Chapter 2

Design strategies and adaptations for a changing climate

Despite even the best mitigation efforts, our climate is experiencing irreversible changes.

Buildings are usually designed with a lifespan of around 60 years. What we build today will still be standing in 2080 and beyond, and we should design for the climate change predicted during that period. We must also carefully consider our reliance on finite resources which move closer to exhaustion by the day. Only in doing so are we able to fulfil our duty towards clients and building users.

Seasons in the UK, in general, are expected to become warmer. We will see drier summers, wetter winters and more extreme winds and rainfall. Although the increases in temperature are incremental, the actual impact on both the natural and the built environment is significant. As an island, the UK is particularly vulnerable to coastal flooding. Inland, extreme rainfall will increase the risk of urban flash floods and swollen rivers. We are also likely to experience more heat waves and droughts which could pose issues of subsidence and affect the way we cool buildings.

This chapter summarises predicted climatic changes and arising design implications and adaptations, both for site planning, building design and during construction.

Symbol indicates relevance to the Code for Sustainable Homes, EcoHomes, BREEAM and LEED.

2.1 A CHANGING CLIMATE: WHAT ARE THE IMPACTS IN THE UK?

By the end of this century, we expect to have seen temperature increases of 2–5°C with the smallest temperature increases in the north of the UK and the largest increases in the southern regions of the UK.[1] Rises in sea level will range from 130 to 760 mm.[2]

UK seasonal rainfall is variable, but in general, each region is predicted to see increased winter rainfall of around 30%, although overall yearly rainfall increases are deceptively modest. This is because the yearly average evens out with similar rainfall decreases in summer.[3] In southern regions, reduced cloud cover during summer is likely to contribute to increased solar radiation and higher temperatures, as well as more extreme rainfall as a result of increased temperatures.

The UK is already experiencing a change in climate:

- Sea-levels around the UK have risen by 100mm since 1900 and there has been a 1°C temperature increase since 1970.[4]
- 2006 was the hottest year recorded in 350 years.[5]
- In the summer of 2003 a prolonged heat wave hit the country; the UK suffered 2,000 heat-related deaths.[6]

Predicted climate changes and impacts in the UK (general)

(based on current trajectory of a global 2°C rise by 2040 and 4°C by 2080)

permanent sea level rise[7] 	Loss of agricultural land, displaced people and loss of species. Infrastructure in low-lying land threatened. South of UK more affected by subsiding land movements.[8]
more rainfall in winter and less rainfall in summer 	Higher risk of regional flooding in winter and localised urban floods in summer. Prolonged droughts damage planting and lead to increased risk of wildfires. Existing housing stock on clay subsoil will be more prone to subsidence/heave.
extreme rainfall events, not unlike tropical rainstorms 	River flooding and localised urban flooding. Threat to underground and ground-floor infrastructure, sewage and clean water supply. Wind-blown water damage due to increased wind pressure.
increased summer temperatures and extremes 	Buildings will struggle to provide thermal comfort. Heat-related deaths and illnesses, especially among the old and fragile. CO_2 emissions from summer cooling are likely to increase, exacerbating global warming. Road surfaces will melt with prolonged temperatures over 35°C and other infrastructure will fail.[9]
increased winter temperatures 	CO_2 emissions from space heating are expected to decrease but this will not cancel out the predicted increase in cooling energy during summer.

2.1.1 Regional future predicted climate changes: Scotland[10]

Region 1: Scotland	**2040s**	**2080s**
sea level	150–390 mm increase	370–750 mm increase
air temperature	An average yearly increase of 1.8–1.9°C. Summer temperatures to increase by around 2°C. Winters to be 1.6°C warmer.	An average yearly increase of 2.9–3.5°C. Summer temperatures to increase by around 3.9°C. Winters to be 2.6°C warmer.
rainfall	Overall yearly increase of 2.7–4.3% in precipitation. A 10% increase in rainfall in winter and the same in autumn. An 8% decrease in summer.	Overall yearly increase of 0.7–1.9% in precipitation. A decrease in precipitation of 15–19% in summer, with increased average rainfall particularly in winter and autumn: 22% and 20% respectively.

2.1.2 Regional future predicted climate changes: north England and north Wales[11]

Region 2: North England and north Wales	**2040s**	**2080s**
sea level	190–450 mm increase	440–840 mm increase
air temperature	An average yearly increase of 2°C. Summer temperatures to increase by around 2.2°C. Winters to be 1.8°C warmer.	An average yearly increase of 3.2–4°C. Summer temperatures to increase by around 4°C. Winters to be 2.7°C warmer.
rainfall	Overall yearly increase of 0.7–1.9% in precipitation. Winter precipitation to increase by around 11% and up to 6% in autumn. Summer precipitation to decrease by 12%.	Overall yearly increase of 6–8.7% in precipitation. An increase in winter precipitation of between 18% and 26%, with a smaller increase in autumn (9%). Summer precipitation to decrease by 21–26%.

2.1.3 Regional future predicted climate changes: Northern Ireland[12]

Region 3: Northern Ireland	**2040s**	**2080s**
sea level	150–400 mm increase	380–750 mm increase
air temperature	An average yearly increase of 1.8°C. Summer temperatures to increase by around 1.9°C. Winters to be 1.6°C warmer.	An average yearly increase of 2.9–3.6°C. Summer temperatures to increase by around 3.7°C. Winters to be 2.7°C warmer.
rainfall	Overall yearly increase of 1.3–2.3% in precipitation. An increase in autumn (6%) and winter (7%) precipitation and and 8.5% decrease in summer precipitation.	Overall yearly increase of 2.7–4.5% in precipitation. A decrease in precipitation in summer of between 15% and18%, with an increase in precipitation in autumn (11%) and winter (12–19%).

2.1.4 Regional future predicted climate changes: south England and south Wales[13]

Region 4: South England and south Wales	**2040s**	**2080s**
sea level	200–490 mm increase	490–900 mm increase
air temperature	An average yearly increase of 2–2.6°C. Summer temperatures to increase by around 2.4°C. Winters to be 2°C warmer.	An average yearly increase of 3.5–4.3°C. Summer temperatures to increase by around 4.5°C. Winters to be 3.4°C warmer.
rainfall	Overall yearly increase of 1–1.9% in precipitation. A 14% increase in winter precipitation predicted, with 3–4% increases in autumn and 12% decreased precipitation in summer.	Overall yearly increase of 2.3–3.3% in precipitation. An increase in winter precipitation of 24–32%, with small increases in autumn (5%) and 21–26% decreased precipitation in summer.

2.2 A CHANGING CLIMATE LEADS TO A CHANGE IN HOW WE DESIGN

Although the predicted weather conditions will be new to the UK, they are already a fact of life for much of the world. Building precedents in Mediterranean countries, for example, can teach us how to adapt our buildings to cope with increased summer temperatures. And the Netherlands, a country with more than 50% of its landmass below sea level, can teach us how to work with water rather than against it. → Jump to Chapter 5.

As shown in Fig. 2.2.1, by 2080 summer air temperatures in the UK's southern regions will resemble those of the Mediterranean, while summer air temperatures in the north will be similar to those of northern France and the Belgian coastal regions.

Fig. 2.2.1 Map of UK cities and predicted 2080 future summer climate 'sister cities' (based on approx. summer air temperature comparisons)

2.2.1 Environmental modelling and climate data

When designing buildings, it is increasingly useful to test how robust the building design will perform in a future predicted climate. Given that the majority of buildings we design today will still be standing by 2080 and beyond, to strive that they are fit for purpose in a changing climate is an ethical obligation. Future predicted climate data, alongside standard climate data, can be obtained from sources below.

Usually environmental modelling tools will use:

- Test Reference Years (TRYs): historic weather data used mainly for energy consumption purposes
- Design Summer Years (DSYs): historic hotter summer weather data for overheating simulations
- future climate change data for the whole of the UK from: http://ukclimateprojections.defra.gov.uk/ and www.cibse.org/knowledge/cibse-other-publications/cibse-weather-data-current,-future-and-combined
- ready-to-use (future) climate data sets for a selection of UK cities from: www.centres.exeter.ac.uk/cee/prometheus

2.3 THE IMPORTANCE OF FUTURE-PROOFING OUR BUILDINGS

Future-proofing anticipates climate changes and makes plans for adaptation without impacting on CO_2 reduction/mitigation efforts. We need to design now for the future.

Future-proofing does not have to mean spending lots of money right now. Many measures are easily implemented simply by planning ahead and thinking differently about site and building design. Other measures can be implemented in the future, if and when climate predictions materialise.

To future-proof, we need to plan ahead. If we know that our buildings may need solar shading, we have to design for this now, even if shading is only installed when it becomes necessary. For example, this means that we need to specify shutter fixings and inward-opening windows right now, which will allow sufficient cross-ventilation when external shutters are fixed in the future. Jump to Chapter 6. If we do not act now, the cost of coping with climate change in the future will be much greater than the price we would pay to prepare today.[14]

Thinking and planning ahead will mean:

- reduced CO_2 emissions as it will minimise remedial measures and waste of resources
- the cost of climate change mitigation will always be substantially less than any adaptation measures[15]
- occupant comfort at all times
- minimised need for building demolition 50 years down the line.

Credits under Code for Sustainable Homes (Sur 1 mandatory, Sur 2), EcoHomes (Pol 3, Pol 5), BREEAM NB (Pol 3), BREEAM Rfrb (Pol 2), BREEAM Com. (SE 10), LEED NC (SSc4), LEED Homes (SSc2, LTp1), LEED Ex. (SSc2, SSc6), LEED Com. (SLLp5). (Related to prevention of flooding and surface water run-off.)

The checklist overleaf gives examples of easy and cost-effective measures which can be included today to future-proof our buildings in a changing climate. This is followed by more detailed design checklists with recommendations for future-proofing the site, buildings and construction work on site.

Future-proofing checklist (see also checklists in sections 1.5.6, 3.8, 6.9 and 4.1.1)		☑ ☒
Dealing with local infrastructure and energy sources		
Section 3.8	Has space for urban infrastructure, including renewables, been considered? Can roofs be angled to maximise later addition of solar panels? Is space for future thermal stores incorporated?	☐
Dealing with likely increasing energy bills		
Chapters 3, 7 & 8	Has energy use been minimised, by measures such as maximising winter solar gain, buffering from cold winter winds, increased fabric efficiency and good airtightness? Some funding may be available to upgrade existing buildings.	☐
Dealing with potential flooding		
Chapter 5	Assess flood risk and sources of flooding, plan land use and site based on this risk and utilise building typologies that work with water (Section 5.1) or adapt buildings to be 'wet-proofed' (Section 5.2), alongside providing sustainable urban drainage systems (SUDS) (Section 5.3). → Jump to checklist 5.1.4.	☐
Dealing with potential water scarcity		
Chapter 5	Specify low-flow taps/shower heads, low-flush toilets and low-volume baths throughout. Consider simple, cost-effective and low energy rainwater collection and grey water recycling systems, only after water efficiency has been maximized. → Jump to Sections 5.4, 5.5 and 5.6.	☐
Dealing with building overheating		
Chapter 6	See detailed checklist Section 6.9	☐
Sections 3.6, 6.4 and 4.2	Has external and internal thermal comfort been maximised by careful building siting? Has vegetation been used to reduce air pollution, moderate the urban heat island effect and increase thermal comfort?	☐
Dealing with building and landscape maintenance and care		
Sections 1.5.6 and 4.1.1	See detailed checklist Section 1.5.6 and 4.1.1, which set out the importance of maintenance for a long building and landscape lifespan.	☐

2.3.1 Increased summer temperatures: design checklist

Relevant to all regions, but most problematic in urban areas and the south of England. Less significant in Region 1: Scotland.

Site strategies: → **Jump to Chapters 3, 4 and 5**

- Have 'cool' surfaces (light-coloured or reflective) been specified? ☐
- Are there bodies of water and vegetation to allow for evaporative cooling and shade ideally incorporated into SUDS at city and district scale? ☐
- Does the design allow for good summer ventilation at street level to disperse pollutants? ☐
- Have narrow street and courtyard designs been proposed? ☐

Building scale: → **Jump to Chapters 6, 7 and 8**

- Well-insulated and airtight buildings are still relevant. Are there passive measures to prevent overheating? Is there provision for solar shading to south, east and west, with inward-opening windows? Does the design include overhanging eaves and large window reveals? ☐
- Does the design provide good natural ventilation, particularly good cross-ventilation and secure night-time cooling? ☐
- Has use been made of thermal mass in exposed surfaces and high floor to ceilings? ☐
- Have you minimised the use of skylights, except where overshadowed by surrounding structure, to limit overheating in summer? ☐
- Does the specification use light-coloured or reflective external building surfaces, including vegetated roofs and walls? ☐
- Have joints been increased or enlarged to allow for more thermal movement, especially at south facing façades and roofs? ☐
- Increased thermal stress and movement will reduce material durability and performance, particularly on window frames and roof finishes. Has this been taken into account and have reflective layers, stones as ballast and protection layers on roofs with flexible material at upstands been used? ☐
- Have you specified durable window seals and designed recessed windows rather than having windows flush with the external façade? ☐
- Have hot water pipes been well insulated to avoid additional internal heat gains? ☐

During construction:

- Has account been taken of the fact that curing of wet plaster/concrete and other wet trades will be affected? (Cementing/concreting, and/or rendering may be difficult on hot days, which could result in cracking and shrinkage with poor finishes and possible structural weakness. Ideal temperature for maximum strength is 23°C.) ☐
- Is it possible to use prefabricated concrete panels or undertake concrete works in spring/autumn or early mornings and shade the working area from the sun? ☐
- Are the workers being protected from heatstroke? ☐
- Higher productivity may speed up site programme, so have you planned to carefully monitor this for its effect on the critical path? ☐

2.3.2 Increased winter temperatures: design checklist

Relevant to all regions.

Site strategies: → **Jump to Chapters 3 and 4**

- Has shelter been provided from cold northerly and north-easterly winds?

Building strategy: → **Jump to Chapters 6, 7 and 8**

- Moderate winter temperature increases mean that current strategies to deal with large heat losses are still relevant, so have you used super-insulation, compactness, porches and good airtightness, and maximised solar gain?
- Has thermal mass been used to stabilise day-/night-time temperatures?
- Are you aware that mechanical ventilation systems such as MVHR may be used?

During construction:

- Do you still need to be concerned about the risk of frost?
- Increased winter temperatures may speed up site programme, so have you planned to carefully monitor this for its effect on the critical path?

2.3.3 Decreased summer rainfall: design checklist

Relevant to all regions, but especially Regions 2 and 4.

Site strategies: → **Jump to Chapters 4 and 5**

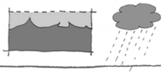
- Has specialist advice been obtained before removing or adding trees near existing buildings? Is there an increased foundation depth near trees?
- Has landscaping/planting been used that contains a mix of drought-tolerant species as well as native, water-loving species?
- Pressure on water resources: are you collecting water locally and reusing it for landscaping?

Building strategies: → **Jump to Chapter 5**

- Has allowance been made for larger roof rainwater collectors to irrigate landscape for longer periods of time?
- Have low-flow taps/shower heads, low-flush toilets and low-volume baths been specified? After prioritising water-efficiency, have you considered simple, cost-effective and low-energy use rainwater and grey water harvesting systems?
- Has thought been given to the foundation pressures for existing buildings, which may be at risk of subsidence? (Pre-1970 dwellings with foundations of 450 mm or less depth are at particularly high risk of heave/subsidence which will become more pronounced with a changing climate.)
- Has allowance been made for deeper foundations (+0.5 m depth) for new buildings, particularly on clay soils, especially in Region 4, which is mostly clay? Scotland/Region 1 is least affected by subsidence.

During construction:

- Has thought been given to the issue of water shortage during construction, which may affect landscaping schemes and prevent plants from taking root and surviving?



2.3.4 Increased flood risk from sea and rivers: design checklist

Relevant to all coastal regions, especially eastern coasts in UK and cities along river mouths.

Site strategies: → **Jump to Chapter 5**

- Is the site in a high flood risk zone? If so, avoid development.
- Has the Environment Agency been consulted about the flood risk designation?
- Have you responded with strategic planning, such as zoning of functions and programme?
- Is there enough site-wide water retention for sustainable urban drainage systems (SUDS) so that we work with water rather than against it?
- Are there strategic escape routes to safe higher ground?

Building strategies: → **Jump to Chapter 5**

- Do you need flood-proof building features such as sacrificial basements, elevated ground, stilts or floating structures?
- Have services and infrastructure been located on upper floors, where appropriate, and have you used robust materials on the lower floors?

During construction:

As Section 2.3.5

2.3.5 Increased winter rainfall and increase in extreme weather events: design checklist

Relevant to all regions. Wind-driven rain: Scotland and western UK.

Site strategies: → **Jump to Chapters 3, 4 and 5**

- Can wind buffers be created by use of vegetation and building location?
- Have large-scale SUDS, permeable paving and water retention been used on site to prevent localised flooding? (Increased local water retention is required on clay soils owing to higher risk of flash floods.)
- To avoid slope instabilities, is there increased vegetation, particularly on clay soils, as roots protect slopes and absorb water? Do measures include reduced slope angles, the construction of retention or stability measures and additional drainage?
- Is there a tree maintenance plan to contain growth?

Building strategies: → **Jump to Chapters 5 and 7**

Roofs

- Are all roof pitches >25°? Have roof penetrations and flush rooflights been minimised? Does the design include large roof overhangs and increased fixing density for roof tiles/slates?
- Has the gutter capacity and/or the number of pipes and outlets been increased? Has the use of internal gutters been avoided? Have flat roof upstands been increased and have they been fully waterproofed with flexible materials?
- Has rainwater harvesting for summer landscaping been employed?

Structure

- Has the design allowed for increased wind pressure, especially above 10 storeys? The design loads may increase by 10%, so have foundations and core walls been increased suffciently? ☐
- Have cladding systems been designed to stiffen in increased wind pressure? ☐
- Has the decrease in snowfall, particularly in Regions 1 and 2, been taken into account? ☐
- Does the design use robust materials, especially on ground and lower floors, including concrete foundations? ☐
- Has heave been taken into account for existing buildings (pre-1970 dwellings with foundations of 450 mm or less depth particularly), and are deeper foundations (+0.5 m depth) provided for new buildings? (Scotland is least affected by subsidence/heave.) ☐

Windows and walls

- Has attention been given to avoiding water penetration at weak points and junctions, particularly windows and doors? Have you avoided externally flush windows and allowed for recessing of all windows with overhanging window sills and providing porches or overhangs to doors? (Windows, doors and rendered surfaces will suffer more than in other EU countries owing to wind-driven rain.) ☐
- Has the design avoided full-fill cavity walls with organic insulation or insulation which performs badly when wet? (Check NHBC and building regulations approval, particularly in Scotland.) ☐
- Have shutters and other external fixings been designed to avoid cracks and movement joints which may allow wind-driven rain into the fabric? ☐
- Does the design specify lower-movement materials such as light-coloured/reflective surfaces and hardwood in preference to softwood cladding, to minimise the risk of cracking? ☐
- Since higher relative humidity means potential for mould growth, particularly where ill-heated/ventilated, have thermal bridges been avoided? ☐

During construction:

- As working at heights may become difficult or unsafe, has the use of cranes in exposed areas been minimised? ☐
- Has the safety of scaffolding been reviewed, and has water protection for construction elements been provided? ☐
- Has careful consideration been given to the storage of materials to cope with the increased risk of flooding on site and to avoid mould growth by protecting building site/organic materials, etc. from damp? ☐
- Has the moving of activities away from the site been considered, e.g. prefabrication in a controlled environment? ☐
- Have plans been made to cope with possible site delays/disruption? ☐
- Does the design deliver construction watertightness as soon as possible? ☐
- Has the winter wet season been avoided for certain trades, such as groundworks, foundation, curing of concrete and other wet trades such as rammed earth? ☐

2.4 FURTHER READING

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- Welsh Assembly www.wales.gov.uk/climatechange
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