Risks to health, wellbeing and productivity from overheating in buildings

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Climate Change Committee

Contents

Executive Summary

As the UK's climate changes in the coming decades, periods of high temperature will become more common and more intense. As recent heatwaves have demonstrated, high temperatures are a dangerous threat to health and wellbeing and reduce economic productivity. Tackling this risk is one of the highest priorities for an effective response to climate change in the UK. This briefing summarises the evidence base on the impacts of current and future extreme temperatures in the UK and the adaptation actions that can help address these risks within buildings.

The key conclusions are:

- **Impacts from periods of high temperature are already being felt in the UK today.** There is a robust evidence base linking increased temperature to health impacts and reduced productivity, including impacts on key services such as healthcare and education. Increases in temperature have been linked with an increase in the death rate (particularly amongst older people) across the UK, including in recent heatwaves in every year from 2018 to 2021. Recent estimates suggest that around a fifth of homes in the UK are already overheating in summers today.

- **Increasingly hot summers could lead to a trebling of health and productivity impacts without additional adaptation.** Climate projections suggest that a 'hot' summer such as 2018 will become the average summer by 2050, even with deep cuts in global greenhouse gas emissions. The combination of increasing hot weather, and an ageing population, means that heat-related deaths may treble without further adaptation actions.

- **There are multiple effective strategies to help limit the health, wellbeing and productivity impacts of overheating which can be implemented today.** Buildings can be kept cool during hot weather either through passive building design or energy-intensive methods to control internal temperatures such as air conditioning (which exacerbate urban temperatures and increase emissions). Urban design incorporating vegetation and water can also help reduce outdoor air temperatures. Effective heatwave response plans are also needed to limit the consequences of heat waves when they do occur. Proactive action is needed now across all these fronts to minimise impacts from overheating.

- **Government has a critical role in encouraging proactive adaptation to limit overheating health and wellbeing impacts.** A vision for a well-adapted UK building stock, backed up with clear and quantitative targets, is needed to drive action across the UK and join up adaptation action with plans to decarbonise buildings. Government should build on recent policy to limit overheating in new homes by implementing corresponding policies to require action in the rest of the stock. Information provision, appropriate inspection and enforcement as well as access to finance are needed to enable this.

This briefing is focused on overheating in buildings; it is set out in two sections:

1. Overheating risks to health, wellbeing and productivity

2. Ensuring buildings are fit for the future climate

1. Overheating risks to health, wellbeing and productivity

Periods of high temperatures can pose a significant threat to people's health and wellbeing. This section describes the risks to health, wellbeing and productivity from high temperatures today and in the future.

It is structured in three sub-sections:

(a) Overheating in the UK today

(b) Overheating impacts on health, wellbeing and productivity

(c) Future overheating impacts without adaptation action

(a) Overheating in the UK today

The UK has already experienced significant changes to its climate in recent years due to human-induced global temperature rise. For the UK as a whole, summers as hot as in 2018 (the joint warmest summer on record) are currently expected to occur in up to 20% of years, whereas they would be expected in less than 10% of years only a few decades ago.[1] The UK's average temperature has risen by around 0.3°C per decade since the 1980s and is expected to continue rising.[2] Further changes in the UK's climate are inevitable until the middle of the century, including increasingly intense and frequent heatwaves, even if the world succeeds in rapidly reducing global greenhouse gas (GHG) emissions.

These increasingly frequent and extreme high temperatures are felt by people primarily via their impact on internal building temperature, as people in the UK spend a very large fraction of their time inside.[3]

The location, level of urbanisation, building type and occupant behaviour all affect the extent of overheating in buildings.

Many buildings in the UK's varied building stock were not built to cope with the high temperatures that parts of the UK already experience (Box 1).[*] The location, level of urbanisation, building type and occupant behaviour all affect whether individual buildings overheat during warm weather:

- **Location**: Overheating risks are present throughout the UK, however more frequent and more intense high temperature extremes are reached in the south of England and London. According to the latest UK climate projections, there is currently a 5% chance annually of reaching a maximum temperature of at least 35.4°C in London, 33.5°C in Southampton and 29.6°C in Glasgow.[4]

- **Urbanisation:** Cities tend to be at greater risk of overheating due to the 'urban heat island' effect. Urban heat islands (UHIs) occur where cities experience higher temperatures than surrounding areas (particularly at night), as heat is retained by the built environment and additional waste heat is produced by activities such as transport. Research shows that major UK cities, such as Manchester and Birmingham have experienced peak

[*] A UK heatwave threshold is met when a location records a period of at least three consecutive days with daily maximum temperatures meeting or exceeding the heatwave temperature threshold. The threshold varies by UK county.

temperatures up to 5°C warmer than their surrounding areas within the past two decades.[5] A UHI effect of 7°C has been recorded in London.[6]

- **Building type:** Some building types, such as flats, tend to have an increased risk of overheating and there can be increased risk of overheating in some more energy efficient buildings (often newer buildings with high levels of insulation and poor ventilation).* Specific features of some buildings – such as those with large plate glass windows or converted flats from office blocks with large windows – can result in very high internal temperatures due to solar gains in summer. A study in 2018 found maximum internal temperatures of almost 50°C in a London office building converted to apartments, when they had no shading.[7]

- **Occupant behaviour**: The way buildings are used has an impact on whether they overheat in hot weather. For example, opening windows at night and closing blinds or curtains during the day can help avoid sustained high internal temperatures. However, there are factors that can limit the ability of people to manage temperatures appropriately including pollution, noise, building design and safety with one study suggesting around 70% of people opened only one or two windows at night in London for security reasons.[8]

Overheating homes are an important contributor to overall overheating impacts in the UK due to the extended periods of time that people spend there, particularly overnight. Across the stock, estimates from monitoring data indicate that roughly a fifth of English houses are already overheating during summers today (Box 2).† [9]

Box 1
Defining overheating

Overheating within buildings occurs when people begin to feel uncomfortable due to high internal temperatures. Two main approaches can be used to assess the extent of overheating based on measured temperatures: the static and adaptive approaches. The below descriptions are taken from the CIBSE standard methodology for assessing overheating, TM59:[10]

- **The static approach** uses a fixed temperature threshold and states the number of hours of exceedance of this threshold that is deemed to constitute overheating. Using the static approach for bedrooms, a building is classified as overheated if more than 32 hours of night-time temperatures (between 22:00 and 7:00) in a year are greater than 26°C.
- **The adaptive approach** recognises that people adapt to warmer temperatures, both psychologically and physiologically. The adaptive temperature threshold increases as the average temperature rises. According to the adaptive definition, overheating occurs in a room if there are more than 3% of occupied hours during May to September in which the temperature was 1°C or more over the adaptive thermal comfort threshold.

The adaptive approach is increasingly seen as a more credible method of assessing overheating and has been widely used for assessing overheating in living spaces based on measurement.

* Not all more energy efficient buildings have greater overheating risk. Energy efficiency, if well installed, will also reduce the risk of overheating by keeping out hot air.

† The results are the percentage of homes where main bedrooms are overheated using the adaptive criterion from TM 59.

Box 2
Measured and perceived overheating in UK homes

The Energy Follow Up Survey (EFUS)[11] and the English Housing Survey provide key sources of evidence on the extent of overheating in UK buildings today. The surveys are part of the government's efforts to develop an understanding of energy use within households across the UK. These datasets include half-hourly temperature measurements from 750 homes between autumn 2017 and spring 2019, and a survey of over 2,600 households.

Measured data found that around one-fifth of homes were overheating under summer weather conditions today. Key factors identified from these studies that affected measured overheating risk were:

- **Dwelling type:** In flats, 30% of the living rooms were overheated compared with 12% in houses. The prevalence of overheating in the bedrooms of flats (17%) was not significantly different from that in houses (19%).
- **Floor area:** In dwellings with a floor area <50m^2, 35% of living rooms were overheated compared with 7% to 16% in larger dwellings. There were no significant differences seen for main bedrooms.
- **Region:** The prevalence of overheating in living rooms and bedrooms was significantly higher in the London region compared with all other regions.
- **Energy efficiency**: There was some evidence to suggest that the prevalence of overheating in living rooms was greater in dwellings with an EPC rating of A to C (15%) compared with dwellings with EPC D or below (10%).
- **Occupancy:** Overheating in living rooms was more common in households with a pensioner present (24%) than in those without (11%). Households in the lowest two income quintiles had a higher prevalence of overheating in the living room (24% and 21%) compared with those in the highest income quintile (5%). Households with no-one in employment had a higher prevalence of overheating in the living room (24%) compared to those without (11%).
- **Tenure:** Households in the social sector had a higher prevalence of overheating, both in the living room and in the main bedroom (26% and 29% respectively) compared with households in the private sector (13% and 17%)

The survey results of occupants' perception of comfort were similar to the measured results above. 11% of households (equivalent to 2.5 million) reported living rooms that were uncomfortably warm 'often' or 'all the time' and 17% of households (3.8 million) reported their main bedroom was uncomfortably warm 'often' or 'all the time'. The most common factors reported as the cause for overheating in both living rooms and bedrooms were those relating to the external weather and the building fabric/sunlight; while around one-fifth of households reported that internal heat gains or lack of ventilation were the causes.

Source: BEIS (2021) *Energy Follow Up Survey.*

Overheating in other non-residential buildings such as hospitals, care homes and schools has impacts on particularly vulnerable people.

Overheating is also regularly documented in other building types such as hospitals, care homes and schools occupied by some of the most vulnerable people to heat-health impacts, but data on the full extent remains patchy.

- In hospitals, there were 3,600 recorded instances of overheating in 2019-20. 90% of hospital wards in the UK are estimated to be at risk of overheating.[*12,13] There is also increasing evidence of overheating in care settings.[14]
- A HM Inspectorate of Prisons' report included concerns from inmates during inspections which included difficulty of breathing, the heating in cells being continuously on, high ambient temperatures in cells and limited oxygen

[*] Overheating is defined as occurring where the daily maximum temperature exceeded 26˚Cin a ward or clinical area.

from poor ventilation.[15] Inmates in prisons have little capacity to adapt to increased indoor temperatures.

- A survey of teachers found that 90% reported taking additional measures to reduce classroom temperature, including purchasing portable air conditioners.[16] Schools in London have also reported that concentration levels of children had been affected due to high temperatures in recent years, with the annual period for public examinations being one of the hottest parts of the year.[17]

Overheating in workplaces has clear links to detrimental productivity impacts (discussed further in next sub-section), but a full picture of overheating in UK workplaces is not known.

(b) Overheating impacts on health, wellbeing and productivity

High temperatures cause a range of negative health impacts in addition to discomfort.

(i) Health and wellbeing impacts

Exposure to extended periods of high temperature can cause a range of direct and indirect health impacts in addition to discomfort. In turn, these can have knock-on consequences on wellbeing and workplace productivity.

- **Heat stress:** The Health and Safety Executive (HSE) defines heat stress as occurring "when the body's means of controlling its internal temperature starts to fail". Heat stress results in core body temperature rising and increasing heart rate which can lead to heat exhaustion or heat stroke. The temperatures above which heat stress occurs vary, but studies suggest it can occur from a wet-bulb globe temperature of 26°C and upwards.*[18]

- **Maternal health:** High temperatures can adversely affect the health of pregnant women, particularly increasing the risk of preterm birth.

- **Mental health**: High temperatures can worsen mental health symptoms. There is clear evidence of a relationship between higher temperatures and increased suicides.[19]

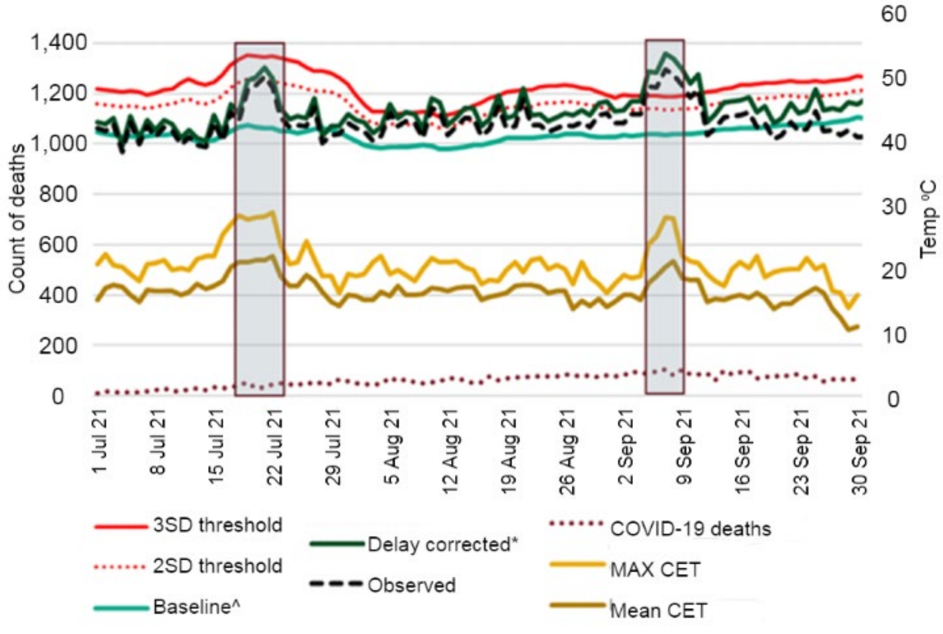
- **Unintentional injury and accidents:** There is good evidence that high temperatures can increase the risk of injury, particularly in children. A literature review found that, on days with moderate temperatures, the increased injury risk varied between 0.4% and 5.3% for every 1°C increase in temperature.[20]

For the most vulnerable, high temperatures can lead to death. There was significant excess mortality during each of the heatwave periods from 2018 to 2021.

For the most vulnerable people, high temperatures can lead to death. There is a robust link between increases in the number of recorded daily deaths and high temperatures, particularly for those who are vulnerable, such as the elderly (Figure 1).[21] Typically around 2,000 heat-related deaths already occur per year in the UK, although with significant year-to-year variability. These heat-related deaths occur both during heatwave periods and outside of them, with increases in death rates detectable from 21.7°C in the northwest of England and from 24.7°C in London (i.e. lower than the thresholds to trigger heat-wave alerts).[22] Most heat-related deaths occurred in elderly (65+) age groups, however other groups such as the young and those with existing health conditions are also at risk during a heatwave.[23]

* Wet-bulb globe temperature is a measure of apparent temperature which includes temperature, humidity, wind speed and solar radiation from the sun to reflect the temperature as it is perceived.

Figure 1 All-cause excess mortality in 65+ age group during Heat-Health alerting period 2021



Source: PHE (2022) *Heat mortality monitoring report.*
Notes: Heatwave periods are denoted by the grey boxes. The figure shows spikes of excess mortality occurring during heatwave events. CET stands for Central England Temperature. 2SD denotes two standard deviations above the baseline.

(ii) Economic and productivity impacts

The current total economic costs of heat-related mortality are estimated to be £260 – £330 million per year, not including the costs of heat-related illness.

The economic cost of heat related mortality and health impacts is significant. Analysis undertaken for the UK Climate Change Risk Assessment estimated the economic value of the increase in heat-related fatalities in the UK presently and under different future climate scenarios. The current total economic costs of heat-related mortality are estimated to be between £260 million - £300 million per year, not including the costs of heat-related illness, and could rise to between £720 million - £950 million per year by the 2050s under a 2°C global warming level, using conservative estimates.*[24]

Overheating can affect both the productivity of workers and the educational attainment of students, which in turn can affect their lifetime earnings.

Overheating can affect the productivity of workers and the educational attainment of students, both directly impacting productivity through discomfort and heat stress in the workplace or educational facilities, and indirectly through sleep disruption associated with domestic overheating.

- **Direct effect of overheating on productivity**. Heat and humidity impact employee productivity in the workplace. Heat typically leads to a reduction in work intensity or an increase in breaks.[25] Workers in some occupations, for example heavy outdoor manual labour, are likely to be at the greatest risk of heat stress.

* This analysis uses 'Value of a Life Year (VOLY)' estimates for the value of mortality, rather than a Value of a Prevented Fatality (VPF) approach. Similar analysis using a VPF approach results in a much greater estimate of £4 billion per year. All the numbers presented include a 2% annual uplift to reflect that the willingness to pay for better health rises with GDP per capita growth.

- A study focused on the US found that average productivity in the US on individual days declines roughly 1.7% for each 1°C (1.8°F) increase in daily average temperature above 15°C.[26] Another study has found that in a typical year, annual heat-related losses amount to more than 0.5% of economic activity in more than half of US counties. Whilst losses are proportionally largest in sectors such as agriculture and construction where outdoor work is prevalent, they had greatest absolute magnitude in services, the sector with the highest economic value.[27]

- This pattern could be similar in the UK. Despite a limited UK-specific evidence base, one study suggests that a 2°C warming trajectory could cost around 0.4% of economic output for London in a warm year due to a reduction in productivity.[*28]

Exposure to heat inhibits cognitive skill development in students. Research has shown that hotter school days prior to tests has resulted in lower test outcomes.

- **Direct effect of overheating on educational attainment.** Exposure to heat inhibits cognitive skill development in students. Research has shown that hotter school days prior to tests have resulted in lower test outcomes.

  - One study found that without air conditioning, each 0.6°C increase in school year temperature reduces the amount learned that year by one percent.[29] A separate study found that taking an exam on a 32°C day leads to around an 10% lower likelihood of passing compared to a 22°C day.[30]

  - Research by the Department for Education found that the average increase in earnings of a one grade improvement in a GSCE exam is £8,600 per student.[31] Over 600,000 students sat 4.8 million GSCE exams in 2021, implying a potentially large reduction in lifetime earnings due to students being exposed to high temperatures and underperforming.[†32]

- **Indirect effect of overheating.** Overheating can impair sleep quality and quantity which has consequential impacts on productivity through reduced concentration and alertness, general cognitive performance decreases or other means.[33] Overheating was found to reduce good sleep by one or two hours (or cause an equivalent reduction in sleep quality), although considerable variation across the population is expected.[34]

  - One study estimated that relative to sleeping 7-9 hours, 'productivity loss' was estimated to be 3.7 working days per year if sleeping 6-7 hours and 6.0 working days if sleeping <6 hours.[35] Recent analysis by the Department for Levelling Up, Housing and Communities (DLUHC) found the economic cost of productivity losses due to sleep disruption in England in all new-build homes built in one year was £8.4m per year.[36] The equivalent number for existing homes would be potentially significantly greater.[‡37,38]

* The study compared the impact of high temperatures on productivity in London, Bilbao and Antwerp. London was found to have a small relative drop in productivity compared to the other sectors, due to the nature of its economy being oriented towards services.

† Due to the Covid-19 pandemic, students did not sit exams in person in 2021. The figures represented here are an indication of how many students sit GSCE exams in one year.

‡ There are 24.9 million homes in England, while the rate of building new homes is just under 200,000 per year.

A shift to home-based working may also exacerbate the risk of overheating within homes. This behavioural shift could lengthen the time that people are exposed to high temperatures indoors and negatively impact the productivity of homeworkers (Box 3).

Box 3
Impact of COVID-19 pandemic on overheating risks

There has been a shift to home-based working since the COVID-19 pandemic for certain occupations. It is too early to be certain of how common home working will be in the long-term future, but recent surveys suggest that both businesses and workers expect longer-term higher levels of hybrid working after the pandemic.[39]

More common and frequent home-based working will affect the productivity of home workers during periods of high temperatures.

- Some factors may exacerbate the productivity impact of overheating, such as having to take time to manage the indoor environment. Office buildings are also more likely to have air conditioning to moderate indoor air temperatures than homes are.
- Other factors may reduce the impact of overheating for home-workers, due to them having increased flexibility to choose a cooler location – or time of day - to work. or homeworkers having increased flexibility to wear lighter, cooler, clothes whilst working.

Over coming years, the long-term persistence of shifts to more homeworking will become clearer, enabling a better understanding of the relative importance of home and office overheating for productivity impacts.

(c) Future overheating impacts without adaptation action

Future climate changes, an increasingly elderly population, and the nature of the UK building stock will all contribute to increasing levels of overheating risk in the UK without additional adaptation.

- **Climate change.** All regions in the UK will experience more frequent and severe extreme daily high temperatures (Figure 2). The UK's latest climate projections (UKCP18) estimate that a "hot" summer such as 2018 has historically had an annual probability of around 10%, but this will increase to 50% by mid-century irrespective of the emissions scenario. Currently there is only a very small chance of exceeding 40°C in the UK, but by 2080, under a high-emissions global warming scenario, the frequency of exceeding 40°C would be similar to the frequency of exceeding 32°C currently.*[40] Night-time urban heat island effects are expected to be more intense, leading to more 'tropical nights' in major cities. These increases in night-time temperatures will lead to sleep disruption and knock-on impacts on productivity.[41]

There are currently 12.5 million people in the UK aged 65 years or older, this is anticipated to rise to 17.9 million by 2050.

- **Ageing population.** The UK has an aging population – leading to an increase in the number and proportion of people vulnerable to significant heat-related impacts (Figure 3). There are currently 12.5 million people in the UK aged 65 years or older,† this is anticipated to rise to 17.9 million by 2050.[42]

* A new UK record for maximum daily temperature of 40.3°C was set during a brief but exceptional heatwave in July 2022. This is record is provisional at time of writing.

† The 'current' figure is the number of people aged over 65 in 2020, as the ONS population projections are '2020-based' the 2022 value in the latest statistics is a projection.

Greater numbers of older people will require care in the future (projected to reach 70,000 by 2025 and 190,000 by 2035 in England only).[43] This ageing population means that inadequate heat management in new and existing care homes, and care in the home could lock-in large numbers of people to heat risks. People in care homes can be more vulnerable to climate impacts as they have less ability to control the temperatures of their environment.[44]

The vast majority of the houses that will exist in 2050 have already been built.

- **Building stock.** By 2039 the Government expects the number of households in the UK to increase from 28 million currently to 31 million, with further increases expected thereafter.[45] Despite Government targets to increase house building rates, most of the homes that will exist in 2050 have already been built. This means that without significant retrofitting of existing houses to reduce overheating risks, the hotter summers expected in future will lead to an increase in the fraction of UK houses overheating, beyond the 20% level today.

- **Societal changes.** Broader societal changes could combine with these trends to influence overheating risks. For example, a shift towards home-based care would increase the importance of internal temperatures in the home for heat-related impacts, and the recent shift to home-working due to the COVID-19 pandemic (if maintained in the long-term) could also increase the importance of overheating in homes for overall worker productivity (also discussed in Box 3).*

Without additional adaptation actions the combination of climate and demographic changes are expected to lead to large increases in heat-health risks in the UK.

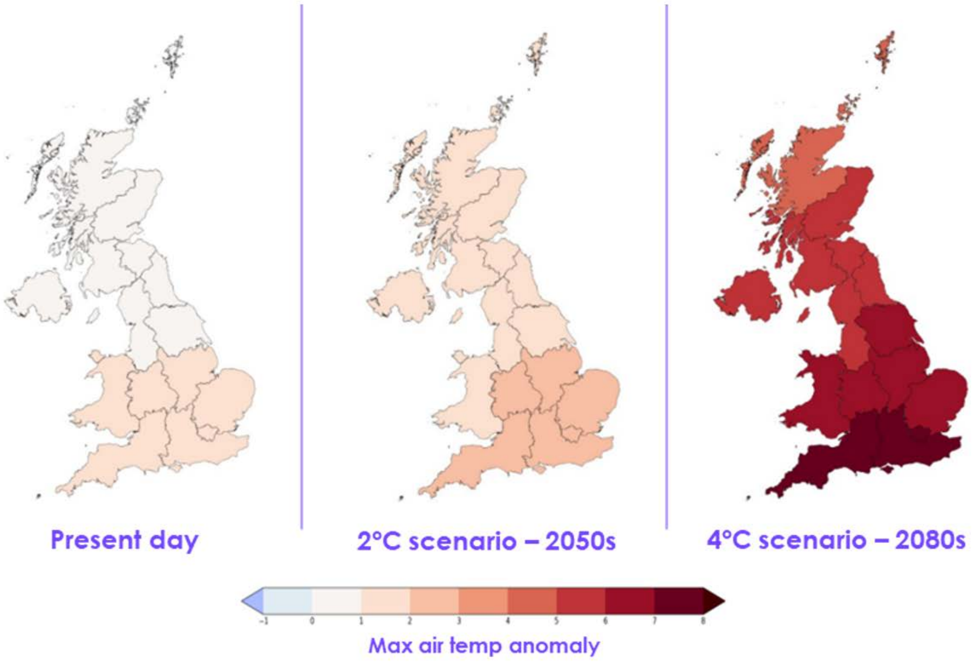
Without additional adaptation actions the combination of climate and demographic changes described above are expected to lead to large increases in heat-related health risks in the UK. Research on heat-related mortality carried out in 2014 projected fatalities rising from 2,000 per year historically, to potentially more than triple to 7,000 per year by the 2050s if population and age distribution changes are considered.†[46]

The spatial variations in all the aspects that contribute to overheating risk mean that future heat-related risks will themselves not be evenly distributed across the UK (Figure 4).[47] Hotspots for the greatest future risk due to the combination of climate hazard and vulnerability can be seen in London and along England's south and east coasts, although risks will increase for all locations.

* According to survey evidence, by the start of 2022, the percentage of people who are working from home is similar to pre-pandemic levels. However, it isn't clear whether there are now more people working from home on average during any given day.

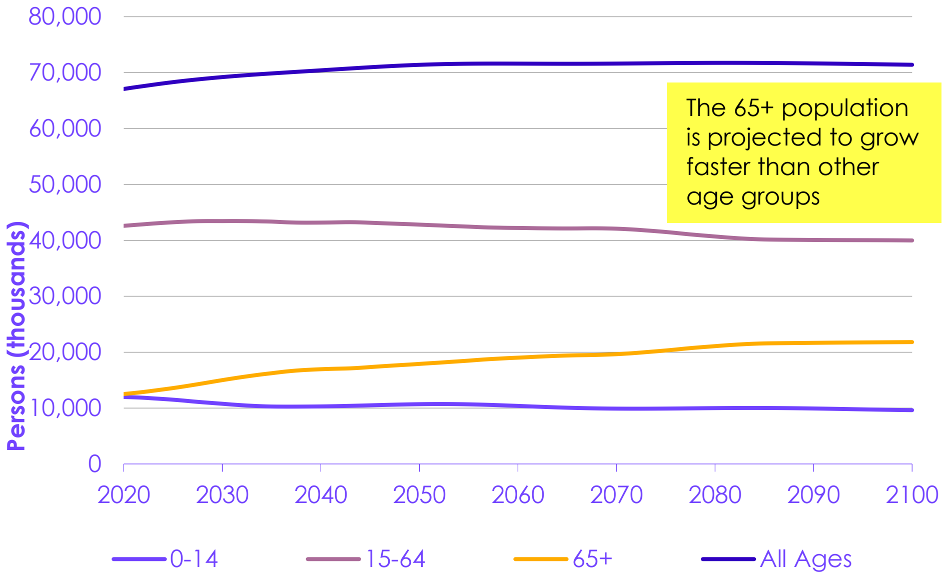
† These estimates may be an underestimation of future impacts considering the higher temperatures projected in the latest set of UK climate projections published in 2018. They may also not fully capture future extreme temperature impacts or urban heat island effects, which might increase these impacts. However, they also do not include the effects of natural acclimatisation or existing adaptation policy, which could reduce impacts.

Figure 2 Change in maximum summer air temperature from 1981 - 2000 baseline



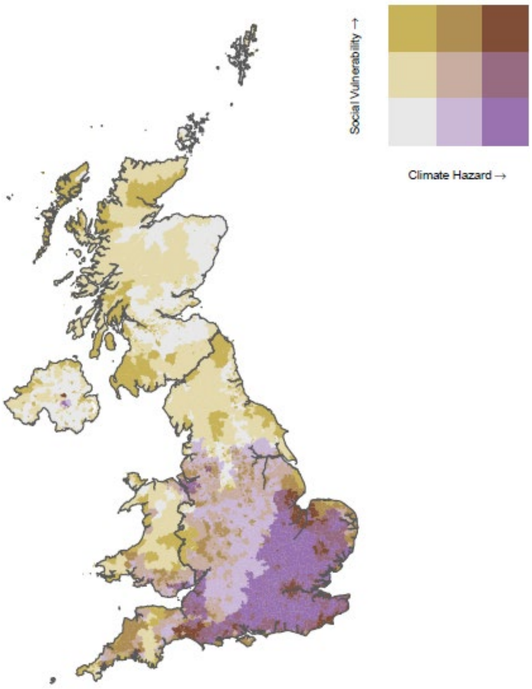
Source: Met Office (2018) *UKCP18 projections.*
Notes: Probabilistic projections for the 1-year average change in summer maximum air temperature from 1981-2000 baseline for 2021, 2050 (RCP2.6 50th percentile) and 2080 (RCP6.0 90th percentile)

Figure 3 Population projections for United Kingdom, by age group



Source: ONS (2022) *UK population by age groups.*

Figure 4 Vulnerability to future heat stress impacts



Source: Kennedy-Asser et al (2022)
Note: The map shows the level of heat health risks in 2050 under a 3°C warming climate scenario.

Good buildings are comfortable and healthy places to be in. This means warm in the winter, cool in the summer – with good natural light, fresh air, and protected from climate impacts such as flooding and overheating. Similarly for our places of work, our hospitals and care homes, our schools and other public buildings.

The previous section describes the current scale of overheating health impacts in the UK and how without additional adaptation action these risks will increase in the future. This section summarises the options available to ensure that new and existing buildings in the UK are fit for future climate and the role for Government and other organisations in achieving this. It is structured in three sub-sections:

(a) Adaptation options to limit heat-related impacts

(b) Roles and responsibilities for Government

(c) Recommendations

(a) Adaptation options to limit heat-related impacts

Strategies for addressing heat-related impacts can be grouped into four categories. These include anticipatory adaptation actions to reduce the exposure and vulnerability of the population to overheating in buildings, and actions to put in place effective emergency plans which can function well to minimise impacts in periods of hot weather.

- **Cooler buildings**. New buildings can be designed from the outset to reduce the risk of overheating in future climate conditions, and existing buildings can be retrofitted with, for example, shading, ventilation and cooling measures where necessary.
- **Behavioural change**. Building occupants can manage buildings (e.g., timing of opening and shutting of windows or shading) to help limit internal temperatures during hot weather. Changing daily routines, such as avoiding work during the hottest hours of the day, can also limit heat-related health impacts.
- **Urban cooling**. Urban design choices (e.g. on-street natural shading, green space and blue and green infrastructure) can help reduce outdoor temperatures in urban areas in periods of high temperature.
- **Emergency responses.** During periods of hot weather, public agencies (e.g., health and local authorities) need effective plans which can help protect the most vulnerable in society and limit disruption to critical systems.

Different adaptation strategies will need to be used in tandem to effectively respond to this climate risk.

All these actions will be needed to minimise the impacts of increasing temperatures. The following sub-section describes each of these strategies in turn.

(i) Cooler buildings

Approaches to cooling buildings can be split into two categories:

- **Passive cooling** uses aspects of building design to regulate internal temperatures (e.g. by creating shading or providing ventilation, particularly 'through' ventilation).

- **Active (or mechanical) cooling** methods use energy to keep internal temperatures low either by operating mechanical ventilation systems which circulate air or air conditioning which uses electricity and a refrigerant cycle to cool down buildings. Active cooling will require a continual input of energy to operate.

Passive cooling measures do not add waste heat to the environment, avoid contributing to urban heat island effects and do not increase home energy use.

Table 1 summarises the main passive and active cooling options available to help keep buildings cool. Unlike active measures, passive cooling measures do not add waste heat to the environment, avoid contributing to urban heat island effects and do not increase home energy use. However, the cooling potential of passive measures is fundamentally limited by the temperature of the outdoor environment. During intense and prolonged heatwaves, passive measures may be unable to reduce indoor temperatures to comfortable levels and active cooling may be necessary in parts of the country, especially cities experiencing large urban heat island effects in the Southeast (Box 4).

Table 1
Passive and active cooling options

Cooling approach	Description
External Shading	Provides shading for windows and outdoor areas using shutters, canopies, balconies or external blinds.
Internal Shading	Measures such as blinds or curtains provide shading internally. This is generally lower cost but is less effective than external shading.
High performance windows	Improving the glazing of windows, or using reflective coatings on windows, limits the amount of heat that is transferred through the window
Ventilation	Mechanical and natural ventilation can help to cool buildings when the outside air is cooler than the internal temperature.
Thermal Mass	Thermal mass is the ability of a material to absorb, store and release heat. High thermal mass buildings take time to change temperature so can mitigate peaks in external temperature by allowing the thermal mass to absorb the heat and dissipate it later.
Reflective	Selecting surface finishes with a high reflectivity can reduce the warming effect of solar radiation. These can be simple measures such as painting walls, roofs and paving in white or another light colour.
Green roofs/ walls	Covering roofs and walls with certain plants can cool an urban environment through evapotranspiration and cool buildings by providing shade for the surface. Green roofs and walls also have biodiversity and wider amenity benefits.
Active (mechanical) Technologies	Active technologies use electricity to reduce internal temperatures. Mechanical ventilation methods tend to circulate air to cool down buildings. Air conditioning involves lowering the temperature in a room using a compressor cycle to remove heat from an indoor space, using electricity.
Building Form	Designing the shape and layout of a building can reduce the risk of overheating by using the building form to shade key areas and facilitating the preferred ventilation strategy

Box 4
Role of air conditioning

Active cooling, such as air conditioning, uses electricity to run and expels waste heat into the environment. This waste heat can contribute to the urban heat island (UHI) effect. There is limited evidence on the size of this effect, studies suggest it can increase urban air temperature by over 1°C.[48] Active cooling will also increase electricity bills and potentially emissions depending on how the electricity is generated when it runs.

In the UK currently, active cooling is largely installed in non-residential buildings and has only low levels of uptake in residential properties. This could change as the climate warms. There is already anecdotal evidence of active cooling being installed in luxury flats and more households that are able to pay for active cooling may install it in the future. Further research is necessary to understand the likely future take-up rate of air conditioning by the public.

Evidence suggests that the installation of passive measures in a building before active cooling can significantly reduce the running costs of the active measures and lead to the lowest costs overall in tackling overheating.[49]

There are several key principles that should guide Government policy on air conditioning:

- It is lower cost for buildings to install passive cooling options first, before installing active cooling.[50] Building regulations currently support a 'passive first' approach, which should be followed in new residential buildings. The planning system should also encourage a passive first approach, an example of this is seen in the 'Cooling Hierarchy' of the London Plan.[51]
- Spatial analysis of the residential building stock will be able to determine areas of the country where properties may be likely to overheat even with passive measures and contain a population which are vulnerable to high temperatures. The installation of air conditioning could be targeted to these buildings.
- The Government should consider the impact on the electricity grid of increased air conditioning use. Spatial analysis could help to understand areas where many buildings may install active cooling, with an impact on the local electricity distribution system.

The relative costs and effectiveness of reducing overheating risk for each of the measures vary depending on whether they are being retrofitted or included at build-stage, and the type of dwelling that they will be applied to. Measures such as external wall insulation and thermal mass tend to be relatively more expensive but have a relatively greater impact on overheating compared to less costly measures such as forms of internal shading.[52]

(ii) Behavioural changes

The way that people behave during spells of hot weather can significantly impact how comfortable they are in their homes.

The way that people behave during spells of hot weather can significantly impact how comfortable they are in their homes. Public health activities which raise awareness regarding appropriate occupant behaviour (such as closing curtains during the day to limit solar gains) are an effective, low-cost adaptation option to address overheating. The current Heatwave Action Plan aims to provide this and contains many simple messages that advise people how to stay healthy during hot weather, such as staying hydrated and avoiding the hottest times of the day.

Additionally, there are behavioural strategies to limit the negative impacts of heat on productivity either in the workplace or in educational settings. Changing hours of work to avoid physical exertion during the hottest hours of the day is an example of this, as is ensuring that outdoor workers are provided with shaded spaces to take breaks.

Within educational settings, behavioural changes could include moving exam timetables to avoid the hottest point in the day. Workplaces and schools may also consider having access to communal ‘cool spaces’ where people can escape high temperatures.

The UK could learn from other countries with more experience of adapting behaviours in workplaces and educational facilities to cope with higher temperatures.

Urban cooling measures have the potential to reduce urban heat island effects and to moderate outdoor temperatures.

(iii) Urban cooling

Reducing outdoor temperatures in urban areas can help limit both on-street temperatures and internal temperatures in buildings. Urban cooling measures, such as enhancing green space (creating shading and evapotranspiration) or making building specific modifications, have the potential to reduce urban heat island effects and moderate outdoor temperatures.

Many different types of urban cooling measures exist.

- **Green and blue Infrastructure**. This includes the network of urban trees and woodlands, private and public greenspaces as well as vegetated areas around water bodies. Increasing tree and vegetation cover can lower outdoor temperatures by providing shade from the canopy cover, and cooling through evapotranspiration.[*] Green infrastructure can also simultaneously help mitigate flooding risk.

- **Green roofs.** A vegetative layer on a rooftop reduces temperature of the roof surface and surrounding air by providing shade and evapotranspiration. Green roofs can also store rainwater, thus mitigating flood risk.

- **Cool roofs/ pavements.** Cool roofs – made of materials or coatings that significantly reflect sunlight and heat away from a building – reduce roof temperatures, increase the comfort of occupants, and lower energy demand. Similar materials can be used to construct pavements which cool their surface and the surrounding air. A simulation study of cool roofs in the West Midlands estimated that the introduction of cool roofs reduced population-weighted temperature by 0.3°C and could potentially offset 25% of heat-related mortality due to the urban heat island effect during heatwaves.[53] As well as benefitting individual buildings, cool roofs also reduce outdoor temperatures locally.

Recent studies have shown the benefits of urban cooling. A modelling study in Vienna found that well-designed blue and green infrastructure can reduce air temperatures by up to 1°C.[†54] There are numerous examples of well-designed urban cooling in the UK which brings multiple environmental benefits (Box 6).

[*] Evapotranspiration is a process whereby some of the energy absorbed by plants evaporates water within their leaves, cooling them and the air surrounding them.

[†] The GLA estimated that within four areas of Central London, there was the potential to save 19,200 MWh of energy and store 80,000m^3 of rainwater.

Box 6
Example of cooling urban design

Kent County Council is undertaking an innovative programme of work in Margate to reduce the risk of flooding and heat stress in an area which is susceptible to both. The project has included the installation of sustainable drainage systems to manage water flow along the road, alongside conventional tree planting which provides canopy cover and mitigates against heat stress. The project was funded by EU Interreg funding and the Defra Urban Tree Challenge Fund.

The new landscaping in the park provides multiple benefits – as well as flood and temperature mitigation it provides a more attractive environment and a network of footpaths. The project has engaged with the Isle of Thanet Tree and Woodland Initiative to include over 40 trees within the park which will be planted by the local community group.

The project shows that local authorities can deliver projects which make a difference. However, they need funding support. The project has demonstrated the importance of involving a range of local stakeholders in delivering a successful project.

(iv) Emergency response

Heatwave emergency action plans describe how key bodies should prepare for a heatwave and behave during one.

Heatwaves can put pressure on health and social systems through their impact on vulnerable people – advanced planning is needed by these agencies to respond to these situations. Heatwave emergency action plans have been in place in England since 2004 and describe how key bodies should prepare for a heatwave and behave during one, with a heatwave alert triggering a series of actions by different organisations (GP surgeries, social care, hospitals, local authorities & national agencies) and individuals, as well as awareness raising with the public.

The England Heatwave Action Plan is currently being combined with the cold weather action plan into a Single Adverse Weather plan, which is due to be published in late 2022. For this plan to be effective it is critical that these response strategies are regularly updated, with sufficient resourcing and training for staff to allow them to be carried out effectively when required.

(b) Roles and responsibilities for Government

Government has a key role in enabling and incentivising adaptation across the UK building stock.

Implementing the actions to mitigate overheating outlined in the previous sub-section will require involvement from a broad range of organisations and people, from house occupants and private homeowners through to public agencies. Government has a key role in enabling this set of actors to manage overheating risks, by creating the right conditions.

(i) Setting out an evidence-based vision for a well-adapted UK

A vision for how heat-related risks can be minimised, backed up with clear and quantitative targets is needed to drive actions to address overheating across society.

The Government should set out a positive vision for a well-adapted building stock that is resilient to future climate impacts, backed up by quantitative targets.

- **Set out a clear vision**. The four nations of the UK should set out a positive vision for a well-adapted building stock that is resilient to future climate impacts. The vision should include a clear pathway, including quantitative targets, which sets out how buildings across the UK will be adapted to overheating risks over time. This vision should be linked to plans to decarbonise the building stock as well as to upcoming changes to the National Planning Policy Framework and will help adaptation to be integrated into all policies that impact the built environment.

- **Indicators.** The vision should be backed up by clear indicators to show how the risk of overheating in buildings is being managed. It is the role of Government to ensure these are in place. A key indicator of this risk will be annual attributed heat-related mortality, but wider indicators are also needed to build a full picture, for example, regular monitoring of indoor temperatures in vulnerable buildings and data collection on the number of homes that are well-adapted.

Developing a clear vision and set of underpinning indicators will require targeted development of the evidence base, including addressing key areas where there is limited evidence (Box 7).

Box 7
Areas of limited evidence

There are several areas that require further research to enable quantitative trajectories of indicators to be set out so progress can be tracked effectively. For many of them, there is a clear role for Government to lead the development of the evidence base as part of setting out a vision for a well-adapted UK building stock. The areas are as follows:

- **Overheating monitoring**: there should be regular monitoring of internal temperatures in samples of residential dwellings and other building types with potentially vulnerable occupants (e.g. schools, hospitals, care homes etc) to understand how the risk is varying over time and across the building stock. This will help to build data sets on the numbers of buildings that are well-adapted to current and future heat risks across the UK and the spatial variation of heat-health risk across the UK.
- **Productivity:** there is limited UK-specific evidence on the impact of overheating on productivity. A better understanding of this impact will identify effective interventions to reduce these impacts and build the case for private investment in overheating workplaces.
- **Overheating thresholds:** further research to understand at what internal temperature impacts on health begin to occur would be useful for understanding the extent of different heat-health risks. The current methodology for assessing overheating in dwellings, is more aligned to comfort rather than health impacts.

(ii) Enabling adaptation action to address overheating

Government should tackle barriers which limit the take up of adaptation actions, using existing policy frameworks.

Table 2 sets out possible ways Government policy levers can enable adaptation to overheating risks in different parts of the building stock. Table 2 identifies areas where Government has relevant powers that could be used more, while Table 3 below sets out the Committee's specific recommendations. Responsibility for these actions is dispersed across Government departments, demonstrating that coordination will be needed for an effective Government response.

More broadly, Government should tackle barriers which limit the take-up of adaptation actions in the private building stock, which include a lack of incentives to act and low awareness of the benefits of adapting to this climate risk.

Table 2
Additional roles for government in enabling adaptation action

		Regulation	Financing and funding
New buildings (BEIS, DLUHC, HMT)		Building regulations guide how new buildings are constructed, including how well they address future overheating risk.* Planning decisions reflect various criteria, which could include overheating risk. Given relevant powers, local authorities could require more stringent overheating standards in major cities and other areas of high risk or vulnerability.	Local authorities monitor and enforce compliance with building regulations – more funding may be needed to ensure compliance.
Existing Homes (BEIS/ DLUHC/ HMT/ UK Infrastructure Bank)	**Owner Occupied**	Government has various levers for homeowners that could be adapted to encourage overheating measures: information such as Energy Performance Certificates that could be extended to Green Building Passports, green mortgage requirements, stamp duty and council tax that could offer differential rates.	Government has various levers to facilitate access to finance for owners for the upfront costs of adaptation measures.
	Rented	Private rented sector regulations place various obligations on landlords, which could extend to overheating risk.	
	Social housing	The 'Decent homes standard' sets a minimum level for public housing that could include addressing overheating risks.	Grants are provided to improve energy efficiency for vulnerable households and could be extended to overheating measures.
Public Buildings (BEIS, MoJ, DfE)		Government puts various requirements on public buildings, which could include how resilient a building is to future climate. Overheating could be included in inspections of schools, care homes and prisons.	Government provides funding and finance for public buildings which could also cover overheating mitigation.
Commercial Buildings (BEIS)		Private rented sector regulations also apply to commercial landlords. Commercial buildings above a certain size are required to show information (e.g., on their energy use), which could include how resilient a building is to future climate.	Government can facilitate access to finance for owners for the upfront costs of adaptation measures.
Emergency Response (DHSC, UKHSA)		Government plans to develop and publish a Single Adverse Weather plan.	
Urban cooling (DLUHC, Defra)		Planning legislation could require urban cooling through blue and green infrastructure which increases the area of high-quality green space in urban areas.	Government has a direct role in expanding some urban greenspaces.
Research (BEIS, UKRI)			Government funds research, which is needed on overheating and adaptation strategies.

* Current building regulations require only new build homes to be built with a consideration of overheating.

The introduction of a recent overheating standard for new build homes is a significant step forward.

Progress is being made on some of these roles for Government. For example, the Cooling Hierarchy within the London Plan is an example of local government using its position as a planning authority to encourage adaptation action. Additionally, the introduction of a recent overheating standard for new build homes is a significant step forward (Box 5). However, many gaps remain, such as policy to incentivise overheating adaptation in the existing building stock and in new public and commercial buildings.

Box 8
Building regulations - Approved Document O

Approved Document O describes how to comply with the new overheating requirements of building regulations. The requirement applies only to new residential buildings and took effect on 15th June 2022. Part O of the building regulations is a significant step forward in addressing overheating in residential buildings. Compliance is based on the CIBSE TM59 definition of overheating.

The aim of the requirement is to protect the health and welfare of the occupants of a building by reducing the occurrence of high indoor temperatures. This is achieved by:

- Limiting unwanted solar gains in summer; and
- Providing an adequate means of removing excess heat from the indoor environment.

In meeting the obligations, account must be taken of the safety of an occupant and their enjoyment of the residence. The building owner must be provided with information about how the house has been designed to limit the risk of overheating, and how to use any of the building's features to limit overheating (i.e., when to use shutters or open windows).

The requirement should be extended to cover conversion of non-residential buildings into residential. Additionally, Approved Document O could be made stronger by requiring housing developers to consider overheating risk in both 2°C and 4°C warming scenarios and over a longer time horizon than the current methodology which uses weather scenarios that end in 2040.

Source: DLUHC (2022) *Approved Document O.*

There are a series of cross-cutting enabling factors that are necessary to adapt to this risk:

- **Interaction with Net Zero.** The Government must ensure that all policies for decarbonisation – such as energy efficiency retrofit - actively consider adaptation, and ensure that policies for decarbonising buildings do not inadvertently exacerbate health risks in homes. Government should explore extending existing policy frameworks and national or international standards (including those related to decarbonisation) to include adaptation to future climate risks such as overheating and flooding.

- **Skills.** Adapting the UK's building stock will require a skilled workforce to install measures effectively and a supply chain to support them. Government should consider actions such as including adaptation within the Energy Supply Chain Taskforce.

- **Public Engagement (information provision).** A crucial enabling measure to limit the health and wellbeing impacts of overheating is effective public engagement. This includes the provision of information regarding strategies to keep cool during hot weather and information about measures to cool homes.

- **Finance.** Many overheating adaptation measures require significant amounts of upfront investment. Government should consider how to help unlock private finance for homes and businesses to adapt to increasing overheating risks. For example, adaptation could be considered within the criteria for defining a green mortgage.

- **Enforcement and compliance.** Enforcement of existing policies is essential. Government must ensure that local authorities are properly funded and able to enforce standards.

(c) Recommendations

The CCC's Advice Report to Government for CCRA3 highlighted risks to health and productivity from exposure to heat in homes and other buildings as one of the top eight risks requiring urgent action from Government in the next two years.

Table 3 summarises the Committee's key recommendations for Government to tackle this risk.

Table 3
Recommendations

Dept/ Organisation	Recommendation
Cross-cutting	Ensure that adaptation is integrated into all policies regarding buildings decarbonisation.
	Create a public energy advice service to provide households with guidance on decarbonising and adapting their homes to climate change, as committed in the Energy Security Strategy. This should include an online platform including high-level trusted information and advice (including on Government schemes), a link to local providers who can undertake assessments of home energy performance, and bespoke support for households wishing to undertake more complex retrofits.
DLUHC	Expand the overheating requirement in building regulations to cover refurbishments of existing buildings and conversions of non-domestic buildings to residential.
	Give local authorities powers to allow more stringent overheating requirements in certain areas.
	Work with HMT to ensure that local authorities are properly funded to enforce building standards.
	Ensure the upcoming Planning Bill has provisions to expand urban cooling. This should include requirements on expanding blue and green infrastructure and increasing the area of green space in urban areas.
	Expand the remit of the new building safety regulator to cover climate change mitigation and adaptation, strengthened through an explicit responsibility for sustainability; and ensure it is fully equipped to monitor and enforce compliance with buildings standards.
BEIS	Update existing policies regarding the decarbonisation of buildings – such as private rented sector regulation, or regulation of owner-occupiers - to include adaptation explicitly.
	Overheating risk considered and mitigated against, if necessary, when doing energy efficiency retrofit programmes.
	Make finance available for adaptation measures. This could be via grant schemes or green finance for private owners, with public funding targeted at low-income or vulnerable households alongside energy efficiency retrofit. Include adaptation in the definition of a Green Mortgage.
	Further research to understand when overheating occurs in existing homes, including: ongoing monitoring of temperatures in the housing stock, and number of homes currently adapted.
Defra	Introduce an urban greenspace target to reverse the decline and ensure towns and cities are adapted to more frequent heatwaves in the future and that the 25-Year goals are met.
HM Treasury (and UKIB)	Work with DLUHC to ensure that local authorities are properly funded to enforce building standards.
	Make finance available to install adaptation measures. This could be via grant schemes or green finance for private owners, with public funding targeted at low-income or vulnerable households alongside energy efficiency retrofit.
DHSC	Assess health sector vulnerability to existing and future climate risks, particularly, for care homes and home-based care. Following this, develop a cross-sector approach to address risks. This cross-sector approach should include input from CQC, PHE, NHS, DLUHC and local level public health bodies.
DfE, MoJ, DHSC	Inspections of schools, prisons and hospitals to include an assessment of overheating.

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