul Osmond consider the potential for green roof retrofit to provide space for reintroducing or increasing the amount of indigenous or endangered species. The multiple environmental, social and economic benefits of green roofs are increasingly well understood among built environment practitioners and in the broader community. However, the issue of biodiversity protection and conservation of endangered flora in our densifying cities has received much less attention than benefits such as stormwater detention or building energy savings. This chapter provides a brief strategic overview of urban biodiversity conservation before examining the current state of play regarding the application of roof greening in the protection of endangered flora, including the identification of key knowledge gaps. The Eastern Suburbs Banksia Scrub – a threatened plant community indigenous to the coastal zone of Sydney, Australia – is introduced here as the focus for a proposed five-year research programme aimed at evaluating the role of green roofs in the management of this particular community and, it is hoped, helping to address the more general research gaps around roof greening as a viable flora conservation strategy.

Food security is an issue that we need to be conscious of, and in Chapter 9, Sara Wilkinson and Fraser Torpy examine the potential of green roof retrofit for urban food production. Human populations are becoming increasingly urbanised and thus distanced, both physically and psychologically, from the sources of their food. Decentralising food production from remote rural regions to within urban centres will address both the growing sense of disconnect and the growing costs associated with food transport. This chapter describes the social, environmental and economic aspects of local-scale urban food production, as well as setting out typical specifications and considerations in respect of bed systems, with a focus on the health and safety, technical, environmental and economic aspects of larger-scale rooftop food production. Our empirical observations demonstrate that there is great potential in most cities for the expansion of urban rooftop farming, and that many of the traditional barriers to growing food in cities – such as fears over food safety – can be overcome in virtually all situations.

As well as environmental sustainability, green roofs can provide social sustainability. Sumita Ghosh, Ilaria Vanni Accarigi and Angela Giovangeli report on the social aspects of rooftop gardens in Chapter 10. Rooftop gardens have a long history, dating back many centuries. In the contemporary context, the rooftop garden reflects a concern for the natural and built environment in terms of sustainability, community and food production. This chapter explores the social aspects of rooftop gardens by examining mainly two Sydney inner-city rooftop gardens in Australia: the University of Technology Sydney, an educational institution in Ultimo and 107 Projects, a permaculture garden that is part of a multidisciplinary creative space in Redfern. Eight rooftop gardens in different universities from other parts of the world are also considered. Through interviews, sensory ethnography and comparative analysis, this chapter highlights that rooftop gardens in different types of institutional settings revolve around shared interests in growing food as well as a shared ethos in creating community links in the workplace and beyond.

In Chapter 11, Dominique Hes, Christopher Jensen and Lu Aye consider an alternative to green roofs, where thermal performance and a reduction of building-related GHG emissions is the goal; this option is the cool or white roof. Cool roof paint (CRP) is a practical, low-cost and retrofit option for improving the thermal performance where there are significant cooling loads. This chapter looks at their viability in cool-temperate climates, where there is a higher heating load. The chapter presents the results of four experiments investigating a CRP roof retrofit of a 20-year-old metal roof; the extension of this data through modelling to test the sensitivity of CRP to changes in shading, roof pitch, insulation levels, insulation location and building roof-to-surface area ratios; the testing of the CRP against a green roof retrofit; and the benefit of white roofs on electricity production through photovoltaics. There is a benefit to CRPs used in a residential sense in Melbourne, reducing the cooling loads depending on ceiling insulation levels. The research shows that the CRPs are most beneficial for the retrofit of short (high roof area to overall surface area) industrial buildings. Other effective retrofit scenarios are discussed. Compared with CRP retrofits, the green roof reflected less energy back into the external environment and provided an additional reduction in internal temperature of up to 3°C on a hot summer's day (based on the retrofit of a 20-year-old metal roof with insulation of less than 1 R-value). CRP treatments have a valuable role to play in adding to the retrofit options when a green roof may not be appropriate.

In Chapter 12, Sara Wilkinson and Tim Dixon review the preceding chapters and highlight the importance of green roofs in the context of cities, neighbourhoods and individual buildings.

1.7 Conclusion

This chapter has outlined the context in which green roof retrofit can be seen to provide a means for reducing the environmental impact of the built environment on climate change and global warming. The structure of the book has been outlined to show how empirical research in three continents is being developed and implemented to address a range of social, environmental and economic issues related to sustainable development. For many practitioners this is a new area of practice, and the aim of the book is to raise awareness of the primary and related benefits that occur with green roof retrofit, as well as increasing knowledge to reduce risk and increase uptake of the technology.

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