Adapting to the impact of climate change on buildings, neighbourhoods and cities

A Briefing Guide for the North West

Prepared on behalf of **CCI NW**

for the **Northwest Climate Change Adaptation Group**

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Contents

Preface

Last year, the UK Government published, as part of its most recent projections of the impact of climate change, a Briefing Report[1] aimed at decision-makers and planners. In his introduction, Professor Robert Watson, the Chief Scientific Advisor to Defra, commented:

> *"That the world's climate is changing is irrefutable. The Intergovernmental Panel on Climate Change stated in its most recent Assessment Report that it is very likely that the changes we have seen and measured are the result of anthropogenic emissions of greenhouse gases. While there may be some opportunities to be gained from a changing climate, we expect the bulk of the changes associated with a warming world to be negative for our society, economic sectors and the natural environment. And because of the time lag in the climate system, even with the most ambitious mitigation efforts, we are locked in to a further amount of climate change over the coming decades. Governments across the UK have an obligation to put in place measures to ensure that the negative effects of this are minimised for the UK, as well as taking advantage of any opportunities."*

Three factors: the high likelihood that mankind has already begun to change the earth's climate, the projections of significant impacts in the future, and the commitment to further change over the next few decades irrespective of any emission reductions in the short term, argue very strongly for a **strategy of adaptation** to minimise the consequences, and maximise the opportunities, of climate change.

To adapt effectively, planners and decision-makers need as much good information as possible on how climate will evolve, and supplying this is the aim of the new projections of UK climate change in the 21st century, known as UKCP09. They are one part of a UK government programme of work to put in place **a new statutory framework on, and provide practical support for, adaptation.**

[1] http://ukclimateprojections.defra.gov.uk/images/stories/briefing_pdfs/UKCP09_Briefing.pdf

BACKGROUND

Graphics by I eat ART http://ieatart.carbonmade.com/

Introduction to this Guide

This Briefing Guide has been prepared for the Northwest Climate Change Adaptation Group[2](see Appendix 3). The Guide is aimed at those decision-makers whose actions directly affect the design, construction, maintenance and regeneration of the built environment – developers, clients, planners, designers and constructors.

The Guide has a simple purpose. It seeks to summarise what are currently seen as the key impacts on the built environment of climate change in the UK and then to signal what can be done to adapt to them. This is done in six-steps.

Six steps followed in this Briefing Guide

1. Identify climate changes, especially in relation to the North West of England.
2. Identify the impacts of these changes
3. List possible responses to these impacts at three spatial scales – building, neighbourhood and city
4. Signpost to where up-to-date information can be found about the practical implementation of these responses
5. Identify, where available, well-documented UK cases studies
6. List, where available, local examples in the North West.

The first part of the Guide describes the background to adapting to climate change in built environment. The second part provides information about what can be done to adapt to the impacts of climate change identified.

2 http://www.climatechangenorthwest.co.uk/?page_id=386

About Climate Change Adaptation

This Guide is only directly concerned with **climate change adaptation**. It does not provide information on **climate change mitigation**. In practice, these two terms are often not clearly understood or differentiated. They also are used differently (more precisely) amongst the climate change science and research communities than they are by the lay public or built environment professionals.

Climate Change Science definition of **Adaptation**
Adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploit beneficial opportunities. (UKCIP)[3]

Within the built environment sector, **climate change adaptation** is often used simply to mean changes that can be made to the design or construction (less often the operation or use) of buildings and landscaping in order to cope with the consequences of one or more of the impacts of climate change.

It is this latter, looser meaning of adaptation which is employed in this report, because it is the one that prevails in the sector being addressed.

Climate Change Science definition of **Mitigation**
Efforts to limit the man-made causes of climate change. (UKCIP)

In other words, **mitigation** involves taking actions to reduce greenhouse gas emissions and to enhance sinks aimed at reducing the extent of climate change whereas **adaptation** involves taking actions to minimize the effects, and take advantage of the opportunities, of climate change (both current and those yet to come). To date, most of the UK Government's policy initiatives in relation to climate change and the built environment – such as Energy Performance Certificates, the Code for Sustainable Homes, and Zero Carbon Development – have been focused on **mitigation**. Only those specifically focused on **adaptation** are signposted in this Guide, see Appendix 1.

In practice, however, as the London Climate Change Partnership has signalled:[4]

> *"… adaptation and mitigation need to be tackled in parallel. Reducing carbon emissions (mitigation) is essential but adaptation is also critical. Some climate change is now inevitable and unless urgent, concerted global action is taken to reduce greenhouse gas emissions, further changes to our climate may become unavoidable, This means that preparing for and adapting to the changes is not an alternative strategy to reducing greenhouse gas emissions, but a parallel, complementary and highly necessary one."*

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3 http://www.ukcip.org.uk/index.php?option=com_content&task=view&id=54&Itemid=179
4 London's Commercial Building Stock and Climate Change Adaptations, http://www.london.gov.uk/lccp/publications/londons-commercial-buildings-09.jsp

How will climate change impact on the UK?

There is now broad agreement that the earth's climate is changing as a result of human activity through the emission of greenhouse gases into the atmosphere.[5] And it is accepted that we are committed to at least 40 to 50 years of climate change whatever we do now, and in the future, to reduce our CO_2 emissions. The UK Climate Projections (UKCP09) identify climate change as perhaps the biggest threat that humanity faces[6] and give climate information for the UK up to the end of this century to support efforts to reduce greenhouse gases and to adapt to the climate change that already cannot be avoided.

The projections illustrate three different scenarios (high, medium and low greenhouse gas emissions) for 30 year time periods (2010-2039, referred to as 'the 2020s'; 2040-2069, referred to as 'the 2050s'; and 2070-2099, referred to as 'the 2080s') and at three levels of probability (10%, 50% and 90%)[7]. Probability level maps indicate the strength of evidence for the projected change. For 50% probability, for instance, a change is just as likely to be greater than the values shown, as it is to be less than the values shown. UKCIP calls this 50% probability the central estimate. As UKCIP stress, it is not necessarily the most likely projection. The changes presented are relative to a 1961-1990 baseline.

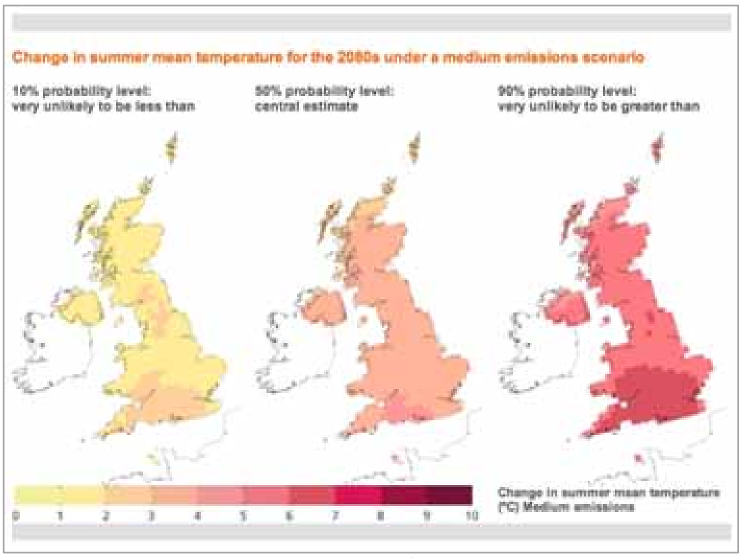

Figure 1. The medium emissions scenario for change in mean summer temperature for the whole of the UK by the 2080s

UKCP09's **key findings for the whole of the UK** over the coming century are:

- all areas of the UK get warmer, and the warming is greater in summer than in winter.
- there is little change in the amount of precipitation (rain, hail, snow etc) that falls annually, but it is likely that more of it will fall in the winter, with drier summers, for much of the UK, and
- sea levels rise, and are greater in the south of the UK than the north.

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5 UK Climate Change Committee, 2008, http://www.theccc.org.uk/reports/building-a-low-carbon-economy

6 http://ukcp09.defra.gov.uk/content/view/4/4. UKCP09 gives climate information for the UK up to the end of the century. Projections of future changes are provided based on simulations from climate models, see http://ukcip.org.uk/index.php?=com_content&task=view&id=163

7 A user interface also allows the data to be interrogated for other time periods and probability levels.

How will climate change impact on the North West?

UKCP09 provides a range data of climate variables as shown in Tables 1 and 2 below. For each emission scenario, the projected value of change is shown for: 10th percentile (the value 10% of the projected values are below), 50th percentile (the value 50% of the projected values are below) and 90th percentile (the value 90% of the projected values are below).

Climate variables are presented in this way to best reflect the probabilistic nature of UKCP09 projections. Additionally, a wider range is shown which corresponds to the lowest 10th percentile and the highest 90th percentile from all three emissions scenarios for each climate variable. For climate variables within the 2020s, the ranges of projected values overlap greatly. This becomes increasing less within the 2080s projected values due to increasing uncertainty when projecting further into the future, the greater uncertainty within the models and the extent to which changes in the future are likely to be greater changes than in the next few decades.

Table 1 Temperature data for future all scenarios provided by UKCP09

	Mean temperature summer °C			**Mean daily maximum temperature summer °C**			**Mean daily minimum Temperature summer °C**			**Mean temperature winter °C**		
Probability Level %	10	20	90	10	20	90	10	20	90	10	20	90
2020's												
Low emissions	0.8	1.6	2.5	0.6	2.0	3.5	0.6	1.5	2.6	0.4	1.2	2.0
Medium emissions	0.6	1.5	2.5	0.4	1.9	3.5	0.5	1.5	2.6	0.5	1.2	2.0
High emissions	0.6	1.5	2.5	0.5	1.9	3.3	0.5	1.4	2.5	0.3	1.2	2.0
2050's												
Low emissions	1.1	2.4	3.8	1.0	3.1	5.3	0.9	2.3	3.9	0.8	1.8	2.8
Medium emissions	1.2	2.6	4.1	1.0	3.3	5.8	1.0	2.5	4.4	1.0	1.9	3.0
High emissions	1.5	3.0	4.7	1.3	3.8	6.5	1.3	2.9	4.9	1.2	2.1	3.3
2080's												
Low emissions	1.3	2.8	4.6	1.0	3.6	6.6	1.1	2.8	4.9	1.3	2.3	3.5
Medium emissions	2.0	3.7	5.9	1.6	4.8	8.3	1.6	3.7	6.4	1.4	2.6	4.0
High emissions	2.5	4.7	7.3	2.3	6.0	10.1	2.2	4.6	7.8	1.9	3.1	4.8

Table 2 Precipitation data for future all scenarios provided by UKCP09

	Annual mean precipitation %			**Summer mean precipitation %**			**Winter mean precipitation %**		
Probability Level %	10	20	90	10	20	90	10	20	90
2020's									
Low emissions	-5	1	7	-20	-6	8	-4	4	4
Medium emissions	-5	0	6	-23	-8	9	-1	6	14
High emissions	-6	0	6	-19	-5	10	-1	6	16
2050's									
Low emissions	-8	-1	6	-34	-14	8	-1	8	20
Medium emissions	-6	0	6	-36	-18	1	3	13	26
High emissions	-7	0	8	-37	-18	2	3	13	27
2080's									
Low emissions	-6	0	7	-35	-17	3	5	15	30
Medium emissions	-8	0	8	-43	-22	0	3	16	34
High emissions	-10	1	12	-51	-28	-2	9	26	50

Without action, likely consequences of the projected climate variables will be wide ranging from increase flood risk and coastal erosion, potential water shortages, ground instability issues to associated health impacts of increased temperatures and detrimental effects on the current and future infrastructure.

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What is the North West doing?

Climate change is seen as a 'make or break' issue for the North West. But no other region is seen as being better equipped to tackle the environmental challenge that it presents. The Northwest Climate Change Action Plan[8] was first published in 2006 to stimulate and measure the region's progress towards a low carbon economy, prepare it for the challenges of a changing climate and expected energy demands, while protecting and enhancing quality of life and preserving its rich environment.

The Action Plan has been developed in partnership with regional organisations and experts. It is being delivered by the Northwest Climate Change Partnership over an initial phase 2008-10. The Plan details prioritized actions which need to be delivered within the context of the Northwest Sustainable Energy Strategy and the Regional Economic Strategy. A Regional Adaptation Group, with specific sub-groups, has been established to oversee enabling actions and provide sector-specific focus for adaptation activitis across the region. The North West's leading regional organisations have jointly signalled:

> *"The stakes are undoubtedly high. There is no city or town, no industrial sector, no wildlife habitat or indeed any household that will not feel the impact of climate change in the years ahead. We have a once-in-a-lifetime chance to develop and deploy the strategies and technologies that will secure our future and realize the economic opportunities presented by climate change."*

The region's vision is for a low carbon and well-adapted North West by 2020.

In support of the Action Plan, the Northwest Climate Change Partnership recently commissioned Arup to assess the latest data on future climate change impacts across the region and their consequences for key business sectors and public services.[9] This commission was part of a series of enabling actions to develop the evidence base to support the delivery of the regional climate change action plan.

The sectors identified with the highest exposure to climate change impacts were the marine and logistics sectors, visitor economy, construction industry, food and drink, and retailing. The cumulative effects of changes will mean that, without early action on adaptation, every sector will find it more challenging and costly to resolve issues identified compared to taking action now.

Under the Action Plan, the NWDA is promoting a strategy for catalyzing support for sustainable building design and construction in the region (Action 23 of the CC Action Plan). NWDA introduced its **Sustainable Buildings Policy** in 2007. This sets standards in ten key policy areas for developments seeking NWDA funding.[10] The place of Climate Change Adaptation in this policy is currently under review. In 2009, the NWDA launched its '**Sustainable Buildings Awareness Raising and Knowledge Transfer Programme**', run by CCI, to help make public and private sector developers, Local Authorities, architects and contractors aware of the policy, the tools and techniques available to enable the reduction of carbon emissions and help to make the Northwest ready for sustainable development.

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8 http://www.nwda.co.uk/publications/business/rising-to-the-challenge---a-cl.aspx

9 http://www.climatechangenorthwest.co.uk/assets/_files/documents/jul_09/cli__1246471269_0011_Final_Report_April_2009_LH.pdf

10 http://www.ccinw.com/sites/breeam_pages.html?site_id=16&section_id=192

How will climate change impact on the built environment?

Climate change's multiple impacts should be taken into account when planning and designing new developments and when refurbishing and regeneration the existing stock of buildings. These changes and their likely impacts are listed in below.[11]

Main changes	Likely impacts
 **Higher temperatures**	Higher day time peaks Higher night time lows Higher winter temperatures Enhanced urban heat island effect Reduced air quality (e.g. increase in summer ozone episodes) Health implications, e.g. heat stress in frail and elderly
 **Drier summers and drought**	Reduced water availability/shortages Reduced water quality Reduced soil moisture content/ increased subsidence Changes in biodiversity Health implications
 **Sea temperature rise**	Sea level rise Increased sea surge height
 **Increased precipitation**	More rainfall in winter Heavier rain in winter and summer/hail/snow (BUT less snow projected) Increased river flooding Increased urban drainage flooding Health implications
 **Higher wind speeds**	Increased storm damage Outage of emergency, infrastructure and transportation services

The key challenge is to plan, design and construct cities, neighbourhoods and buildings, in accordance with the principles of sustainable development, that perform effectively not just in terms of today's climate but in the future as well.

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11 The information presented in the left hand column of the table is taken from UKCP09 and in the right hand column is summarised from published guidance and advisory documents on how to adapt to climate change in the built environment, see Recommended Guidance Documents.

GUIDANCE

About the Guidance

The guidance and advice contained in this briefing guide has been collated from reviewing a wide range of easily available publications. Three guiding principles have informed its development.

Guiding principles

1. Wherever possible, information has only been collated from guidance documents that are accessible from the web for free. This same principle has been applied to signaling where further and more detailed information on particular responses to climate change can be found.
2. National case studies of the responses proposed in the guidance documents are only included if they are well documented. They are restricted to those for which some sort of evidence base exists about their actual performance - and, where possible, a contact can be provided for further information about them.
3. Local examples of the responses recommended are also provided, where possible, but these have not been subjected to same degree of filtering applied to national case studies. The local examples used have been provided by members of the Guide's Steering Committee, see Appendix 3.

This stringent approach is appropriate here because the information collated and the advice offered may be called upon to support policy-making and decisions about investment regionally, sub-regionally as well as locally.

The first of the principles specified above was easy to fulfill. As the Recommended Guidance Documents show (page 32), there are now many publications offering guidance and advice on how to adapt the built environment to climate change (even if, in practice, as the Steering Committee reported, adaptation is not yet commonly addressed in the design of new buildings). But, in terms of substantive detail, there are still really only two leading edge documents in this area.

The Three Regions Climate Group's (2006) ***Adapting to Climate Change Impacts – a good practice guide for sustainable communities***, and

The TCPA's (2007) ***Climate Change Adaptation by Design: a guide for sustainable communities***.

Despite the material in these two guides, however, the second principle above proved much more difficult to fulfill. Even the best current guidance documents provide scant information about how the responses they promote can be or have been implemented in practice. In particular, they rarely signpost to where detailed information can be found about the performance in use of these examples can be found.

In addition, our understanding of climate change and how we can adapt to it is a rapidly moving field. The guidance documents listed above are already three or four years old. Some of the information sources to which they point are already out of date or are no longer accessible. In this briefing guide, pains have been taken to provide, wherever possible, access to further, up-to-date information via live web links.

Possible responses to the impact of climate change on the built environment

The climate changes listed in the previous section of the guide impact on the built environment at three spatial scales.

 **Buildings**

 **Neighbourhoods**

 **Cities**

Examples of responses appropriate at each of these scales, in this case for managing high temperatures, are illustrated in Figure 2, taken from the TCPA's **Climate Change Adaptation by Design**.[12]

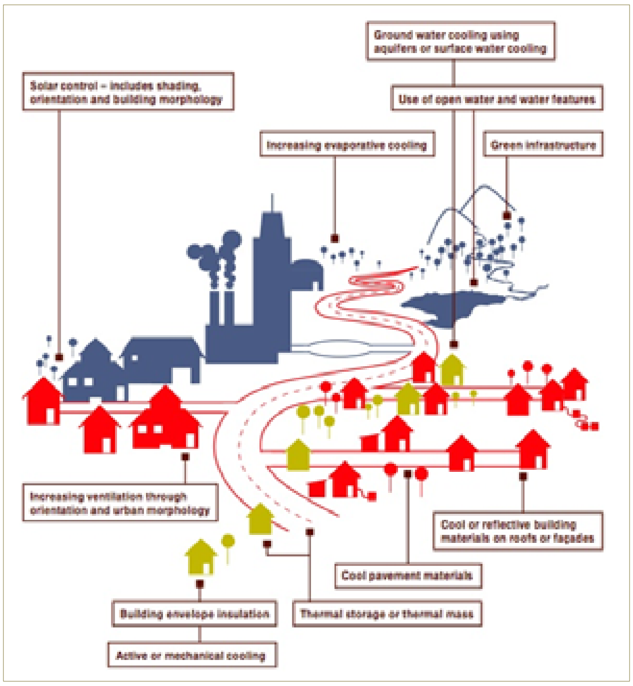

Figure 2. Responses at different spatial scales

Possible responses to all of the impacts at each of these three spatial scales are listed in Table 1 below. This list of responses has been compiled from the guidance and advice publications reviewed. Where a cell in Table 1 remains empty, this is because no recommendations on how to respond have been found in the publications examined.

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12 http://www.tcpa.org.uk/data/files/bd_cca.pdf

Table 1. The climate change impacts and possible built environment responses

Climate change impact	Possible responses		
	Building	**Neighbourhood**	**City**
Higher day time peaks/Urban Heat Island Effect	▪ employ building shape and orientation to provide solar control ▪ employ cool or reflective building materials on roofs and facades ▪ use green or brown roofs and green walls to regulate temperature ▪ provide external solar shading ▪ install (controllable, secure) natural (night time) ventilation, integrated with security ▪ Increase thermal capacity of construction ▪ Increase insulation and airtightness of building envelope ▪ reduce internal heat gains through correct location and use of energy efficient appliances and lighting ▪ use ground water source heat exchange for cooling (heating) ▪ where mechanical air handling units intalled, ensure don't discharge into frequented external spaces ▪ allow for appropriate in-house storage of composting, waste and recycling in hot weather ▪ plan for long term management and maintenance of adaptation measures ▪ monitor and evaluate performance (internal conditions and external spaces)	▪ use green infrastructure planning to ensure no net loss of green/blue cover and aim to increase it ▪ use cool pavement materials ▪ use external surface materials for thermal storage or mass ▪ provide sheltered outside spaces and facilities ▪ use trees and plants that mature to have large canopies to provide shade and cooling ▪ provide sustainable irrigation of vegetation so it can provide evaporative cooling in droughts ▪ provide external water features for evaporative cooling ▪ allow for appropriate local storage of composting, waste and recycling in hot weather ▪ plan for long term management and maintenance of adaptation measures ▪ monitor and evaluate performance (local outside conditions and spaces)	▪ use green infrastructure planning to ensure no net loss of green/blue cover and aim to increase it, especially where people gather and where communities are most vulnerable to heat stress ▪ increase ventilation through orientation and urban morphology, including designating and protecting green infrastructure that allows air to flow in and our of city ▪ provide sheltered outside spaces and facilities ▪ use trees and plants to provide shade and cooling ▪ provide ground water cooling through aquifers and surface water cooling ▪ allow for appropriate area-based storage of composting, waste and recycling in hot weather ▪ plan for long term management and maintenance of adaptation measures ▪ monitor and evaluate performance (area and urban scale conditions and spaces)

Table 1 continued

Climate change impact	Possible responses		
	Building	**Neighbourhood**	**City**
Higher night time lows	▪ install (controllable, secure) natural (night time) ventilation/cooling, integrated with security	▪ plan noise and nuisance abatement policies to cope with increased 24/7 use	▪ plan noise and nuisance abatement policies to cope with increased 24/7 use
Higher winter temperatures	▪ eliminate/reduce sizing of heating systems	▪ provide sheltered outside spaces and facilities	▪ provide sheltered outside spaces and facilities
Health implications ▪ **heat stress in elderly and young** ▪ **reduced productivity**	▪ provide well ventilated/cooled internal (retreat) spaces	▪ remove traffic and improve walking and cycling facilities to avoid pollution build up ▪ provide rest areas (seating) under shaded canopies/trees	▪ city-wide heat wave action plan ▪ undertake vulnerability assessments of population ▪ strategic green infrastructure planning ▪ remove traffic and improve walking and cycling facilities to avoid pollution build up ▪ provide rest areas (seating) under shaded canopies/trees

Table 1 continued

Climate change impact	Possible responses		
	Building	**Neighbourhood**	**City**
changes in biodiversity	▪ use green/brown roofs to provide habitats ▪ bird and bat boxes ▪ swales in streets ▪ ensure buildings do not obstruct flight paths, corridors or networks	▪ incorporate biodiversity into existing, non-biodiverse green spaces ▪ strengthen integrity of local ecosystems avoiding fragmentation ▪ provide patches, gardens and green corridors for possible shifts of species and habitats ▪ assist movement of species (northward) to new climate spaces ▪ align biodiversity networks with blue infrastructure green infrastructure (e.g. road verges)	▪ strengthen integrity of urban scale ecosystems avoiding fragmentation ▪ provide corridors for possible shifts of species and habitats ▪ green infrastructure planning to provide more permeable landscape ▪ wild-life friendly management of green infrastructure resources

Table 1 continued

Climate change impact	Possible responses		
	Building	**Neighbourhood**	**City**
Reduced water availability/ shortages	▪ design planting and landscaping to provide summer shading for building ▪ install water efficient fixtures, fitting, and appliances ▪ use rainwater harvesting including water butts ▪ use greywater recycling	▪ design layout to maximise potential use of communal scale rainwater harvesting and greywater recycling (space for on site treatment such as reed beds) ▪ provide sustainable irrigation to maintain cooling of vegetation ▪ design communal planting and landscaping to provide summer shading for buildings and outside spaces	▪ design layout to maximise potential use of area and urban scale rainwater harvesting greywater recycling (space for on site treatment such as reed beds ▪ design area-based planting and landscaping to provide summer shading for buildings and public realm spaces ▪ identify sustainable sources of water for irrigating green infrastructure to maintain evaporative cooling effect, e.g. low quality aquifers, harvested rainwater, etc.
Reduced water quality	▪ design in accordance with SUDS Design Manual to preventing water pollution underlying water, particularly underlying water ▪ where mains sewer not available, select sewage treatments that comply with European standards ▪ for industrial developments, ensure drainage from contaminated areas is directed to foul sewer	▪ design clearly labelled separate black and grey water drainage systems to avoid wrong connections ▪ seal rainwater downspouts on domestic properties to discourage wrong connections	▪ check availability of sewage treatment capacity at wastewater treatment works when selecting location of large developments ▪ consider environmental capacity of local water environment before development progresses, e.g. vulnerability of underlying groundwater, tolerance of local watercourse of large discharge of effluent, impact on bathing waters, etc.

Table 1 continued

Climate change impact	Possible responses		
	Building	**Neighbourhood**	**City**
Reduced soil moisture content/ increased subsidence	▪ design foundations and structure to cope with increased subsidence on shrinking and swelling soils and in proximity to vegetation	▪ where land is at risk of subsidence, design for soft uses such as open space ▪ ensure vegetation, including large trees, included and adequately managed in new developments (to prevent unnecessary removal)	▪ where land is at risk of subsidence, design for soft uses such as open space ▪ ensure vegetation, including large trees, included and adequately managed in new developments (to prevent unnecessary removal)
Reduced biodiversity	▪ use green/brown roofs to provide habitats ▪ swales in streets ▪ ensure buildings do not obstruct flight paths, corridors or networks	▪ incorporate biodiversity into existing, non-biodiverse green spaces ▪ strengthen integrity of local ecosystems avoiding fragmentation ▪ provide patches, gardens and green corridors for possible shifts of species and habitats ▪ assist movement of species (northward) to new climate spaces ▪ align biodiversity networks with blue infrastructure green infrastructure (e.g. road verges)	▪ strengthen integrity of urban scale ecosystems avoiding fragmentation ▪ provide corridors for possible shifts of species and habitats
Health implications			

Table 1 continued

Climate change impact	Possible responses		
	Building	**Neighbourhood**	**City**
Sea level rise	▪ avoid development in flood risk locations ▪ provide temporary/permanent flooding defences for at risk properties ▪ fit (removable) flood defence products to properties ▪ design building and use materials that can withstand flooding ▪ locate electrical services above flood levels ▪ employ flood-resilient materials ▪ wet proof unprotectable buildings ▪ prevent back up of drains into building	▪ avoid development in flood risk locations ▪ managed retreat using mud flats and wet lands as flood storage areas ▪ plan routes for emergency vehicles to have secure access in event of flooding	▪ avoid development in flood risk locations ▪ managed retreat using mud flats and wet lands as flood storage areas ▪ plan routes for emergency vehicles to have secure access in event of flooding ▪
Increased sea surge height	▪ follow PPS25 sequential approach to locating development ▪ maximise density of development in non-flood risk areas (bearing in mind other climate change challenges such as higher temperatures) ▪ provide temporary/permanent flooding defences for at risk properties ▪ fit (removable) flood defence products to properties ▪ locate electrical services above flood levels ▪ employ flood-resilient materials ▪ wet proof unprotectable buildings ▪ prevent back up of drains into building	▪ follow PPS25 sequential approach to locating development ▪ maximise density of development in non-flood risk areas ▪ provide temporary/permanent flooding defences for at risk properties ▪ plan routes for emergency vehicles to have secure access in event of flooding	▪ follow PPS25 sequential approach to locating development ▪ maximise density of development in non-flood risk areas ▪ provide temporary/permanent flooding defences for at risk properties ▪ plan routes for emergency vehicles to have secure access in event of flooding

Table 1 continued

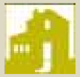
Climate change impact	Possible responses		
	 **Building**	 **Neighbourhood**	 **City**
Heavier (driving) rain/hail/snow	▪ consider prevailing wind and driving rain when planning layout ▪ install wider gutters ▪ upgrade rainwater disposal systems ▪ employ sustainable urban drainage systems ▪ provide green and blue cover ▪ detail external envelope to withstand driving rain ▪ prevent back up of drains into building ▪ install mechanical or UV light systems to prevent damp and mould growth	▪ consider prevailing wind and driving rain when planning layout ▪ use sustainable urban drainage systems, including street swales and ponds ▪ provide green and blue cover	▪ consider prevailing wind and driving rain when planning layout ▪ use sustainable urban drainage systems, including street swales and ponds ▪ provide green and blue cover

Table 1 continued

Climate change impact	Possible responses		
	Building	**Neighbourhood**	**City**
Increased river flooding	▪ follow PPS25 sequential approach to locating development ▪ maximise density of development in non-flood risk areas ▪ use soft defences as buffer as part of green/blue landscaping ▪ open water courses across site for amenity and flood absorption ▪ provide emergency access points ▪ provide temporary/permanent flooding defences for at risk properties ▪ fit (removable) flood defence products to properties ▪ locate electrical services above flood levels ▪ wet proof unprotectable buildings ▪ install mechanical or UV light systems to prevent damp and mould growth	▪ follow PPS25 sequential approach to locating development ▪ maximise density of development in non-flood risk areas ▪ use soft defences as buffer as part of green/blue infrastructure ▪ open water courses and SUDS across neighbourhood for amenity and flood absorption ▪ set development back from flood defences using space for linear park and walk/cycle routes ▪ ensure vulnerable uses are located away from areas of high risk ▪ provide emergency access points ▪ provide temporary/permanent flooding defences for at risk existing and new properties ▪ fit (removable) flood defence products to properties ▪ wet proof unprotectable buildings ▪ provide local safety retreat facilities against failure of flood defences as appropriate ▪ engage community about risk assessment/response	▪ follow PPS25 sequential approach to locating development ▪ maximise density of development in non-flood risk areas ▪ use soft defences as buffer as part of green/blue infrastructure, providing flood plans for up and down stream flooding ▪ provide emergency access routes and points ▪ provide city-wide safety retreat facilities against failure of flood defences as appropriate ▪ consider river restoration: deculverting,storing water temporarily in green spaces alongside rivers ▪ re-naturalise flood plan and flood plain forestry

Table 1 continued

Climate change impact	Possible responses		
	 **Building**	 **Neighbourhood**	 **City**
Increased urban drainage flooding	▪ minimise peak run-off and annual surface water run-off rates ▪ use sustainable urban drainage systems (permeable paving attenuation systems, filter drains, ponds, wetlands) ▪ prevent drainage back-up	▪ use sustainable urban drainage systems (permeable paving attenuation systems, filter drains, ponds, wetlands) ▪ use landscaping, including tree canopies, to soak up rain ▪ avoid impermeable surfaces, especially where soils have high infiltration capacities ▪ use landscaping to intercept rain	▪ identify vulnerable areas across city (e.g. where known incidence of surface water flooding, low drain capacity, soils with high infiltration rates) ▪ use SUDS and green infrastructure in vulnerable areas (permeable paving attenuation systems, filter drains, culverts, ponds, wetlands)
Health implications			
			
Increased storm damage	▪ detail external envelope to increased wind velocity and withstand driving rain ▪ employ resilient ducting, overhead cabling, drainage and other services	▪ provide safety retreat facilities ▪ design public spaces safe to use during high winds ▪ plan pedestrian and cycle routes protected from exposure to high wind speeds	▪ provide safety retreat facilities ▪ design layout of area and urban public spaces to be safe to use during high winds
Lost emergency, and other services	▪ provide local (standby) generation	▪ provide local (standby) generation ▪ design integrated service provision with back-up capabilities	▪ provide local (standby) generation ▪ provide stand-by, back-up facilities for use in emergencies
			
Health implications			

Multi-purpose responses

The diverse range of possible responses to the impact of climate change listed above in Table 1 can be grouped into ten broad design features. Most of these features can be employed to adapt to more than one climate change impact, as Table 2 indicates.

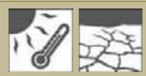
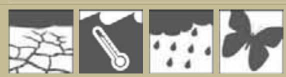
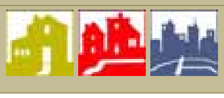
Design features	Spatial scales	Impacts addressed
Location (e.g. away from sources of pollution, flood plains, biodiversity/habits or integrate into development)		
Layout and orientation (e.g. solar gain, prevailing wind for natural ventilation)		
Materials/structure (e.g. reflective building/landscaping materials, insulation, air tightness, foundations to cope with subsidence		
Environmental performance (e.g. integrated design of ventilation, daylighting and heating)		
Services and appliances (e.g. energy efficient appliances, heating system)		
Green roofs/walls, brown roofs		
Rainwater harvesting/ greywater recycling		
Sustainable Urban Drainage Systems (SUDS		
Green and blue infrastructure (e.g. private gardens, green spaces, street trees, landscaping, ponds, fountains, ground water cooling etc.)		
Waste management (e.g. composting, recycling etc.)		

Table 2. Multi-response design features

Additional information on design features is provided below.

Comment [s1]: At which it is implemented?? This is tricky. E.g. green roofs obviously apply at a building scale. However, you could have a city wide or neighbourhood level planning policy that says to implement green roofs. Similarly, green infrastructure planning can be employed at a city/neighbourhood scale, but implementation (e.g. through provision of a green roof/wall, garden) could be at a building scale.

Comment [s2]: Again, needs to reflect comments in changes/impacts table

Location

As the BREEAM Environmental Assessment method makes clear, the location of a development is responsible for a significant part of its environmental impact, affecting issues such as travel plans and access to public transport and local amenities[13], to which can be added exposure to extreme weather, vulnerability to flood risk, and loss of habitats and biodiversity. As a result, BREEAM advises that, in choosing the location for a new development, consideration is given to re-using a brownfield or contaminated site and making the best use of a building's footprint. It also recommends making ecological enhancements to the site beyond just protecting existing ecological features.

But, in most case, relocation is not an option. Existing properties, particularly those in city centres, may be extremely vulnerable to the impact of climate change. The frequency of very warm summer days with temperatures above 30°C will increase causing heat stress.[14] It is not unusual for urban heat islands to maintain temperatures 3°C–4°C above that of surrounding rural land, increasing cooling requirements and producing localized smog. By 2025 summer overheating is likely to have become a problem, with natural ventilation now longer sufficient.[15] Cooling solutions include natural ventilation with night cooling, pre-cooling of the supply air using an underground labyrinth, and passive cooling combined with 'top up' chilled water cooling of the supply air.[16] Other measures intended to reduce the urban heat island effect include tree planting, installation of green roofs on buildings, roofing with reflective membranes or coatings, and installation of light-colored (higher-albedo) pavement and walkway surfaces. Neighborhood-based policies with community participation to address urban heat islands can achieve larger benefits, than action on individual buildings, since strategies are more effective if they have widespread implementation.[17]

Regional and local case studies

Regional spatial planning and urban design can provide solutions that make our communities less vulnerable to climate change. The University of Manchester is working with the NWDA to help integrate the use of green structure into mainstream planning by exchanging knowledge and experience and encouraging the transfer of good practice on climate change adaptation strategies to local and regional authorities.[18]

Eco Cities[19] is a joint initiative between the University of Manchester and office provider Bruntwood that seeks to provide a blueprint for the first climate change adaptation strategy for Greater Manchester. The Eco Cities team, in partnership with Red Rose Forest, are providing support to Manchester City Council to encouragw local authorities and relevant Local Strategic Partnership stakeholders to establish appropriate measures to manage climate risk and opportunities.

13 http://www.breeam.org/page.jsp?id=13
14 http://www.lucid-project.org.uk/
15 http://www.iea.org/work/2004/cooling/Levermore.pdf
16 http://www.ijovent.org.uk/IJV%20Vol%203/IJV%20V3%20No%204/IJV%20Abstract%20Vol%203%20No4%20Paper%201.htm
17 See also www.climatesoutheast.org.uk/images/uploads/Adaptation_Checklist_for_Development_Nov_2005.pdf, page 17
18 http://www.sed.manchester.ac.uk/architecture/research/ecocities/projects/associatedprojects/associated_projects_GRABS.pdf
19 http://www.ecocitiesproject.org.uk/ecocities/page.aspx?id=596&category=1

Layout and orientation

Orientation, along with window design and careful planning of a building's internal layout, can be designed to optimize solar gain in order to reduce the need for winter heating. Design principles for achieving this have been well codified in the UK over the past two decades for individual[20] and groups[21] of buildings and site layout[22]. But, with the onset of climate change, there will also be a need to avoid summer overheating without resorting to mechanical air conditioning. Emerging best practice is to reduce a building's cooling load as far as possible using passive solutions and then find the best mechanical solution to meet any remaining cooling requirement using the option that best fits other design objectives. Orientation and window design can be used to prevent high-level summer sunshine from entering buildings, particularly on windows on south-facing facades, while still allowing it in during the winter when the sun is lower in the sky. Projecting overhangs, louvred sunscreens, or external shades directly over windows, can prevent solar energy passing through the window in the first place. Such solar shading should be designed, not just in combination with window size and orientation, but with ventilation and thermal capacity as well. Detailed guidance on the solar shading of buildings was provided by the BRE in 1999 (Report BR364).[23]

UK case study

The Butterfield Park Business and Innovation Centre in Luton incorporates overhangs and external shading with an innovative ventilation system using earth ducts, which reduces energy consumption by up to 75%, regulates air temperature and guarantees excellent air quality. Fresh air is drawn through earth ducts below the ground, effectively using the earth as a source of heat in winter and of cooling in summer, without the need for air conditioning. The fresh air is supplied into the buildings via a pressurised floor plenum. The building achieved a BREEAM Excellent, an 'A' rating under the European Energy Performance of Buildings Directive, and was given a Green Apple Award for achieving the highest standards in environmental sustainability.[24]

Local examples	Location	Contact
Cumbria Police Divisional HQ	Carlisle CA1 1XX	Architects: Taylor Young - Richard Mallinson, richard.mallinson@tayloryoung.co.uk, 01625 542 200. Contractor: Thomas Barnes - Zoe Brook Zoebrooke@thomasbarnes.co.uk 0161 797 5115.
Office building, 24 Mount Street	Manchester: M2	Architects: Sheppard Robson - Alex Solk Alex.Solk@SheppardRobson.com 0161 233 8944.
Loreto College	Manchester M15 5PB	Architects: Taylor Young - David Dealtry, david.dealtry@tayloryoung.co.uk, 01625 542 200.
Speke Health Centre	Liverpool L24 3TY	Architects : Taylor Young - Rachel Bruce Rachel.bruce@tayloryoung.co.uk 0151 702 6501.

[20] http://www.esru.strath.ac.uk/EandE/Web_sites/01-02/RE_info/passive_solar.htm#How%20does%20passive%20solar%20design%20use%20the%20sun%92s%20power

[21] GIR 27, http://www.energysavingtrust.org.uk/business/Business/Resources/Publications-and-Case-Studies

[22] http://www.brebookshop.com/details.jsp?id=321450. Note: this publication cannot be downloaded for free.

[23] http://www.brebookshop.com/details.jsp?id=324618. Note: this publication cannot be downloaded for free.

[24] http://www.climatechangenorthwest.co.uk/butterfield.html

Materials and structure

The use of reflective materials on the external surfaces of buildings or in hard landscaping to lessen the impact of climate change is based on the albedo effect. This is the extent to which a material reflects light, e.g. from the sun, with a range of possible values from 0 (dark) to 1 (bright). Replacing dark roofs and pavements with lighter-coloured ones increases urban albedo. Most existing flat roofs are dark and reflect only 10 to 20% of the sunlight falling on them. Such roofs can be replaced with a lighter-coloured material capable of reflecting 40% or more of the incoming sunlight so reducing heat gain by the building fabric.[25] The Met Office has advised that reflective roof coverings and light-coloured building materials can help combat over-heating in cities.[26] And, used as a form of geo-engineering, the IMecheE has suggests that reflective roofing could reduce cooling energy use by up to 60% but notes that issues of glare and aesthetics would need to be considered.[27]

In adapting to climate change, the materials used for the structure of buildings and for their internal surfaces are also important because of the effect of thermal mass. The thermal behavior of a material depends on its density, thermal conductivity and specific heat capacity. A high thermal mass is capable of absorbing, storing and slowly releasing heat. Traditional forms of building where thermal mass is integrated with natural ventilation, small window openings and deep eaves can keep buildings cool in hot climates. Just how much thermal mass is required in modern building in the UK remains a topic of debate, with those promoting specific materials taking differing positions.[28][29]

UK case study

As part of the EU-funded REVIVAL project[30], thermal mass and night cooling have been exploited in the refurbishment of offices for Stevenage Borough Council to reduce daytime temperatures. A night-time cooling system uses the hidden mass of the building. During summer, cool outside air is introduced into the offices by window fans at night. Ceiling fans circulate this air under the floor duct to enable cooling to be stored in its thermal mass. Next day, ceiling fans release stored cooling. Monitoring before and after indicate that a reduction of about 5 K in internal temperatures has been achieved relative to ambient temperatures. Areas with night ventilation are also reported as fresher in the morning.

Local examples	Location	Contact
Office building, 24 Mount Street (reflective materials)	Manchester M2	Architects: Sheppard Robson - Alex Solk Alex.Solk@SheppardRobson.com 0161 233 8944
Speke Health Centre (reflective materials)	Liverpool L24 3TY	Architects : Taylor Young - Rachel Bruce Rachel.bruce@tayloryoung.co.uk 0151 702 6501
Loreto College (thermal mass)	Manchester M15 5PB	Architects: Taylor Young - David Dealtry, david.dealtry@tayloryoung.co.uk, 01625 542 200
Office building, 1 New York Street (thermal mass)	Manchester M2 3HQ.	Client: Bruntwood. Engineering Consultants, Buro Happold, Hannah Adams, Hannah.Adams@BuroHappold.com 0113 204 2200

25 http://environmentalresearchweb.org/cws/article/futures/37492
26 http://actonco2.direct.gov.uk/actonco2/dms/Met-Office-climate-change-guide.pdf.
27 http://www.nce.co.uk/Journals/3/Files/2009/8/27/GeoEngineering_Positition_Statement.pdf
28 http://www.timber-frame.org/html/technical-guidance/thermal-mass-in-housing/?PHPSESSID=36cae5e0d2776920a6c6a
29 http://www.sustainableconcrete.org.uk/main.asp?page=113
30 http://www.revival-eu.net/main_sites.html.

Environmental performance

Adapting buildings to the impact of climate change requires an integrated approach to environmental design and to the performance of buildings in use. For example, if closely coupled with the design of building form, external envelope and daylighting, natural ventilation can not only provide part or all of a building's ventilation needs but it can also be used to remove excess heat. Heating and cooling requirements are driven by building type, internal loads and building envelope design - and by climate. Climate change is likely to bring a greater need for cooling. The cooling capacity of natural ventilation is limited and varies with weather conditions. If peak cooling loads can be limited to the capacity of natural ventilation to remove excess heat, then a significant amount of energy can be saved by offsetting the need for both mechanical ventilation and cooling. If needed, efficient systems such as district heating,[31] (solar) hydronic heating[32] and/or cooling and displacement ventilation[33] can be used to supplement natural ventilation.

UK case study

Defra's Estates Division wanted its new office accommodation, Lion House, Alnwick, to be an exemplar of sustainable development. The design maximised use of natural daylight, with the build orientation and shading also enabling the use of winter solar gains;. Natural cross-ventilation is predominantly used for general office spaces, with capability for mechanical displacement ventilation to offset seasonal variations. A ceiling mounted 'red-green' system advises occupants when windows may be open to aid natural ventilation and when mechanical ventilation is operating. Exposed thermal mass allows passive night cooling in order to maintain optimum internal temperatures during warmer times of the year. The building is the subject of an OGC case study.[34]

Local examples	Location	Contact
Office building, 24 Mount Street	Manchester M2	Architects: Sheppard Robson - Alex Solk Alex.Solk@SheppardRobson.com 0161 233 8944
Cumbria Police Divisional HQ	Carlisle CA1 1XX	Architects: Taylor Young - Richard Mallinson, richard.mallinson@tayloryoung.co.uk, 01625 542 200. Contractor: Thomas Barnes - Zoe Brook Zoebrooke@thomasbarnes.co.uk 0161 797 5115.
Speke Health Centre	Liverpool L24 3TY	Architects : Taylor Young - Rachel Bruce Rachel.bruce@tayloryoung.co.uk 0151 702 6501

31 Developing District Heating in the UK, http://www.bre.co.uk/accreditation/page.jsp?id=1756
32 http://www.greenworks-energy.co.uk/hydronic-underfloor-heating.php
33 Displacement Ventilation in Non-Industrial Premises, http://www.cibse.org/index.cfm?go=publications.view&item=190. . Note: this publication cannot be downloaded for free.
34 http://www.ogc.gov.uk/documents/Lion_House.pdf

Green and brown roofs

A green roof is partially or completely covered with vegetation and soil, or other growing medium, planted over a waterproofing membrane. It may also include additional layers such as a root barrier and drainage and irrigation systems. Green roofs, and green areas on façades of buildings called living walls, can offer a wide range of benefits, including reduced pollution, attenuation of rainwater run-off, improved thermal stability and energy conservation, reduced maintenance, enhanced air quality, provide food and habitat for wildlife, and open space. In addition, they are attractive to look at and by greening living environments can enhance the quality of life of residents.

Brown roofs, also known as bio-diverse roofs, are used to mitigate the loss of habitat by covering the flat roofs of new developments with a layer of locally sourced material. Construction techniques for brown roofs are typically similar to those used to create flat green roofs. The main difference is the choice of growing medium (usually locally sourced rubble, gravel, spoil etc). Brown roofs may be left to self-colonise with plants. They may be seeded to increase their biodiversity potential in the short term. Roofs can also be designed to meet specific environmental objectives. For instance, roofs can be colonised by spiders and insects (many of which are becoming extremely rare in the UK as such sites are developed) and provide a feeding site for insectivorous birds.

UK and regional case studies

The effectiveness of green roofs and green walls have been monitored and assessed for biodiversity, storm-water management and climate change mitigation and adaptation. These are reported in **Building Greener: Guidance on the use of green roofs, green walls and complementary features on buildings,** published by CIRIA in 2007.[35] [36] The Commission for the New Economy and Manchester City Council commissioned the **Green Roof Guidance** to explore the feasibility of substantially increasing the installation of green roofs on new and existing buildings across Greater Manchester. [37] A similar review is available for Liverpool. [38][39]

Local examples	Location	Contact
Kendal College	LA9 5AY	Sue Chadwick, Taylor Young, sue.chadwick@tayloryoung.co.uk, 01625 542 200
Bolton Co-Location College	BL2 1ER	Jorn Ahlhelm, jorn.ahlhelm@tayloryoung.co.uk, 01625 542 200
Loreto College, Manchester	M15 5PB	David Dealtry, david.dealtry@tayloryoung.co.uk, 01625 542 200
Cumbria Constabulary Divisional Headquarters, Carlisle	CA1 3NQ	Richard Mallinson, richard.mallinson@tayloryoung.co.uk, 01625 542 200

35 An free excerpt from this guidance can be found at http://www.ciria.org/service/Web_Site/AM/ContentManagerNet/ContentDisplay.aspx?Section=Web_Site&ContentID=8976
36 Further information about the monitored performance of brown roofs can be found from the Birmingham Brown Roofs Demonstrations, http://www.switchurbanwater.eu/outputs/pdfs/W6-2_CBIR_POS_demo.pdf
37 http://www.driversjonas.com/img.aspx?docid=34060&fldname=AttachmentFile&n=0&langid=1&log=1
38 http://merseyforest.org.uk/files/Roof%20Greening%20in%20Liverpool.pdf
39 See also www.livingroofs.org and http://www.thegreenroofcentre.co.uk/ which is a research and demonstration hub.

Rainwater harvesting and greywater re-use

Rainwater harvesting involves capturing non-potable rainwater (non- drinking standard) at the point of fall, then substituting it for mains water for specific applications. The Code for Sustainable Homes, and commercial equivalents such BREEAM assessments, already require that all new buildings are designed t o reduce the demand on mains water supplies. The UK Rainwater Harvesting Association has produced an **Introductory Guide to Rainwater Harvesting**,[40] Rainwater Harvesting Systems can be as simple as a water butt located under a down pipe from guttering that can be used to fill a watering can or connected to an inexpensive syphon hose for watering a garden. At the other end of the scale, there are large systems with above or underground tanks, filters and pumps that will can be fed into all the non-potable uses inside buildings such as toilets, washing machines, showers and baths.

Greywater is household waste water that has not come into contact with toilet waste. It comes from the bath, shower, bathroom wash basins, and washing machines. Typically, domestic reuse systems collect greywater and store it before reusing it to flush the toilet. More advanced systems treat greywater to a standard that, it is claimed, can be used in washing machines and the garden. The most basic systems simply divert cooled and untreated bath water to irrigate the garden. This uses a valuable on-site resource, conserves precious drinking water and reduces the load on wastewater disposal systems. If applied appropriately to gardens, greywater re-use presents minimal health and environmental pollution risks. Using saved water for irrigation means green spaces will provide to provide evaporative cooling when most needed.

BS 8515 has been published to protect the public and to make sure that reliable systems are designed, installed and maintained. The British Standard gives guidance on the design, installation, testing and maintenance of rainwater harvesting systems supplying non-potable water in the UK.[41]

UK case studies

The Environment Agency provides information on rainwater harvesting and greywater reuse in its 2007 publication on **Conserving Water in Buildings: a Practical Guide**.[42] The Centre for Alternative Technology provides an 2008 information sheet on both which contains a list of useful contacts.[43]

Access to detailed case studies and demonstration projects - that aren't subscriber-restricted or commercially promoted - is difficult to find in the UK. But, for example, the performance has been monitored on a Millenium Green speculative housing project, with data collected by Severn Trent Water.[44] WWUK's GROW system links green roofs and the re-use of water.[45]

Local examples	Location	Contact
Cumbria Police Divisional HQ	Carlisle CA1 1XX	Architects: Taylor Young - Richard Mallinson, richard.mallinson@tayloryoung.co.uk, 01625 542 200.
Litherland High School	Liverpool L21 0DB	Architect: Sheppard Robson - Alex Solk Alex.Solk@SheppardRobson.com 0161 233 8944.
Chavasse Park (rainwater harvesting and irrigation)	Liverpool	Concept Landscape Architects - Building Design Partnership, Karen Howell karen.howell@bdp.com 0161 828 22000. Landscape Contractor: Willerby Landscapes - John Melmoe, john.melmoe@willerby-landscapes.co.uk 01732 700646

40 http://www.ukrha.org/downloads
41 http://shop.bsigroup.com/en/ProductDetail/?pid=000000000030171876
42 http://www.environment-agency.gov.uk/static/documents/Leisure/geho1107bnjree_1934318.pdf
43 http://www.cat.org.uk/information/pdf/RainAndGreyWater.pdf
44 http://www.modbs.co.uk/news/fullstory.php/aid/2793/Rainwater_harvesting%20.html
45 http://www.wwuk.co.uk/grow.htm

Sustainable drainage

Sustainable Drainage is an environmentally friendly way of dealing with surface water run-off that avoids the problems associated with conventional drainage practice. **Sustainable Drainage Systems** are designed to reduce the potential impact of surface water drainage discharges in new and existing developments They seek to replicate natural systems by using cost effective solutions with low environmental impact to drain away dirty and surface water run-off through collection, storage, and cleaning before allowing it to be released slowly back into local water courses. SUDS are designed to counter the effects of conventional drainage systems that often allow for flooding, pollution of the environment - with the resultant harm to wildlife - and contamination of groundwater sources used to provide drinking water. SUDS should be easy to manage, requiring little or no energy input (except from environmental sources such as sunlight, etc.), resilient to use, and being environmentally as well as aesthetically attractive. Examples of this type of system are reed beds and other wetland habitats that collect, store, and filter dirty water along with providing a habitat for wildlife.

UK case studies

CIRIA's **The SUDS Manual** (C697), published in 2007, provides comprehensive guidance on the planning, design, construction and operation of SUDS. The accompanying **Site handbook for the construction of SUDS** (C698), aimed at site engineers and SUDS practitioners, provides guidance on the construction of SUDS to facilitate their effective implementation within developments.[46]

The NBS also provides an introduction explaining how SUDS work and list case studies, further information and contacts.[47] Further information on SUDS can be found at the Sustainable Drainage website[48] and at the UK SUDS Database.[49] Both include case studies. Both websites illustrate a demonstration project - the Hopwood Motorway Service Area, M42 Junction 2, near Bromsgrove.[50] Upton One Urban Extension, Northamptonshire is an example of SUDS employed manages rainwater run-off and promotes local biodiversity.[51]

Local examples	Location	Contact
Central reservation, dual carriageway A66, Basenthwaite	Lake District	Client: Highways Agency Contractor: Amey Mouche
Buckshaw Village	Near Chorley PR7 7NA	Client: Lancashire County Council
Stonebridge Business Park	Liverpool	Client: Mohanned Ahmad, mahmad@liverpoolvision.co.uk Liverpool Vision, 0151 600 2918
Litherland High School	Liverpool L21 0DB	Architect: Sheppard Robson - Alex Solk Alex.Solk@SheppardRobson.com 0161 233 8944.

46 These publications can be downloaded for free at http://www.ciria.org.uk/suds/publications.htm.
47 http://www.thenbs.com/topics/Environment/articles/sudsIntro.asp,
48 http://www.sustainabledrainage.co.uk/
49 http://www.ciria.com/suds/sites/
50 Contact Robert Bray Associates: bob@robertbrayassociates.co.uk, 01453 764 885.
51 http://www.northampton.gov.uk/downloads/CE195_-_Upton_case_study.pdf

Green/blue infrastructure

Green infrastructure is defined in the North West as “the region's life support system – the network of natural environmental components and green and blue spaces that lie within and between our cities, towns and villages and provide multiple social, economic and environmental benefits”[52]. The economic benefits of green infrastructure have been grouped into: climate change adaptation and mitigation, flood alleviation and water management, quality of place, health and well-being, land and property values, economic growth and investment, labour productivity, tourism, recreation and leisure, land and biodiversity, and products from the land[53]. Green infrastructure has its own physical components, referred to as “green infrastructure types”. These range from street trees and private gardens, through derelict land and parks and public gardens, to agricultural land, woodland, coastal habitats, grassland, heathland, moorland and scrubland. Green roofs and some SUDS form part of green infrastructure and harvested rainwater can be stored within it and used to irrigate it. Green infrastructure planning and delivery take place at a range of scales: from strategic policy making and planning at regional, sub-regional, and city levels, to local authority plans which can be embedded as part of the planning system, to neighbourhood plans to inform the masterplanning process, and delivery of projects at neighbourhood, street and building levels.

UK and regional case studies

In the UK, the concept of green infrastructure emerged at a regional level and is now being picked up at a national level[54]. Natural England's **Green Infrastructure Guidance**[55] gives an overview and signposts to relevant information, including a set of case studies[56] and an economic benefit assessment toolkit. Case studies included from the North West are the Weaver Valley Regional Park Green Infrastructure Plan, the River Dee Corridor Green Infrastructure Framework, and the Rochdale Green Infrastructure Strategy.There is a wealth of activity across the North West. The regional green infrastructure website[57] contains more information and contacts. It includes a dedicated climate change section[58] with a searchable evidence base of research, policy and delivery projects.

Local examples	Location	Contact
Green Streets (community involvement in street tree planting and neighbourhood greening)	Greater Manchester, Merseyside and North Cheshire	Greater Manchester – Hilary Wood, Red Rose Forest, hilary@redroseforest.co.uk, 0161 8721660Merseyside and North Cheshire - Ben Greenaway, The Mersey Forest, ben.greenaway@merseyforest.org.uk, 01925 816217
Liverpool Knowledge Quarter Green Infrastructure Plan. (Embedding green infrastructure in development and delivery plan.	Liverpool City centre	Paul Nolan, The Mersey Forest, paul.nolan@merseyforest.org.uk, 01925 816217
Irwell City Park Green Infrastructure (long term delivery of a new river corridor based public realm and regeneration framework)	Manchester, Salford, Trafford	Mike Savage, Red Rose Forest, mike@redroseforest.co.uk, 0161 8721660
Chavasse Park	Liverpool	Concept Landscape Architects - Building Design Partnership, Karen Howell karen.howell@bdp.com 0161 828 22000.

52 http://www.ginw.co.uk/resources/GIguide.pdf
53 http://www.nwda.co.uk/PDF/EconomicValueofGreenInfrastructure.pdf and http://www.naturaleconomynorthwest.co.uk/
54 e.g. http://www.sustainablecities.org.uk/green-infrastructure/
55 http://naturalengland.etraderstores.com/NaturalEnglandShop/Product.aspx?ProductID=cda68051-1381-452f-8e5b-8d7297783bbd
56 http://www.naturalengland.org.uk/Images/GI%20case%20studies_tcm6-10331.pdf
57 www.ginw.co.uk
58 www.ginw.co.uk/climate change/

Recommended Guidance Documents

Publication	Description	Accessible from:
CABE, 2008, **Public Space Lessons: adapting public space to climate change**	A briefing report setting out the lessons learned, nationally and internationally, from using public spaces to adapt to climate change	http://www.cabe.org.uk/files/adapting-public-space-to-climate-change.pdf
CABE, **Sustainable Cities**	Web-based resources for preparing towns and cities for climate change	http://www.sustainablecities.org.uk/
CLG, 2008, **Development and Flood Risk - Practice Guide**	This practice guide is complementary to Planning Policy Statement 25: Development and Flood Risk (PPS25) and provides guidelines on how to implement development and flood risk policies by the land use planning system. The guide also includes working examples through case studies.	www.communities.gov.uk/publications/planningandbuilding/pps25practiceguide
Land Use Consultants, Oxford Brookes University, CAG Consultants, and Gardiner & Theobald, 2006, **Adapting to climate change impacts – a good practice guide for sustainable communities**	Highly detailed guidance (86 pages) to planners and developers on how to ensure new homes and businesses can cope with predicted changes in climate. Applies UKCIP ' risk, uncertainty and decision-making framework ' to planning policy and development decision-making.	Defra & Three Regions Climate Change Group http://www.london.gov.uk/lccp/publications/docs/guide-sustainable-communities.pdf
Shaw, R., Colley, M. and Connell, R., 2007, **Climate change adaptation by design: a guide for sustainable communities**	Detailed (47 page) guidance on how adaptation options are influenced by geographical scale and scale of development. Considers the interrelated roles of the planning system, communities and other stakeholders and delivery bodies through case studies from around the world.	TCPA http://www.tcpa.org.uk/data/files/bd_cca.pdf www.tcpa.org.uk/downloads/20070523_CCA_lowres.pdf
TCPA, 2008, **The Essential Role of Green infrastructure: eco-towns green infrastructure worksheet**	Provides guidance on multifunctional green networks including allotments, community gardens, sustainable drainage systems (SUDs) and flood storage areas. Explains the role that green infrastructure has to play in adapting to climate change (see chapter 1.1)	www.tcpa.org.uk/ecotowns/20081020_ET-WS_Green_Infrastructure.pdf
Three Regions Climate Change Group, 2007, **Adapting to climate change: a case study companion to the checklist for development**	Presents case studies chosen to show examples of where the guidance offered in the checklist is already being put into practice. Case studies illustrate buildings and developments that have particular features which will be appropriate for the conditions in the East and South East of England	http://www.london.gov.uk/lccp/publications/adapting-mar07.jsp

Appendix 1: The Government's response to Climate Change

The Climate Change Act

This Act came in to law in December 2008.[59] Its provisions require the Government to set a target for the year 2050 for the reduction of targeted greenhouse gas emissions and to establish a Committee on Climate Change to oversee the achievement of this target. A statutory Climate Change Committee (CCC) has been established whose core function is to recommend what the UK's 'carbon budgets' should be. These will define the maximum level of CO2 and (potentially) of other greenhouse gases which the UK will emit in each 5 year budget period, beginning with 2008-12.

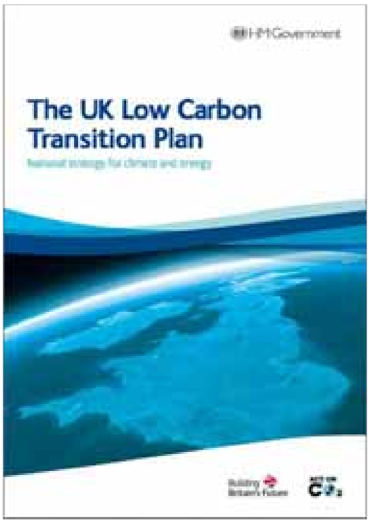
The Climate Change Committee

The CCC has recommended that the UK should commit to reducing its green house gas emissions by at least 80% below 1990 levels by 2050.[60] It announced that reductions of this size are possible without sacrificing the benefits of economic growth and rising prosperity. This can be achieved through exploitation of available or under-development technologies which deliver low carbon energy and lifestyle changes which will not undermine welfare. Many of the actions required to tackle climate change we should want to do anyway because these have economic, wider environmental and security of energy supply benefits.

The path confronting us is seen as being attainable at manageable cost and following it is essential if the UK is to play its part in avoiding the fair higher cost of harmful climate change.

The transition to a low carbon economy

In June 2009, the Government signalled that its ambition, through internationally-binding negotiations, to limit climate change to an increase in global average temperature of 2degC.[61] In order to play our part in reducing global emissions, the UK needs to become a low carbon country. The Government has set out, in a White Paper, the UK's transition plan for building a low carbon UK – by cutting emissions, maintaining secure energy supplies, maximizing economic opportunities and protecting the most vulnerable.[62]



And, as the UK Low Carbon Transition Plan makes clear, the Government's national strategy for climate and energy will require transforming our homes and communities, our workplaces and jobs.

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59 http://www.uk-legislation.hmso.gov.uk/acts/acts2008/ukpga_20080027_en_1
60 http://www.theccc.org.uk/reports
61 http://www.tsoshop.co.uk/bookstore.asp?FO=1195707&Action=Book&ProductID=9780101765923&From=Subject
62 http://www.decc.gov.uk/en/content/cms/publications/lc_trans_plan/lc_trans_plan.aspx

Appendix 2: The Government's response to the impact of climate change on the built environment

The Government is using four major statutory instruments to bring about the transformation of the built environment that it is seeking. Some are concerned with both mitigating climate change as well as adapting to it.

Planning Policy Statement: Planning and Climate Change [63]

Published as a supplement to PPS1, this sets out how planning should contribute to reducing emissions and to stablising climate change while taking into account the unavoidable consequences. Tackling climate change is signalled as a key Government priority for the planning system. A companion guide provides practical guidance and support for the implementation of the policies in this PPS.

Planning Policy Statement 25: Development and Flood Risk[64]

This sets out Government national policies on development and flood risk, including in response to climate change. It should be read in conjunction with Government policies for flood risk and water management, including those set out in Defra's Making Space for Water[65] and its forthcoming Water Framework Directive guidance.[66] A supporting Practice Guide will provide guidance on the implementation of the policies set out in this PPS.

Draft Flood and Water Management Bill[67]

This will cover all forms of flooding and shift the emphasis from building defences to actual risk management. It requires unitary and county councils to work with all relevant parties to put in place local surface water management plans. It will end the automatic right to connect sewers for surface water drainage and require developers to put SUDS in place in new developments wherever practicable. Connection will be conditional on meeting new national standards on SUDS and drainage. New SUDS will be adopted and maintained by local authorities.

Planning Policy Statement: Eco-towns (also a supplement to PPS1)[68]

This sets out a range of minimum standards which are more demanding than would normally be required for new development. It suggests that many of its principles and stretching standards required could potentially be adopted by other developers as a way of meeting the wider objectives of the PPS on Climate Change planning policy.

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63 http://www.communities.gov.uk/publications/planningandbuilding/ppsclimatechange

64 http://www.communities.gov.uk/publications/planningandbuilding/pps25floodrisk

65 http://library.coastweb.info/269/

66 http://www.defra.gov.uk/ENVIRONMENT/water/wfd/

67 http://www.parliament.uk/parliamentary_committees/environment__food_and_rural_affairs/efra_draft_flood_and_water_bill.cfm

68 http://www.communities.gov.uk/publications/planningandbuilding/pps-ecotowns

Appendix 3: Steering Committee, Northwest Climate Change Adaptation in the Built Environment

The Northwest Climate Change Adaptation Group has been established to work, in conjunction with the Northwest Climate Change Partnership, to co-ordinate the climate change adaptation related actions in the Northwest Climate Change Action Plan.[69]

Northwest Climate Change Adaptation Group's tasks

1. Acting as a single focus for implementation of adaptation actions in the Plan
2. Providing updates on progress made to deliver these actions
3. Promoting adaptations practices and techniques to decision makers in the public and private sectors
4. Communicating the potential regional opportunities associated with climate change adaptation, and
5. Providing a regional link to national climate change adaptation policy and research development.

The Built Environment Steering Committee set up to oversee the production of this Briefing Guide has focused on the third of these tasks. The Briefing Guide has been produced by Eclipse Research Consultants. It has been subjected to detailed scrutiny by members of the Steering Committee. Through several iterations, they have offered comments, made amendments, and provided the local examples cited.

Membership of the Steering Committee

Chair: Emma Kyng, Centre for Construction Innovation Northwest
Annie Atkins, Places Matter
Jo Bradley, Environment Agency
Nick Buck, Drivers Jonas
Tim Daley, Environment Agency
Caroline Duckworth, Taylor Young
Susannah Gill, Community Forests Northwest
Steve Gleave, Taylor Young
Paul Needham, Environment Agency
Paul Nolan, The Mersey Forest
Walter Menzies, Mersey Basin
Alex Solk, Sheppard Robson
Tim Whitehill, BRE

69 http://www.climatechangenorthwest.co.uk/