South East Climate Change Partnership
A partnership of the public, private and voluntary sectors
President: Sir Crispin Tickell GCMG KCVO
Patron: John Craven OBE

Sustainable Development Round Table for the East of England

LONDON climate change PARTNERSHIP

Adapting to climate change:
a case study companion to the checklist for development

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Photographs

(Top left) Chiswick Park, London, photograph by David J Osborn
(Top right) Kronsberg Development, Germany, photograph by Hannover City Administration
(Bottom left) Barclays Building, London, photograph by Living Roofs
(Bottom right) Shinewater Park, East Sussex, photograph by Simon Hurt

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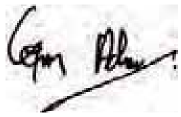
John Rumble
Chair of Climate Change Steering Group
East of England Sustainable Development Roundtable



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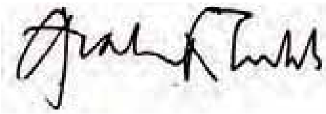
Chair of London Climate Change Partnership



Graham Tubb MBE
Chair of South East Climate Change Partnership

It is clear that the UK's climate is changing. Public and political attention and action now focuses on how we reduce our contribution to climate change and how we adapt to the unavoidable impacts, including those expected over the next 30 to 40 years to which we are already committed.

The UK's changing climate will affect us all, as summer heatwaves make urban areas more uncomfortable and increasing flooding and storminess expose our buildings to greater risks. The national climate change scenarios make it clear that the largest changes in climate will be felt in our South East and Eastern regions, but all areas of the UK will be affected.

Consequently, our developments need to be designed and built for the future climate as well as today's and not based on past designs and techniques developed in response to past climate. The scale of new development happening in the East of England, London and the South East means that it is vital that our future developments are resilient to the impacts of climate change.

Building climate resilience within our domestic and commercial buildings minimises our exposure to climate risks bringing with it social, economic and environmental benefits. It also creates commercial opportunities that will deliver a lasting sustainable legacy in our built environment.

That is why the Three Regions Climate Change Group produced our first document Adapting to climate change: a checklist for development, launched by the Mayor of London at the Thames Gateway Forum in November 2005. That document provides guidance that can assist developers and their design teams to incorporate techniques that minimise at the design stage of development the risks associated with our changing climate.

We have now gone a step further, to demonstrate to you that developments are already incorporating these techniques, thereby suggesting that they can be replicated and enhanced with the objective of becoming the norm rather than the exception.

Adapting to climate change: a case study companion to the checklist for development applies the Checklist's guidance to provide built environment case studies that incorporate climate change adaptation in their design and construction. In the future, we hope to create a website database as more examples of the use of the Checklist's guidance are brought to our attention.

We hope you find the case studies helpful, informative and replicable. Our goal is to see more and more buildings and developments factoring in adaptation measures that are and will be resilient to our changing climate.

Date of publication: 15 March 2007

Introduction

This report "Adapting to climate change: a case study companion to the checklist for development" was commissioned by the Government Office for London's Sustainability Unit in 2006, on behalf of the Three Regions Climate Change Group. This group is made up of representatives from the East of England's Sustainable Development Roundtable, London Climate Change Partnership and the South East Climate Change Partnership.

It is intended to be read in conjunction with the "Checklist for adapting to climate change" – a four page pullout insert within:-

"Adapting to climate change: a checklist for development" guidance on designing developments in a changing climate published by the Greater London Authority, November 2005 (ISBN 1 85261 795 0).

The "Checklist for adapting to climate change" has been included for reference in this report at Appendix A.

Our climate is changing. The latest UK climate change scenarios indicate that, on average, summers will become hotter and drier; there will also be an intensification of the urban heat island effect in urban areas. Winters will be milder and wetter leading to increased flood risk. As well as seasonal changes, there will be more extreme climate events for example, very hot days and intense downpours of rain.

"Adapting to climate change: a case study companion to the checklist for development" uses the same key issues to consider as the checklist for development guidance location, site layout, buildings, ventilation & cooling, drainage, water, outdoor spaces and connectivity. This companion guide provides case studies of developments or buildings that use techniques relevant to key climate change adaptation issues.

The case studies chosen under each heading are relevant to the guidance given within the Checklist and aim to show examples of where this guidance is already being put into practice. Case studies illustrate buildings and developments in the UK and abroad which have particular features that will be appropriate for the conditions for the East and South East of England in the future. The case studies have been selected because they demonstrate techniques or design features which can minimise exposure to climate risk through their design life.

A variety of building and development types from speculative offices, regional masterplans and social housing have been selected as case studies to show how techniques can be applied through a range of different developments.

Many of the case studies feature several techniques which are relevant for more than one section and a colour coding scheme has been used to show where this occurs. All studies are displayed in an identical template and each of the eleven different headings or sub headings are shown at the top of this (see example below).

Example of colour coding system for case studies.

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

An additional section "points to note" is also provided with each case study. This information is not intended to be exhaustive but highlights cost (where available) and benefit information relevant to climate change adaptation. Quantifying actual costs is not always possible and can be misleading as costs will vary between different projects and are often not available in the public domain.

Information on benefits includes financial benefits, often gained through the application of adaptation methods, for example from reductions in water and heating costs to the building occupier.

The section also suggests some of the multiple benefits that adaptation measures can bring, including contributions to increased energy efficiency. This reflects the win-win nature of many of the measures, contributing both to adaptation to climate change and mitigation.

As the public becomes more aware of the advantages of developments that incorporate adaptation measures and planning policy incorporates resilience to climate change, it is anticipated that developers will increasingly be able to acquire a premium from competition by potential users to benefits from the assets created.

Development checklist headings

The presentation of the case studies also shows links to further information on the case study or the associated adaptation technique.

Location

Site Layout

Buildings

- Structure
- Physical envelope
- Materials

Ventilation and cooling

Drainage

Water

Outdoor Spaces

Connectivity

- Infrastructure resilience
- Impact on neighbours

Location

This section shows case studies which provide examples of how the location issues detailed in the checklist for development could be dealt with in the future. Climate change is likely to increase flooding risk in some areas and bring higher summertime temperatures. It will also make it more desirable to ameliorate the urban heat island effect in our cities which will be intensified as climate change impacts increase. Developers will need to respond to these issues in the way they plan their developments.

The Willingdon Levels case study shown in this section provides an excellent example of a scheme where developers and local authorities have been working together to provide measures which maintain the robustness of flood defence schemes whilst allowing the development of prime land.

The Greenwich Peninsula has been redeveloped in the last few years and shows some innovative flood defence techniques and approaches to providing outdoor spaces which mitigate urban heat island effects and provide areas of shade.

The Barclays Building in London is a large office building which has a green roof. Green roofs can help mitigate urban heat island effects by providing evaporative cooling from retained surface moisture.

Holistic flood defences with climate change headroom:

Willingdon Levels Flood Storage Compensation Scheme, East Sussex

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- This scheme was developed with Eastbourne Borough Council in the early 1990's to safeguard the flood storage capacity of a flood catchment area whilst allowing developments which would affect this storage to proceed. PPS25 now requires the application of the sequential and (where relevant) the exception test to guide development away from the floodplain before engineering solutions like this are considered.
- Developers signed Section 106 agreements which stated the volume of flood storage capacity they were required to provide as a result of their proposed development.
- This scheme provides an example of developers engaging with local authorities to provide additional flood prevention resources.
- 70ha of land has been developed since the scheme came into place.
- Financial contribution by developers was made relative to the flood water storage displaced by the new developments.
- A 2001 review following publication of Planning Policy Guidance 25 (PPG25) showed that as a result of the scheme there is no increase of flooding risk on land that does not presently flood.
- The 2001 review also examined how climate change would increase peak flows and raise sea levels and recommended that the scheme change the level of compensatory flood requirements accordingly.

Points to note:

- Flood storage capacity was increased to accommodate calculated increases in peak flow and sea level rise due to climate change.
- This strategic approach to adaptation allowed flood storage to be provided ahead or in parallel with the development rather than waiting until there is a problem.
- The cost of providing flood storage infrastructure was shared by the developer and the local authority.
- The benefit of recreational land and lakes created as a result of the scheme, provides an additional potential income stream from leisure opportunities.

Shinewater Park. Developed in the mid-1990s as part of the Willingdon levels flood compensation scheme (© Simon Hurt)

Further references on case study/ featured adaptation responses:

- www.environment-agency.gov.uk

Eastbourne Borough Plan 2001-2011

Improving flood defences and amelioration of Urban Heat Island effect:
Greenwich Peninsula, London

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- The redevelopment of the Greenwich Peninsula area has created ecologically sound flood defences and also new areas of urban parkland and freshwater lakes.
- Flood defences were in need of repair as their life expectancy was not expected to exceed 5 years in current condition.
- This scheme provides an example of developers engaging with local authorities to provide additional flood prevention resources which then enabled them to build on prime land.
- 1.24km of riverbank defence along the Thames was redeveloped in an innovative scheme including some "setting back" to create enlarged beaches, tidal terraces and an improved flood wall as an alternative to simply replacing the previous wall.
- Over 12,000 trees have been planted in the main parkland areas of the development, providing green spaces which will help mitigate urban heat island effect in the capital.
- Green spaces also provide shade and outdoor space.

Greenwich Millennium Village Ecology Park
(© Government Office for London)

View from Thames Path (© Government Office for London)

Points to note:

- The set-back and terraced flood defences for the new development were less than half the cost of replacing the sheet piling on the same line.
- The combined area of the new green spaces within the development helps to reduce the local effects of the urban heat island.
- The improved appearance of the set-back flood defences also provides improved habitat for animals and plants in the estuary.

Further references on case study/ featured adaptation responses:

- www.englishpartnerships.co.uk
- www.greenwichpeninsula.co.uk

Refer to Environment Agency flood maps to see area of peninsula protected from improved flood defences. See link: www.environment-agency.gov.uk/maps/info/floodmaps/

National Assessment of Defence Needs and Costs for flood and coastal erosion management (NADNAC) report shows cost benefits from improved flood defences. www.defra.gov.uk/environ/fcd/policy/naarmaps.htm

City centre green roof for reducing Urban Heat Island effect:

Barclays, Canary Wharf (London)

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- The Barclays Building's 400m^2 wildflower green roof is one of many green roofs within the Canary Wharf Group Estate, totalling approximately 6000m^2.
- The roof was built principally for biodiversity improvement, but the combined area of all of Canary Wharf's green roofs also contributes to reducing surface run-off, internal heating and contribution to the local urban heat island.
- Reducing heat island effect can in part be achieved by providing green roofs with vegetation which absorb heat and use it through evapo-transpiration- a natural process for plants.
- At the Barclays Building the roof is an extensive (lightweight and self sufficient, accessible only for maintenance) type roof planted with drought and wind tolerant plants 160m above ground level.
- The Barclays green roof is also an excellent SUDS example, reducing run-off by around 40-60%.

Green roof high up at the Barclays Building in London (© www.livingroofs.org)

Points to note:

- The new green roofs within the Canary Wharf Group Estate also provide notable benefits in thermal insulation and reducing energy consumption by replacing the requirement of the original mechanical ventilation systems.
- The combined effect of all the Canary Wharf green roofs is to reduce the effect of the local urban heat island.
- Aggregates were re-used in the construction of the roof, minimising waste and the need for extracting new aggregates.

Further references on case study/ featured adaptation responses:

- www.livingroofs.org

Site Layout

The impacts of climate change will increasingly affect a site's layout and developers will have to consider the increased risk of flooding, heat gain, subsidence and importance of outdoor spaces. The examples in this section are case studies which show techniques where developments:

- provide outdoor spaces with vegetation;
- are arranged such that they have a minimal or even positive impact on flooding; and
- have a layout that helps minimise solar gain in the summer and maximises potential for natural ventilation.

The Kronsberg development in Hannover in Germany is a residential development which has been designed with many sustainable principles, one of which is the provision of much public and private outdoor space with plants and trees.

Plantation Place in London is an example of a speculative commercial office development that has been carefully designed to maximise potential for natural ventilation in a city centre location. It also has roof gardens providing a pleasant outdoor space with vegetation as amenity for its occupants.

The Wessex Water operations centre near Bath is a naturally ventilated building owner-occupied office building that has been designed with its main office areas orientated to face the prevailing wind thus improving the effectiveness of the natural ventilation strategy. The building has an overhanging structure to minimise summer overheating and it also has features which minimise its impact on the landscape and local water flows.

Improving outdoor thermal comfort in a residential development:

Kronsberg Development, Hannover, Germany

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- The Kronsberg development in the south east of Hannover in Germany is a residential development designed with sustainable principles. The layout of the site is very much based on providing green space.
- The development was designed with 5-10% more green, open space than conventional urban developments. Residential developments are arranged around individual parks and each development is bordered by parks and "green corridors".
- Individual dwellings also have private open space ranging from rooftop terraces, private gardens and balconies depending on the accommodation type.
- Two "hillside avenues" running vertically through the scheme provide additional retention areas during periods of heavy rainfall.
- The provision of such areas of public and private open space provides space for people to be outside during hotter temperatures and also allows biodiversity and helps reduce local heat island effects.
- Public space is shaded by both the buildings in the development and trees which will provide shelter during the hotter summer months

Public spaces at Kronsburg for each residential area (© Hannover City Administration)

'Green corridor' at Kronsburg Development (© Hannover City Administration)

Points to note:

- There were additional costs to developers as they contributed to infrastructure costs and the provision of larger than normal open spaces.
- Kronsberg, although built on former agricultural land, was constructed as a high-density development to help conserve the remaining arable and greenfield land around Hannover.

Further references on case study/ featured adaptation responses:

- www.europa.eu.int (search for Kronsberg)
- www.sibart.org

City centre office building maximising potential for natural ventilation:

Plantation Place, London

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- Plantation Place is in the heart of the City of London and provides an adaptable and efficient workplace for almost 4000 people.
- The layout and massing of the building provides opportunities for natural ventilation in a city centre location.
- The top two sections of the building are set back from street level and a double skin façade, combined with a smaller floorplate provides the option of mixed mode ventilation (air conditioning and natural ventilation) and in the case of the top section- full natural ventilation.
- As well as improving comfort the mixed-mode strategy helps reduce energy consumption, therefore reducing CO_2 emissions from the building.
- The setting back of the upper sections of the building also provides roof garden terraces which provide outdoor space for building occupants and green planting.
- Large masonry "fins" which act as shading devices reduce solar heat gain to the office spaces.

Plantation Place from street level (© Government Office for London)

Top section of the building (© Government Office for London)

Points to note:

- The improved thermal performance of the façade means that air conditioning costs were lower than with a standard façade.
- The building benefits from having in-built flexibility in the future through the careful planning in constructing the building to allow a change in HVAC Strategy.

Further references on case study/ featured adaptation responses:

- www.britishland.com
- www.plantationplace.com

British Council for Offices (BCO) Paper "Sustainable buildings are better business"

Site layout reduces solar gain and improves natural ventilation:

Wessex Water Operations Centre, Bath

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- The operations centre for Wessex Water near Bath is an owner occupied office which provides an excellent example of a building which has been designed to maximise use of outdoor space, opportunities for natural ventilation and reduction of solar gains.
- The office building is arranged in an E shape on the side of a hill and is orientated to face the prevailing south westerly winds to maximise the effectiveness of its natural ventilation.
- The office spaces have been designed to facilitate natural cross-ventilation and passive cooling. The exposed structure provides thermal mass to control temperatures within the spaces.
- As well as improving comfort the mixed-mode strategy helps reduce energy consumption, therefore reducing CO_2 emissions from the building.
- Large areas of solar shading on the building help prevent excessive solar gain during the summer and improve the ability of the natural ventilation strategy to ensure minimal hours of overheating during hotter external temperatures.
- Layout of accommodation within building minimises solar gain to meeting rooms and spaces with a typically higher cooling load.

View of building 'stepped' down sloping site (©Wessex Water)

Orientation and shading provide a comfortable low-energy office (©Wessex Water)

Points to note:

- Whole life costing techniques demonstrated the justification for the higher than typical capital cost of the building,
- The optimal integration of natural ventilation considerably reduces the amount of area required for mechanical plant, saving an estimated £50/ m^2. It removes the cost of supplying and installing ductwork (estimated saving £20/ m^2) as well as yielding a saving in running costs (estimated saving £50K per year).

Further references on case study/ featured adaptation responses:

- www.cabe.org.uk
- www.wessexwater.co.uk

Building Structure

Future climatic conditions in the UK will mean hotter summers for the East and South East of England, the possibility of higher winds and more severe storms in the winter. Building structures need to be designed to be resilient to these conditions and to be flexible enough to assist in providing comfortable conditions within the building using such techniques as provision of thermal mass.

Portcullis House in Westminister has exposed concrete slabs which provide thermal mass in the offices and meeting room spaces. This helps absorb heat in summer and is an integral part of the buildings ventilation and cooling strategy.

The Elizabeth Fry Building at the University of East Anglia is an academic building which uses a slab system called TermoDeck. Air is passed through slabs which have hollowed out air paths in-built to help maintain comfortable conditions in the building.

The redevelopment of Kings Cross underground railway station has been undertaken for a 120 year design-life. This meant that there was careful consideration of future ground water movement and additional robustness was built into the foundation design to take account of this.

Thermal mass used in office building to improve indoor comfort:

Portcullis House, London

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- This building in Westminster provides office space and meeting rooms for Members of Parliament and was designed to provide comfortable internal conditions with a low energy ventilation system.
- The building structure uses wave shaped concrete slabs whose undersides are left exposed, forming the ceiling of the spaces within the building.
- The exposed concrete slab provides thermal mass to the occupied space and the wave shape of the slab increases the free area of thermal mass.
- Thermal mass is used to absorb heat in space and stop internal areas heating up so quickly. It is used most effectively when air is passed over it to release the stored heat during the night time.
- By designing a thermally heavy building the ventilation strategy could be designed to be less energy intensive whilst maintaining comfortable internal conditions.
- Layout of accommodation within building minimises solar gain to meeting rooms and spaces with a typically higher cooling load.

Portcullis House, London (© Government Office for London)

Points to note:

- The building uses ground water as a renewable cooling source rather than relying on traditional air conditioning systems.
- Pre-cast slabs were used in the design of the building which were brought to site avoiding potential delays on site.

Further references on case study/ featured adaptation responses:

- www.concretecentre.com – 'Thermal Mass- A concrete solution for the changing climate'.

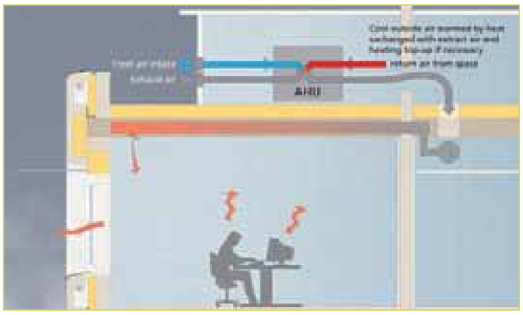
Mechanically assisted passive cooling:

Elizabeth Fry Building, Norwich

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- The Elizabeth Fry Building is an academic building which is part of the University of East Anglia (UEA) in Norwich.
- The building uses a hollow core slab system called TermoDeck. This is a floor slab which acts as a structural component and as a means of ducting ventilation through the building.
- By ventilating through the floor slabs, the mass of the building is used directly to pre warm (in winter) and pre cool (in summer) air that is delivered to the occupied spaces and provide a low-energy heating and cooling system.
- The building has proved popular with its occupants and the TermoDeck system has been implemented in a range of other building types in the UK since.
- By designing a thermally heavy building the ventilation strategy could be designed to be less energy intensive whilst maintaining comfortable internal conditions.
- Layout of accommodation within building minimises solar gain to meeting rooms and spaces with a typically higher cooling load.



During winter days, cool outside air is warmed by heat exchanged with extract air and heating top-up if necessary (© TermoDeck)

Elizabeth Fry Building (©UEA)

Points to note:

- Construction costs were typical and running costs have been minimised because of the passive cooling and the low energy nature of the building.
- The result is a building with a total heat demand from boilers of 24KW (two domestic wall mounted boilers) and no mechanical cooling, serving a building of 3000 m^2 with a potential occupancy of 850 people.

Further references on case study/ featured adaptation responses:

- www.usablebuildings.co.uk – See Probe Studies section

Building Services Journal, April 1995

- www.termodeck.co.uk

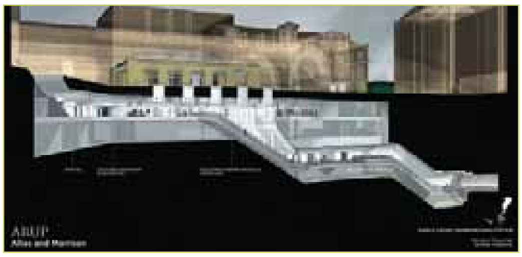
Enhancing protection to groundwater flooding:

Kings Cross Underground Station redevelopment

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- Major refurbishment to one of the busiest underground railway stations in London.
- The station has a 120 year design life and issues such as aquifer levels and their effects on heave were carefully considered during the project.
- In some instances more extreme wetting and drying of soil may cause problems for building foundations in the future. This underground structure will be subject to some of the types of heave forces from aquifers which may be more common in the future.
- Flood studies and the behaviour of underground water movement were undertaken to determine potential flood risks throughout the projects life.
- All these issues were taken into account in the design of the structure of the building.



Deep structure of Northern Ticket Hall (© Arup)

Pipes diverted into an old tunnel (© Metronet Rail SSL Ltd / created by Allies and Morrison)

Points to note:

- The additional design work and more robust foundation design added cost to the design, but this work minimises the risks of failure and the extremely high costs that would be incurred in repairing future flood damage.

Further references on case study/ featured adaptation responses:

- www.arup.com

Building Physical Envelope

The physical envelope of buildings forms the barrier between the internal environment of the building and the external weather conditions. If the climate becomes warmer in summer, wetter and windier in winter in the East and South East of England then it is important that this barrier is suitably air tight, able to prevent excessive solar gain in summer and deal with increased moisture ingress and driving rain.

The first example is a large commercial office development in West London. The buildings have large areas of external shading to help minimise summer sun direct into the building which allows a lower energy ventilation system to be installed.

Another building which has similar responses to summer overheating is Red Kite House near Oxford which houses the West Area Headquarters for the Environment Agency. This building features solar control glass as well as external shading. Rainwater is also collected from its roof which is then used in the building for toilet flushing.

The BRE Environment Building near Watford has an airtight construction and a natural ventilation system which is assisted by "solar chimneys" on the buildings south facing façade. The chimneys are connected to the inside of the building to help draw air out of the building up the chimneys to be replaced by fresher outside air. The shading on the building also provides protection from heating from the sun but allows daylight into the spaces.

The last example is of a residential development in South London called BedZed (Beddington Zero energy development). The envelope of the buildings has high standards of air-tightness and has sunspaces that help warm the building in winter and act as a double skin façade to prevent overheating in summer. The buildings also have green roofs which help ameliorate heat gains in summer and attenuate rainwater run-off.

Shading a commercial building envelope:
Chiswick Park, London

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- This large office building development in West London is a good example of how the physical envelope is used to maintain comfortable conditions within the building.
- The envelope of buildings should reduce the heat gain of the building in summer and buildings that are designed to do this in the present day provide good examples of how more buildings may be able to do this in the future.
- The energy strategy includes external aluminium louvres and retractable external fabric blinds activated by light sensors which together shade 90% of the buildings' surfaces. This significant reduction of solar gain displaces the need for mechanical ventilation systems.
- Additional awning type shading is used on certain facades to increase the protection from direct solar heating.
- The reduction in solar energy entering the building from the use of these facades means that it is easier to keep the building cool in summer and permits a lower energy ventilation and cooling strategy.

Photograph showing office building with large external shading and awnings (© David J Osborn)

Repetition of construction elements helped keep project costs at a minimum (© David J Osborn)

Points to note:

- Costs were minimised by achieving economies of scale, with the office development comprising a number of buildings of almost identical design.

Further references on case study/ featured adaptation responses:

- http://www.enjoy-work.com/chiswick-park/index.html

Office building with solar protection and rainwater collection:

Red Kite House, Oxfordshire

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- Red Kite House is home to the Environment Agency's West Area headquarters and is a 3-storey naturally ventilated building which achieves a BREEAM "excellent" rating.
- The physical envelope of the building helps prevent overheating in the summer thanks to large areas of external shading. This combined with solar control glass helps maximise daylight into spaces and minimises solar gain.
- The main façade of Red Kite House is curved to help improve the effectiveness of the natural ventilation strategy.
- Roof mounted turbines are used to draw air into the top floor of the building. The top floor is most at risk from overheating and this technique decreases the risk of this.
- The roof of the building is used to collect rainwater which is then re-used in the building for toilet flushing.
- Photovolatic cells are also integrated into the south facing façade of the structure and these generate around 20% of the buildings annual electrical demand.
- Solar water heating panels are installed on the roof to help reduce the building hot water demand.

Large external shading at Red Kite House (© Environment Agency)

Points to note:

- Large grants helped to pay for the photovoltaic and solar water heating panels.
- The use of natural ventilation rather than a traditional air conditioning system saves around 3,000kWh/year of energy.

Further references on case study/ featured adaptation responses:

- http://www.environment-agency.gov.uk/ Search for Red Kite House
- http://www.kier.co.uk/

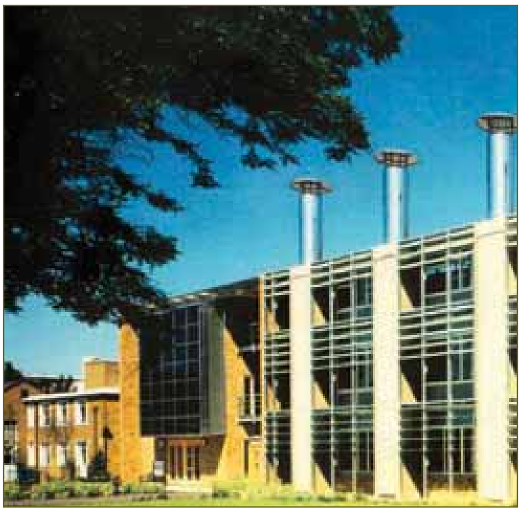
Façade of office building assists in ventilation and solar shading:

BRE Environmental Building, Watford

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- This demonstration office building at the Building Research Establishment shows many of techniques which can be used to ensure the physical envelope of the building protects the building from overheating and enhances its ability to be cooled in a low energy fashion.
- On the south facing façade of the building are five solar chimneys which are connected to the inside of the building at each floor.
- As the sun warms the air inside the chimneys air is drawn from inside the building and exhausted at the tops of the chimney to be replaced by outside air which provides ventilation. Wind passing over the top of the chimneys also increased the effectiveness of the chimneys.
- The large southern façade is designed to allow the most amount of daylight into the building whilst preventing direct solar gain by using motorised translucent louvres.



View of BRE Environmental Building (© BRE)

View of solar chimney and closed louvres (© BRE)

Points to note:

- The complex façade, with natural shading and diffuse light through the louvre blades, allows for a reduction in lighting energy inside the office.
- The large southern façade minimises solar gain during summer, bringing a cost saving through the avoidance of mechanical cooling or air conditioning.

Further references on case study/ featured adaptation responses:

- http://projects.bre.co.uk/envbuild/

European Green Building Forum

Residential development with air-tight envelope and passive solar heating:

Beddington Zero Energy Development, London

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- The Beddington Zero Energy Development in South London comprises live-work buildings and houses where a large variety of techniques have been used which are very applicable to climate change adaptation.
- The building envelope protects the internal spaces from excessive solar gain during the summer but passive heating in winter is used as it saves energy that would be used by conventional heating systems.
- At BedZed heating in the dwelling is from internal heat gains and the sun. South facing double height sunspaces allows heat from the sun into the internal spaces.
- The fabric of the dwellings is highly insulated and airtight. All the dwellings have large areas of exposed thermal mass including ceilings and blockwork walls
- The dwellings have a passive ventilation system provided by wind cowls on the roofs which combine inlet and outlet ducts that turn with the wind depending upon its direction. Heat is recovered from the air leaving the dwelling to avoid wastage.
- During the summer months the thermal mass helps to maintain comfortable conditions inside the dwellings by absorbing heat during the middle of the day and then releasing it at night.
- Buildings have green roofs to ameliorate heat effects in summer.

View of ventilation cowls on roofs of dwellings at BedZed
(© Government Office for London)

Interior of dwelling at BedZed showing sunspaces
(© Graham Gaunt)

Points to note:

- Although the development includes some measures which are more expensive than a typical UK house, other costs have been avoided. For example, the omission of the requirement for a boiler paid for the costs of insulation.
- BedZED seeks to reduce treated potable water demand by more than 50% and to treat effluent on site. This saves natural resource.

Further references on case study/ featured adaptation responses:

- www.bioregional.com
- www.zedfactory.com

Building Materials

Building materials will be affected by climate change. This section shows case studies of buildings designed with materials that will perform well for their design life and of projects that have construction methods which may be more suitable for weather conditions of the future. Adaptation of working processes on site may be necessary in the East and South East of England when considering potential UV and heat exposure for site staff in summer, UV damage to stored materials and the effects of high winds during winter. The case studies featured focus on pre-fabrication and modularization techniques which minimise the exposure to unpredictable site conditions.

The first study shows a modular housing scheme where large sections of detached houses are made off-site and brought to site to be assembled. This reduces requirements for wet trades and reduces time required on site.

The New Inland Revenue building in Nottingham is a large office building which used a lot of prefabricated processes including brickwork piers made off site and pre-cast slabs.

The third case study shows a housing project in North London which used fully fitted-out volumetric units which were constructed in a factory and then craned into place on site.

Consideration should be given to the time of year when modular scheme are assembled if many units need to be lifted in position by crane. High winds may make this impractical in certain conditions, however, so good project planning is required.

Modular construction with high thermal mass for residential development:

Project Meteor, Northampton

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- Adaptation of construction techniques on site may be appropriate for future development due to more frequent periods of extreme weather.
- Project Meteor is a fully modular housing scheme where large sections of the house are constructed off-site in factories and delivered to site where they are lifted into place and finished.
- The safety of site staff may be affected by changes in climate from greater exposure to UV and heat. Techniques which can reduce or modify site based activities may present opportunities to adapt
- The potential for UV damage to stored materials on site is also a consideration which makes pre-fabricated and modular construction a potentially attractive option.
- A feature of the pre-fabricated structure of the Meteor project was the large areas of exposed thermal mass, providing passive cooling and improving the adaptation potential of the dwellings.

The modular roof section is lifted into place at Project Meteor (© Paul McMullin)

Delivery of modular sections directly to site (© Paul McMullin)

Points to note:

- The repeated use of modular elements in the building brings potential cost savings.
- The off-site modular construction process may also allow easier incorporation of climate resilience designs and building materials.
- Although transportation of the modular sections can be a challenge and bring additional cost, this can be off-set by off-site site construction processes being less vulnerable to weather conditions on site.

Further references on case study/ featured adaptation responses:

Building Magazine. Issue 267 (45), November 2002

- http://www.modular-home-systems.com/

Pre-fabricated construction to reduce site time on office development:

New Inland Revenue Centre, Nottingham

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- Inland Revenue centre is a large government office building in Nottingham where a large proportion of the structure has been pre-cast/ pre-assembled off-site.
- It is possible that concrete curing could be more difficult in the higher temperatures that are predicted for the UK in the summer. For the Inland Revenue building, all the concrete floor slabs were pre-cast in more controlled conditions off-site so they were not affected by the weather on site.
- The pre-cast slabs also provide thermal mass to building which will help it maintain comfortable internal temperatures.
- Brickwork piers were constructed off site as was the steel roof structure which was delivered to site for assembly.
- Increased risks of more severe storms in the winter may lead to more days lost on site due to poor weather conditions and more damage to stored materials.

View of the New Inland Revenue Building during construction (© Arup)

Points to note:

- The use of passive cooling means no mechanical ventilation system is required, resulting in reduced running costs and no requirement for suspended false ceilings.
- Through the use of pre-fabricated materials, the development benefited from shorter construction time on site, reduced need for storage of construction materials on site and reduced risks to construction from weather conditions on site.

Further references on case study/ featured adaptation responses:

Architectural Review, no.1179, pp.30-45, (May), 1995

- http://www.hopkins.co.uk/

Fully prefabricated units for apartment block:

Raines Court Housing, London

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- Raines Court is a pioneering housing development built using volumetric units fitted out in a factory and pieced together on site
- Two bed and three bed apartments have been created in this block which benefited from off-site construction, less reliance on the on-site weather and also potential benefits from air tightness.
- Steel framed modules were manufactured in a factory complete with all fixtures and fittings such as tiling, kitchens, plumbing, bathrooms and heating.
- The modules were then transported by road to the site were they were craned into place.
- The development reduced work on site by increasing the level of off-site construction and decreasing the number of modules which form the development.
- The reduced number of modules meant that transport costs could be reduced from factory to site.

Raines Court, London (© Government Office for London)

The building is made of steel framed modules (© Government Office for London)

Points to note:

- Reducing the number of modules which needed to be moved brought lower transport costs.
- However, overall costs were no lower than a normal non-modular housing development, as the economies of scale for the modules were not high enough. The larger the number of modules, the bigger the cost savings.

Further references on case study/ featured adaptation responses:

- www.architecture.com
- www.peabody.org.uk
- www.yorkon.co.uk (Modular manufacturer)

Ventilation and Cooling

This section focuses on examples of buildings which provide secure and effective natural ventilation systems where techniques are used to ensure comfortable conditions inside the buildings for as much of the year as possible. It will become more important in the future to design shading to limit solar gains into the building and to design ventilation strategies that can cope with longer or more intense periods of hotter temperatures.

The emphasis has been to promote natural ventilation over the use of air conditioning. Although air conditioning is an obvious technological adaptation to hotter temperatures it is not necessarily the most desirable for climate change mitigation. Naturally ventilated or mixed-mode buildings are preferable.

The first example is the office of the National Energy Centre in Milton Keynes where a secure natural ventilation system has been combined with a high thermal mass building. External shading helps minimise solar energy through the windows.

The Arup Campus office building near Birmingham has an innovative natural ventilation system which incorporates night cooling of its exposed concrete slabs. It also features external shutter type shading.

The third case study is of a research centre in The Netherlands which has two large atria which office spaces open onto. The atria have motorised vents in their roofs which help improve air movement and the effectiveness of natural ventilation.

Passive cooling techniques for small office building:

National Energy Centre Phase 1, Milton Keynes.

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- Two office buildings for the National Energy Centre in Milton Keynes which demonstrate a range of sustainable building techniques.
- The strategy was to provide a high thermal inertia and the ability to vent overnight in summer
- On the phase 1 building a natural ventilation strategy was adopted throughout the office. To maintain security on ground floors, grilles were used to allow air in and out of the building whilst maintaining a secure perimeter. Lockable doors were also installed to shut these grilles should ventilation not be required.
- To maximise the effectiveness of the natural ventilation strategy the building was designed to be as thermally heavy as possible.
- Concrete slabs provide thermal mass on the ceiling of the ground floor. Multiple (dual) layer dense cement fibre boards on first floor ceiling and dense blockwork walls provide additional mass capacity.
- External shading which act as light shelves to bring daylight into the building whilst providing shading from the sun during summer months.

National Energy Foundation (©NEF)

A view of the external façade of the NEF building (©NEF)

Points to note:

- The Centre was designed to use 40% less energy for space heating/cooling than CIBSE standards and constructed at no extra cost to more conventional buildings.
- The building also has the added benefit of energy savings by avoiding a mechanical cooling system and the cost of a suspended false ceiling.
- Analysis of bills has shown that The National Energy Centre has achieved total energy use of considerably below the Building Research Establishment's Best Practice guidelines for a modern naturally ventilated office.

Further references on case study/ featured adaptation responses:

- www.nef.org.uk

External shading and advanced passive cooling maintain comfortable conditions:

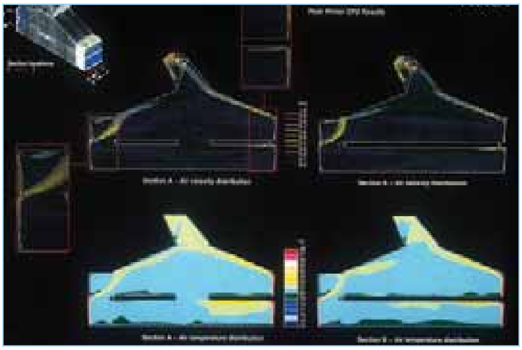
Arup Campus office building, Solihull.

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- Designed as a regional office for the midlands, Arup Campus demonstrates many techniques for creating a good comfortable office space without the need for air conditioning.
- The two linked office pavilions are naturally ventilated and exposed thermal mass from the floor slabs is used to moderate hotter internal temperatures.
- Specially designed vents above the windows can be opened and closed to allow ventilation of the exposed floor slabs during the nighttime. This releases the heat that is stored during day and allows the fabric of the building to cool down.
- The offices feature specially designed wind driven stack ventilation pods on the roofs of the two office pavilions. These work alongside the openable windows on both levels to increase the rate of ventilation to avoid temperature extremes. They allow a deeper floorplate than might typically be suitable for a cross-ventilated building.
- Extensive solar shading, including external shutters on some facades prevents excessive solar gains.
- Air conditioning is avoided in this building by careful ventilation design and the minimising of external solar loads.

Use of external shutter shading to reduce solar gain to the inside of the building (© Peter Cook/VIEW)



Use of external shutter shading to reduce solar gain to the inside of the building (© Peter Cook/VIEW)

Points to note:

- The cost of the advanced natural ventilation system was around 18% lower than in a typical construction, provided additional pay back by displacing air conditioning systems and associated running costs.
- Post occupancy surveys suggest that occupant productivity is improved in the building.

Further references on case study/ featured adaptation responses:

Architects Journal, 215(7), pp.24-35, (February 21), 2002

- www.arupassociates.com

Use of atria to improve ventilation effectiveness in research centre:

Research Centre in Wagenhein, Netherlands.

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- This research centre in The Netherlands is arranged in a capital E shape with glazed atria between the linear wings.
- The building is naturally ventilated and provides office accommodation for over 300 people.
- The building uses high thermal mass to store heat during the summer days and this mass is ventilated at night by opening valves which directly cool the mass.
- At the ground floor level of the atrium green planting and water features help cool the atriums by evaporation.
- At the top of the atria the glazing is modeled on commercial greenhouses and has large moveable shading blinds which can be opened to prevent excessive solar gain.

Points to note:

- The building benefits from energy savings due to its natural ventilation system displacing the need for mechanical ventilation systems.

Further references on case study/ featured adaptation responses:

Sustainable Architecture and Urbanism, Gauzin-Muller, Dominique, 2002.

Drainage

More severe storms during the winter period are predicted for the East and South East of England and this means that drainage systems will be put under more strain due to the effects of increased run-off from new developments and increased risk of flash flooding, particularly in urban areas. New developments must respond by maintaining or even improving the flooding regime of the catchment area they are in. The case studies in this section show certain forms of drainage which aim to avoid increasing run-off to drainage systems.

The first case study is of the Met Office headquarters building in Devon. Large water features have been constructed near the entrance to the building and these act as a run-off store for rainwater from the roof of the building and the site.

Bristol Business Park has many Sustainable Drainage Systems (SUDS) that minimise the impact of this large business park which drains into several catchments. Techniques include permeable paving, swales and detention ponds.

Green roofs are another technique where rainfall from storms can be attenuated to reduce pressure on drainage systems. The Jubilee Campus at Nottingham has many buildings with green roofs which help attenuate water from storms.

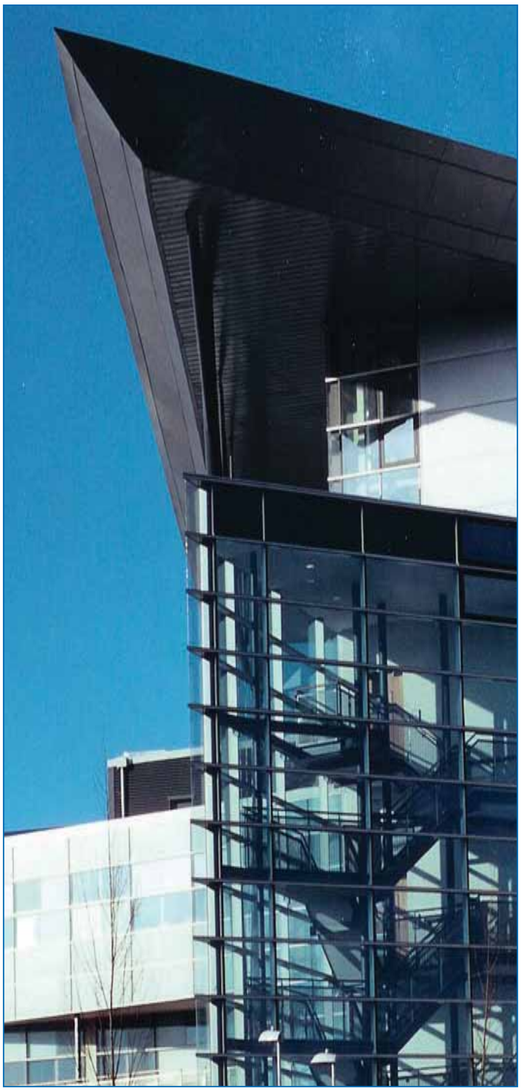
Man-made storage lake to attenuate run-off in office building:

Met Office Headquarters, Devon.

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- New 13,000m^2, 3-storey headquarters building on a 31,400m^2 site provides a good example of drainage techniques which may be appropriate to adapt to climate change.
- Developments, particularly large sites should aim to reduce the area of surface run-off they allow to flow to drains. Increased risk of more heavy rainfall in winter mean that capturing water before releasing it to streams and drains is an important strategy.
- Water features formed near the entrance to the building complex catch rainwater from the site and allow its slow release to the watercourse to prevent flooding.
- These water sources will also provide a source of non-potable water for flushing toilets.
- The Environment Agency is currently recommending an additional 20% to assumed flows to give 'climate change head room' to river flood defences; schemes such as this would provide that additional capacity.



A view of the water feature formed at the entrance of the Meteorological Office Building in Devon (© Still Imaging/CSJV/The Met Office)

Points to note:

- The drainage design for the building's water features reduced water losses into local streams or drains.
- There is the additional benefit of water savings through the use of stored rainwater for toilet flushing within the building.

Further references on case study/ featured adaptation responses:

Contract Journal, 418(6424), pp.18-19, (April 30), 2003

SUDS techniques used to reduce impact of business park development:

Bristol Business Park, Bristol

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- This study provides an example of how a development has used a variety of Sustainable Drainage Systems (SUDS) techniques to minimise its impact.
- The Bristol Business Park is a development of 11.6ha situated on the brow of the hill with run-off to four different catchments.
- The development was phased over a number of years and includes SUDS techniques such as permeable paving in car park areas which drain to swales and a wet detention pond which holds additional water during storms.
- Approximately 1.2ha of permeable paving has been used in parking areas. Swales and retention ponds are used to capture the run-off from the site's permeable paving. Run-off from some of the roofs also discharges into the permeable paving.
- The car parking areas are surfaced with a mixture of permeable and impermeable paving with a porous sub-base running throughout. When rainwater falls on the permeable paving it flows through the gaps into the underlying porous sub-base
- The impermeable aisles are laid to falls so that the runoff is shed to the permeable paving, where it discharges through the joints into the underlying gravel.

Wet retention pond (© London Climate Change Partnership)

Swale at the Bristol Business Park (© London Climate Change Partnership)

Points to note:

- Permeable paving was set out in the contract in all phases of the development, ensuring a consistent approach.
- The use of permeable paving minimised the amount of land required for water retention ponds.
- Permeable paving and swales satisfied the Local Authority's SUDS planning policy requirements.

Further references on case study/ featured adaptation responses:

- www.formpave.co.uk
- www.ciria.org.uk/suds
- See www.sev.org.uk for more examples of SUDS in practice.

Green roofs help attenuate rainwater run-off on University Campus:

Jubilee Campus, University of Nottingham

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- Green Roofs and Rainwater Harvesting are measures that can be adopted to reduce pressure on drainage systems.
- The design of a new Campus at Nottingham University demonstrates some of the principles of water management in its design.
- Designed on a city centre brownfield site a green roof system installed to reduce surface water run off.
- The roofs are planted with low growing resilient alpine plants which help filter water before it is discharged to the man-made lake which has been created.
- The resilient planting would be suitable for potentially higher winds and would be beneficial for increasing the time which water from storms reaches the drains (lag-times).

Green roofs at the Jubilee Campus designed to reduce storm run-off to drains (© Paul McMullin)

Points to note:

- The building's roof system provides not only added insulation for the buildings it covers but also reduces the local urban heat island effect by absorbing solar radiation.
- The cost of the roof is comparable to a good quality upside-down roof when used on a large scale.
- The environmental benefits of the buildings were achieved at an approximate cost of between £105-140 per square foot.

Further references on case study/ featured adaptation responses:

Ingenia, no. 13, pp.35-40, (August/September), 2002

RIBA Journal, 106(11), pp.14-15, (November), 1999

Architectural Review, no. 1236, pp.42-47, (February), 2000

Water

Water, or rather the shortage of water may become a serious problem in the East and South East of England with hotter, drier summers meaning longer spells of high water demand with little rainfall. More severe storms in the winter will mean that water resources must be more efficiently captured to make sure they do not flow straight back into rivers and drains.

This section gives case study examples of developments where techniques include reducing water demand or rainwater harvesting.

The first case study shows a community centre in East London where low consumption fittings have been installed to reduce water demand and a rainwater harvesting tank has been installed to capture run-off from the building's roof.

At the Gallions Ecopark in London water saving features are a major part of this residential development. Low flow fittings are a feature of all the dwellings and each house has a water butt to collect water for garden irrigation as standard.

The Wessex Water building has rainwater harvesting tanks and holding tanks installed as part of its water management strategy. Rainwater is used for toilet flushing and for irrigation of all the external spaces on the site.

Rainwater harvesting and reduction of water demand at community centre:

Eastlea Community Resource Centre, London

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- Eastlea Community Resource Centre (known as The Hub) in East London is a new community centre which places minimum burden on water resources.
- At The Hub, water conservation features include low consumption fixtures and fittings in all bathrooms and kitchens and a root irrigation system for the planted walls.
- The harvested rainwater is used for toilet flushing and plant irrigation which is expected to contribute to a saving in mains water of around 50% per annum.
- The roofs are planted with low growing resilient alpine plants which help filter water before it is discharged to the man-made lake which has been created.

A view of The Hub Community Centre (© Dennis Gilbert/VIEW)

Points to note:

- The use of low flow fixtures and fittings on taps and showerheads provide a relatively low cost method of reducing water use and wastage.
- Payback periods on rainwater harvesting systems can be high, though the savings in water provide an incentive.

Further references on case study/ featured adaptation responses:

RIBA Journal, 112(5), pp.62-64, (May), 2005

Water demand reduction in housing development:

Gallions Ecopark, London

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- The Gallions Ecopark is a development of 39 affordable homes in Thamesmead, East London which includes several features to minimize water use.
- To minimise water use particular features included are solar water heating which helps provide some the domestic hot water load, low flush toilets (2.5 or 4 litre flush toilets), spray taps and water butts outside each dwelling for rainwater collection.
- Rainwater collected in the water butts is used principally for outdoor irrigation but reduces mains water for this purpose.
- Water saving features such as these are particularly important both in water conservation terms and cost terms as water meters are currently being installed in parts of the south east.

Gallions Ecopark (© Government Office for London)

Downpipes from the roofs of the dwellings are fed to water butts outside each dwelling (© Government Office for London)

Points to note:

- The development of the Ecopark demonstrates that sustainable features can be incorporated in low-cost housing without making capital costs unrealistic.
- The houses have been popular with tenants and there are long term energy and water savings for all tenants.
- The project was designed by Dutch Architects and includes sustainable features that would qualify it for additional funding in The Netherlands.
- The overall environmental performance of Gallions Ecopark is 19% better than the standard Dutch row house, caused by a reduction of use of energy by 26%, materials by 41% and water by 14%.
- The annual water use at the Ecopark varies from 28 to 45m^3 per year per person, which is far lower than the standard British household usage of 54m^3 per person per year.

Further references on case study/ featured adaptation responses:

- www.gallionsecopark.co.uk

Rainwater harvesting and holding tanks used at owner-occupied office building:

Wessex Water Operations Centre, Bath

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- The Wessex Water Operations Centre near Bath demonstrates many examples which could be applied for climate change adaptation including excellent water management strategies.
- Several SUDS techniques are used on this building include permeable paving in the car park which drain to soakaways and holding tanks. These tanks provide all the water for the irrigation of the grounds of the building. Storage tanks are also fed by a swale down the western edge of the site.
- Three holding tanks for recycling treated greywater and rainwater from the roof of the building were installed on site which now provides 95% of the water used to flush toilets in the building.

The Wessex Water Operations Centre has a strong water management strategy where much of its water resource is re-used (©Wessex Water)

Points to note:

- The site required additional one-off capital expenditure to install the tanks and associated plant. However, this should be weighed against long term reduced running costs from water savings and the effect of good PR for the company.

Further references on case study/ featured adaptation responses:

- www.wessexwater.co.uk
- www.cabe.org.uk/ search case studies section

Outdoor Spaces

Urban areas will become more adversely affected by the urban heat island effect in the future and the provision of outdoor spaces is an important adaptation method. Outdoor spaces should be permeable so as not to increase surface run-off and should provide pleasant, shaded spaces for people as demand to be outside throughout the year will be likely to increase. Water features can also help provide a cooling effect, although care should be taken over the demand for water they create. In addition, in a warmer climate, decaying waste will smell more so consideration is needed on where to store waste. The case studies in this section are:

The Jubilee Campus at the University of Nottingham has a man-made lake which helps keep the external spaces around the campus cool and makes the site an attractive outdoor environment.

Two residential developments are used as case studies: the Kronsberg development in Hannover, Germany and the Gallions Ecopark in London. At Gallions Ecopark waste separation techniques are used that will help prevent smells in hotter weather and make recycling easier. The Kronsberg development provides high quality public and private outdoor space.

From a commercial perspective there are two examples shown, the Chiswick Park office development in West London and the Jubilee Park in Canary Wharf. Both of these provide high quality external spaces.

Man-made lake helps cool campus area and ventilation air for campus buildings:

Jubilee campus, Univesity of Nottingham

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- The construction of the Jubilee Campus at University of Nottingham included the creation of a man made 1.1ha lake.
- The lake assists with cooling in the campus buildings and also to provide more comfortable and desirable outdoor spaces.
- Buildings are oriented so that prevailing winds pass over a purpose built lake, cooling the air before it reaches the building.
- The outdoor spaces around the lake also benefit from this cooling effect and many of the buildings are cantilevered out to the edge of the water to provide a covered and shaded pedestrian route.
- The lake also acts as a store for rainwater run-off and has created a large new ecological habitat in a previously brownfield site.

Buildings facing the man made lake at Nottingham Jubilee Campus (© Arup)

Points to note:

- The lake acts as an attenuation facility for run-off generated from the site's development, prior to discharging at a controlled rate to the off-site drainage system.
- The lake assists with the natural ventilation strategy for the campus buildings and improves the quality of the outdoor space around it.
- The large amount of excavated material was recycled around the site.

Further references on case study/ featured adaptation responses:

Ingenia, no. 13, pp.35-40, (August/September), 2002

RIBA Journal, 106(11), pp.14-15, (November), 1999

Architectural Review, no. 1236, pp.42-47, (February), 2000

Residential developments providing outdoor space and waste separation:

Gallions Ecopark, London and Kronsberg, Hannover

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- This case study shows the adaptation techniques for outdoors space of two different housing projects; Gallions Ecopark in London and Kronsberg in Hannover, Germany.
- At Gallions Ecopark there is a good strategy for the separation of waste both within the dwellings and centrally in the development which in hotter temperatures may be more important for preventing decay of waste and unpleasant smells.
- Recycling – all homes have waste separation facilities in their kitchens to assist and encourage recycling.
- At Kronsberg in Hannover, similar strategies have been adopted both in the dwellings and centrally with communal composting areas also a feature.
- Kronsberg also has large areas of open space, private and public satisfying a potentially increased demand for more outdoor space.

Gallions Ecopark in London (© Government Office for London)

Waste separation, composting strategies and large areas of outdoor space are key features of the Kronsburg Development in Germany (© Hannover City Administration)

Points to note:

- While there is a higher cost of providing larger areas of green space, this also provides greater marketing opportunities.
- Recycling stations at Kronsberg for pre-separated waste such as paper, packaging and organics, are situated through the neighbourhood and underground glass recycling bins help minimise the visual impact of such facilities.

Further references on case study/ featured adaptation responses:

- www.europa.eu.int (search for Kronsberg)
- www.sibart.org (Kronsberg)
- www.gallionsecopark.co.uk

Commercial developments providing outdoor space with shade and vegetation:

Chiswick Park, London and Jubilee Park, London

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor spaces	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- This case study shows the provision of outdoor spaces in two commercial developments at Chiswick Park in west London and Canary Wharf in east London.
- At Chiswick Park the 12 buildings have been built around a central water feature with areas of green landscaping between them.
- Semi-mature trees have been planted which add to the appeal of the landscaping and provide shade during the summer.
- Vehicular movement is routed around the back of the buildings making the area in the middle pedestrian parkland.
- Jubilee Park is above the new underground station and provide the largest green space at Canary Wharf.
- Vehicular movement is routed around the back of the buildings making the area in the middle pedestrian parkland.
- Jubilee Park is above the new underground station and provide the largest green space at Canary Wharf.
- The park is a worthwhile resource in this high density development in London, offering an outdoor green space, a water feature and shading from trees for the large number of people who work and live in the area.

Semi-mature trees planted in around the Chiswick Park development (© David J Osborn)

Jubilee Park in the centre of Canary Wharf in London (© Government Office for London)

Points to note:

- These sites provide greater available area, increased shade and improved quality of outdoor space which will help with increasing demand during longer periods of warmer weather.
- Good provision of open spaces within these types of developments will become a more valuable asset to commercial developments as recreational areas become more important in warmer temperatures.
- In addition, the combined total of good quality green space helps reduce the localised urban heat island effect.

Further references on case study/ featured adaptation responses:

- www.cabe.org.uk
- http://www.enjoy-work.com/chiswick-park/index.html

Connectivity: infrastructure resilience

The potential for climate change to affect infrastructure is a risk in the future with the possibly of increased flooding causing damage to electrical mains, substation and gas pipelines. Developments in areas at risk can help improve their resilience to these conditions by being more independent from national grid based infrastructure through local generation of heat and power.

The example given here is the Eastlea Community Resource Centre in London where ground source heat pumps provide heating and cooling with photovoltaic panels integrated on the building façade for electricity generation.

Ground source heat pumps and photovoltaic panels as renewable power source:

Eastlea Community Resource Centre, London

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor space	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- Eastlea Community Resource Centre (known as The Hub) in East London is an example of a building having integrated renewable energy technologies which satisfy a proportion of its energy needs independent of the national grid.
- Climate change may affect development infrastructure and there are real risks that flooding would cause major disruption to centralized energy networks. Developments which produce some or all of their energy locally or even within their own building footprint may be less at risk.
- The Hub has 200m^2 of Photovoltaic Cells on its street facing façade to provide electricity and a vertical Bore Hole Ground Source Heat Pump system for heating and cooling.
- The electricity generated from the PV cells annually is nominally sufficient to power the pump for the ground source heat pumps.

Photovoltaic Panels on the front façade of The Hub (© Dennis Gilbert/VIEW)

Points to note:

- Additional capital costs are required for the purchase and installation of photovoltaics and ground source heat pumps, but the photovoltaic output reduces the energy costs of the heat pumps.

Further references on case study/ featured adaptation responses:

RIBA Journal, 112(5), pp.62-64, (May), 2005

Connectivity: impact on neighbours

The creation of any new development will have impacts beyond its own borders and it is necessary to have processes or techniques in place that minimise the negative impacts of this. Changes to water flows can often adversely affect both overground and underground water courses and developers must make careful consideration of these when planning new projects.

Two case studies are used to illustrate these issues. The first is the Water Assessment Method in the Netherlands which is a policy introduced to ensure that developers and water managers meet at early stages of developments to ensure that changes made to water courses are compensated for.

The second case study is of the overall flood protection scheme at Milton Keynes. Balancing lakes have been created around linear parkland to ensure that in the event of storms or floods areas of "sacrificial" parkland are flooded before any built up areas.

Planning assessment method to minimise impact of developments in other areas:

Water Assessment, Netherlands

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor space	Connectivity: infrastructure resilienc	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- The Netherlands is a country well used to dealing with flood risk as much of its land is below sea level.
- Flooding has occurred from extreme rainfall, high river discharges and groundwater problems.
- Since 2001 a new assessment procedure and planning process has been introduced to ensure interaction between developers and water managers in the early stages of scheme proposals.
- The process is designed to ensure that any negative aspects that a development will have on the water system are compensated.
- The process is potentially transferable to the UK and would involve the Water Companies and the Environment Agency being involved in the spatial planning process.
- The procedure could take place on a national or local level.

Points to note:

- The spatial planning authority generally has to fund measures required to keep the water system in condition prior to the realisation of new developments.
- Developers must pay for the cost of measures in private schemes unless the water system does not currently meet national guidelines.

Further references on case study/ featured adaptation responses:

- www.watertoets.net
- www.environment-agency.gov.uk/maps/info/floodmaps/

Local flood protection scheme with sacrificial land for flexibility in flood storage capacity:

Milton Keynes

Location	Site Layout	Building: structure	Building: physical envelope	Building: materials	
Ventilation and cooling	Drainage	Water	Outdoor space	Connectivity: infrastructure resilience	Connectivity: impact on neighbours

Key adaptation responses to climate change:

- In Milton Keynes a scheme has been adopted to provide sacrificial land which can flood without affecting developments, roads or pathways.
- Catchment and collection areas are part of the city masterplan and are well integrated with the city's linear parks.
- Roads and pathways are also linear but at higher level so the scheme is designed to prevent closure of these during flooding.
- Flooding in 1998 and 2001 was contained in sacrificial areas. No new homes were affected and all roads and paths remained open.

Lakes in the Milton Keynes catchment area including dry lakes which flood during storms (© Invest Milton Keynes)

Points to note:

- The Strategy relies on the planning of roads and parkland to create a sacrificial flood plain to allow for development in other surrounding areas.
- During flooding events, damage to property and restriction of access is avoided.

Further references on case study/ featured adaptation responses:

- www.mkweb.co.uk
- www.environment-agency.gov.uk/maps/info/floodmaps/

Case Study Overview

The case studies in the previous sections show individual buildings and developments that have techniques which could be adopted to adapt to the effects of climate change. Care must be taken to ensure that flooding risk is managed, that outdoor space is provided, that buildings will be comfortable in hotter temperatures and that water demand is reduced and drainage carefully managed.

The case studies have been arranged under checklist headings but some of them have relevance to more than one section. This suggests there are some buildings or developments which might already be resilient to several aspects of climate change. This section shows examples of developments where a range of the adaptation measures from several checklist headings can be seen.

Climate change is not going to go away; the UK will face increased impacts of climate change, especially in the East and South East of England. Developments will have to be built in a way that ensures they are able to withstand these impacts throughout their design life. As external climate conditions change and increasingly drive the agenda for developers in the future, other pressures such as increased energy and water prices highlight the importance of building in measures now to improve energy and water efficiency.

Water scarcity is a problem which is becoming more relevant for a large number of people in the UK and in 2006, large areas of the East and South East of England were under hosepipe bans due to drought conditions.

By adapting in a way the Checklist suggests, developments which can provide much of their power through renewable generation and significantly reduce their water consumption or improve water re-use are likely to be the most successful developments of the future.

The costs of some renewable technologies are often prohibitively high but with mass-production likely to increase, the costs should fall through simple economies of scale. Many strategies such as demand reduction for energy and water do not constitute significant extra cost in developments, particularly when considered in life-cycle terms.

Dongtan EcoCity, China

Key adaptation responses to climate change:

- Dongtan is situated on an island north of Shanghai in China and is being designed and masterplanned to become the world's first Eco-City which will in turn inform future developments in China and around the world.
- Principles of "circular economy" have been applied to the design of the city where waste is usefully recycled into a resource.
- The city is being designed in anticipation of future rising sea levels and buildings are being designed above land levels which may be at threat in the future.
- Dongtan will be three quarters the size of Manhattan and will be as close to "carbon neutral" as possible.
- Water will be harvested from the surroundings and purified for use in the city.
- Buildings will be as low energy as possible with efficient use of energy resources and generation of electricity from renewable sources including organic waste from the city.

East Village, Dongtan Ecocity (© Arup)

Night view, Dongtan Ecocity (© Arup)

Further references on case study/featured adaptation response:

- www.sustainability.com
- www.carbonfree.co.uk
- www.arup.com

Upton Housing Project, Northampton

Key adaptation responses to climate change:

- The Upton community is in Northampton and aims to create through local sustainable planning 5000 homes, 280,000m^2 of industrial floorspace, a country park and associated facilities.
- Project partners developed a design code which demanded very high standards and made clear obligations of potential developers.
- Codes included all homes to be of Ecohomes 'Excellent' standard.
- Other requirements include:
  SUDS techniques to be used, developers required to procure electricity from green tariffs, optimising passive solar gains to reduce CO^2 emissions, rainwater harvesting and low water demand fittings to be used, materials to be locally sourced or recycled and waste to be minimised during construction and afterwards.
- The project has been split into 8 development areas which will also be incorporating different technologies such as Photovoltiacs and Micro Combined Heat and Power (CHP).
- The final scheme will create a large development of buildings which demonstrate infrastructure resilience through renewable technologies, appropriate water demand reduction and harvesting, solar design that maximises useful energy from the sun and an excellent standard of building envelopes.

Eco house in Upton Housing Project (© Northampton Chronicle and Echo)

Further references on case study/featured adaptation response:

Energy Saving Trust Publication CE195

- www.englishpartnerships.co.uk

South East Climate Change Partnership
A partnership of the public, private and voluntary sectors
President: Sir Crispin Tickell GCMG KCVO
Patron: John Craven OBE

Sustainable Development Round Table for the East of England

LONDON climate change PARTNERSHIP

Checklist for adapting to climate change

This checklist summarises the key issues that need to be considered when minimising the exposure of your development against the impacts of climate change, and is followed by more detailed guidance on each aspect. ✓

Location

Establish the Environment Agency flood risk designation(s) for the site and ensure that the design of the development accords with it. Check the Environment Agency's Flood Map resource at **www.environment-agency.gov.uk/subjects/flood/826674/829803** ☐

Check with the Local Planning Authority to review any strategic flood risk assessments. ☐

Undertake an appropriate flood risk assessment and evaluate the flood risk over the design life of the development. Demonstrate that this is acceptable for the proposed use(s) and, at a minimum, that there will be no overall increase in flood risk (likelihood and negative impact). ☐

Consult the insurance industry guidance *Strategic Planning for Flood Risk in the Growth Areas – Insurance Considerations* [(i)] about the viability of the development for insurance purposes. ☐

Help reduce the urban heat island [(ii)] effect e.g. by planning green space and using appropriate shade when locating your development. ☐

Consider the implications of coastal erosion when planning a development. ☐

Site Layout

Ensure the overall layout and massing of the development:

- does not increase the flood risk and where possible reduces risk; ☐
- minimises solar gain in summer; ☐
- maximises natural ventilation; ☐
- maximises natural vegetation; ☐
- takes account of the increased risk of subsidence; ☐
- provides homes and other appropriate uses with a private outdoor natural greenspace wherever possible. ☐

Buildings ✓

A: Structure

Demonstrate the structure is:

- strong enough or able to be strengthened if wind speeds increase in the future due to climate change; ☐
- strong enough to avoid movement due to expected future levels of subsidence and heave; ☐
- able to incorporate appropriate ventilation and cooling techniques/mechanisms; ☐
- of an appropriate thermal mass for the intended use and occupancy. ☐

B: Physical envelope of structures

Demonstrate the envelope of the building is designed so that:

- drainage systems and entrance thresholds can cope with more intense rainfall; ☐
- there are opportunities for incorporating green roofs or walls; ☐
- the exterior of buildings reduces heat gain in summer; ☐
- the overall envelope avoids infiltration from increased wind and temperatures; ☐
- cladding materials are able to cope with higher wind speeds. ☐

C: Materials

Ensure the materials specified will perform adequately in the climate throughout the lifetime of the development. ☐

Ensure the construction methods to be used are suitable for the weather conditions at the time of construction. ☐

Ventilation and Cooling

Ensure that ventilation brings clean pollution-free air into the building and does not compromise noise levels or security. ☐

Demonstrate the building has or is capable of having installed a ventilation system which will deliver comfortable temperatures (i.e. exceeding 28°C for less than 1% of the time and exceeding 25°C for less than 5% of the time) for the expected climate throughout the design life of the development. ☐

Cooling and ventilation systems, where necessary, should be designed to use as little carbon-based energy as possible by utilising renewable energies and being as energy efficient as practicable. ☐

✓

Drainage

Carry out a site survey to determine which SUDS techniques will be appropriate for use on the site. For example, ground conditions will determine the suitability of infiltration systems. Consider rainwater harvesting, green roof systems and opportunities for permeable paving if soil permeability is low. ☐

Ensure, in consultation with the Environment Agency, that the requirements of the Groundwater Regulations are complied with (you should though note that shallow, extensive infiltration systems will minimise risks to groundwater). ☐

Demonstrate consideration is given to future maintenance requirements of SUDS including the need, where necessary, for the removal of silt which will be treated as a controlled waste, and that space requirements for this purpose are allowed for in the design ☐

Ensure that responsibility for maintaining SUDS is clear at the planning application stage [iii]. ☐

Consider using permeable paving anywhere that loadings will not cause structural failure. In practice, all pavements, driveways, footpaths, car parking areas and access roads could have permeable surfaces. ☐

In developing the drainage plan for the site, ensure that the design standard takes account of climate change and that carriageways, paths and other features of the site are designed to convey this excess flow safely. ☐

Water

Estimate the net water consumption of the development under normal use and under water conservation conditions (i.e. during a drought), both initially and during the lifetime of the development in consultation with the relevant water company. ☐

Discuss existing sewerage infrastructure and sewage treatment capacity with the local sewerage provider. ☐

✓

Regarding water use, for housing, achieve a target of 30 cubic metres per person per year under typical use and for offices, 1.05 cubic metres per person per year. ☐

Minimise water use in buildings, consider the use of rainwater collection/re-use systems and consider the environmental impact (in terms of water consumption) of products, materials and building methods. ☐

Outdoor Spaces

Incorporate an appropriate range of public and private outdoor spaces in developments, with appropriate shade, vegetation and water features. ☐

Ensure the design of surfaces take account of more intense use, permeability, potential for causing dust and for soil erosion. ☐

Ensure the selection of vegetation with longer life (over 10 years) takes account of future climate change. ☐

Ensure water features have minimal net water use. ☐

Provide a rainwater collection system/grey-water recycling for watering gardens and landscaped areas. ☐

Ensure there are arrangements for storing waste which allow for separation and prevent excessive smell in hotter conditions. ☐

Connectivity

A: Infrastructure Resilience

Ensure there are safe access routes above the likely flood levels and the routes are clearly marked (e.g. by a series of poles) during the design life of the development. ☐

Negotiate with utilities and others over the resilience of services and infrastructure to the development. ☐

B: Impact on Neighbours

Identify immediate neighbour impacts as well as the cumulative impacts and the increased demands on services. ☐

(i) Strategic Planning for Flood Risk in the Growth Areas – Insurance Considerations, Association of British Insurers July 2004, www.abi.org.uk/display/File/Child/554/Strategic_Planning_for_Flood_Risk_thamesgateway.pdf

(ii) Microclimates, The Met Office, www.metoffice.com/education/secondary/students/microclimates.html

(iii) Interim Code of Practice for SUDS, National SUDS Working Group 2004, www.environment-agency.gov.uk/business/444304/502508/464710/465036/466851/?land=_e

Funding Partners

London Climate Change Partnership
www.london.gov.uk/climatechangepartnership

Government Office for London
www.gos.gov.uk/gol

Environment Agency
www.environment-agency.gov.uk

South East Climate Change Partnership
www.climatesoutheast.org.uk

South East England Development Agency
www.seeda.co.uk