



Keep Bristol Cool

A Framework for Urban Heat Resilience



You can request alternative formats of this document by contacting:
Ben.Smallwood@bristol.gov.uk



Foreword

Councillor Kye Dudd

The UK needs to adapt to the effects of global heating. If we take preventive action now we will reduce its impact in the future. This is crucial in cities where infrastructure was largely not built for, and therefore is not prepared for, periods of sustained hot weather, which is fast becoming the norm each summer.

Our [climate is changing](#) and will continue to do so as a result of global greenhouse gas emissions. Despite efforts to reduce emissions, the effects will have impacts

for years to come. One of the significant impacts will be rising temperatures.

Building our heat preparedness and resilience to climate change impacts is a cost-effective and essential way to protect our people, economy and environment. Many of the risks and associated actions will directly involve the role of the City council through our management of critical public infrastructure, policy and services.

We have shown steady firm leadership in climate and ecology over the years. We were the first UK Green Capital in 2015, and I'm proud that Bristol was the first local authority to declare a climate emergency, and subsequently, an ecological emergency too. The creation of Bristol City Leap this year shows that we are a city ready to take the necessary action at the scale that's needed to fight climate change.

Our One City Climate Strategy sets out a long-term strategic vision of the city's journey to reach net zero, adapt to climate change and ensure our journey to net zero is a just transition for all residents. The strategy rightfully puts a strong emphasis on public health impacts felt by the climate emergency over the coming years. It includes a key target that the city is a safe place for citizens during climate change induced extreme heat conditions. The Keep Bristol Cool Framework is the beginning of an action plan of this strategic approach when it comes to this issue of global heating.

Like the One City Climate Strategy, this framework takes a holistic approach, that makes sure action happens at a council-wide level, that speaks to all seven themes in our corporate strategy and is truly cross-cutting. This involves alignment between actions tackling both urban heat and wider determinants of health – such as the environment we live in, ensuring good quality housing, reducing air pollution, and reducing inequalities.

Similar to so many other issues relating to the Climate Emergency and inequality in a more general sense, there is key correlation between the most deprived neighbourhoods and citizens being at the largest risk of the hazards relating to sustained hot weather and its consequences. This enshrines the need for a just transition when it comes to net zero and ensure action we take as a council across the city leads to sustainable and inclusive growth across actions relating to net zero and beyond.

This is a framework for Bristol City Council, that I hope will work as a springboard for citywide action, strongly rooted in a One City Approach to the issue. As we look at the practical side of what we can deliver as a council such as trees on streets, heat resilient improvements to our social housing stock, wider city planning and the council's immediate response to heatwaves; we also want this framework to strengthen the city's approach to global heating by convening key anchor institutions and empowering partners from VCSE, Transport, Education, trade union, and private sector groups. It's only through this joined-up approach with partners that we are going to be able to deliver the benefits of this framework as we strive toward net zero and nature recovery.

I'd also like to thank the work that has preceded the Keep Bristol Cool Framework. This framework was built around the evidence of Bristol's pioneering heat vulnerability map, which wouldn't have been possible without the UK Climate Resilience programme and its expertise using the Met Office's world-leading science, combined with insights from Bristol residents.



**Councillor
Kye Dudd,
Cabinet Member
for climate, ecology,
waste and energy**



Contents

Executive Summary	5
Introduction	8
Background	9
Case for action	13
Developing the framework	15
Our baseline assessment of urban heat risks	17
Our work to tackle the climate and ecological emergency	35
Our strategic Goals and Themes for urban heat resilience	36
Next steps	42
Monitoring and reporting	42
Acknowledgements	43
Appendix	44



Executive Summary

This framework sets out the challenges facing Bristol regarding increasing temperature in the city due to climate change over the coming years and decades.

By the 2080s, average summer temperatures could increase by up to 7°C when compared to the end of the 20th Century. By this point about 1 in 5 days could be hotter than 25°C, with one in 15 over 30°C. Sustained and extreme heat can have significant impacts on human health, the city's infrastructure and nature.

We have developed an extensive evidence base of the urban heat risks and vulnerabilities of Bristol, including the Heat Vulnerability Index used in the Keep Bristol Cool Mapping Tool. This evidence base has been used to establish the Framework's Goals and Themes.

By the 2080s

average summer temperatures could increase by up to

7°C

1 in 5 days could be hotter than

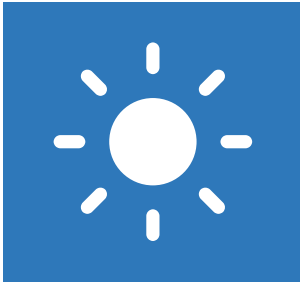
25°C

and 1 in 15 days over

30°C

Keep Bristol Cool

Framework's Goals



Protecting vulnerable people, the public, council employees and council services during heatwaves

Protecting people's health and wellbeing during heatwave events including maintenance of critical public infrastructure and services.

Themes under this goal:

- Improving severe weather planning
- Using latest evidence to warn and inform
- Improving heatwave preparedness
- Trialling the monitoring of heat impacts
- Providing cool places



Future-proofing growth and city regeneration

Building urban heat resilience into new pieces of the city, city infrastructure, and new developments.

Themes under this goal:

- Local Plan climate adaptation policies
- Using latest evidence to inform regeneration frameworks
- Understanding resilience of council infrastructure
- Working with infrastructure providers to understand their heat vulnerability
- Engaging citizens with visions of the future



Tackling overheating risk in people's homes

Making people's homes safer and more comfortable for communities, visitors and workers when building new homes and retrofitting existing properties.

Themes under this goal:

- Understanding resilience of care settings
- Taking an integrated approach to retrofitting homes
- Ensuring the council's new homes do not overheat
- Working with the wider housing sector to improve resilience
- Awareness raising with homeowners



Using blue green infrastructure for cooling streets and public spaces

Making places safer and more comfortable for communities, visitors, and workers when creating new places and retrofitting existing neighbourhoods.

Themes under this goal:

- Defining a potential cool corridors network
- Understanding the resilience of major public spaces
- Trialling nature-based solutions
- Improving community resilience
- Harnessing citizen science

These goals and their themes will anchor our subsequent action plan over the coming years, working with the wider council and city partners, to embed resilience and pro-active work around urban heat in Bristol.

Introduction

Bristol is on an ambitious journey to build a city that is carbon neutral and climate resilient city by 2030¹ and is making an ecological recovery. The city recognises the urgent need for greater action, better preparing the city for the growing impacts of climate change and building on a proud record of climate action.

We are already feeling climate change impacts through extreme weather events – floods, storms, droughts, and heatwaves - alongside sea level rise, shifting weather patterns, and changing seasons bringing hotter, drier summers and milder, wetter winters. We could also see flooding from heavy downpours in summer. These impacts have knock-on consequences for people, nature, the economy and society. We have seen how record-breaking temperatures last summer brought unprecedented numbers of heat-related deaths, wildfire incidents and significant infrastructure disruption².

The UK's national assessment of climate risks identified the risk of high temperatures as one of the major risks facing the country due to its detrimental impact on health, wellbeing, and productivity³. Our own local climate risk assessment also identified the potentially serious and wide-ranging impacts of extreme heat on the city's people, public services and assets⁴.

The One City Climate Strategy recognised the urgent need to prepare a local management plan to address urban heat risks, and to investigate the impact of extreme heat on the city to fill a critical data and knowledge gap. This council-led framework is a fulfilment of these recommendations addressing five aims:

Our five aims

1. Building a common understanding of Bristol's urban heat risks.
2. Supporting decision-makers through a new evidence base.
3. Setting objectives for delivering urban heat resilience across priority themes.
4. Maximising co-benefits through a joined-up response to climate resilience, net zero and nature recovery.
5. Advocating wider action across the city.

¹ [One City Climate Strategy](#)

² [Progress in adapting to climate change – 2023 Report](#)

³ [Independent Assessment of UK Climate Risk \(CCRA3\)](#)

⁴ [Bristol One City Climate Strategy](#)

⁵ Adapted from the Bristol Resilience Strategy definition of city resilience

Our working definition

“Urban heat resilience is the capacity of individuals, communities, institutions, businesses, and systems within Bristol to survive, adapt and grow in the face of increasing temperatures and more severe heatwaves”⁵.

The audience for this framework is policy makers and practitioners, council teams, businesses, organisations and communities with the responsibility and capacity to accelerate action and influence others, those already engaged in climate change issues, the general public and our communities, and for anyone else interested in finding out what the council's doing on climate resilience.



Background

Record-breaking temperatures

The UK and Europe experienced a record-breaking summer last year with extreme heatwaves, wildfires, and the worst drought in 500 years.

Five spells of hot weather over the summer months of 2022 caused the premature death of around 3,000 people in the UK¹. Climate change is making extreme weather events like heatwaves more likely, with increases in their frequency, intensity, and duration.

In July 2022 red alert warnings were issued by the Met Office and the UK Health Security Agency in order to protect life and help people, businesses and service providers get ready for unprecedented temperatures. This was the first-time 40°C was recorded in the UK since records began. Cities like Bristol experienced three extremely hot days in the mid-30°Cs, with night-time temperatures as high as 20°C in some homes.

¹ [UKHSA and ONS release estimates of excess deaths during summer of 2022 – GOV.UK](#)

² [Record breaking 2022 indicative of future UK climate – Met Office](#)

³ [bbc.co.uk/news/science-environment-66084543](https://www.bbc.co.uk/news/science-environment-66084543)

Not only was 2022 the first year in the UK when 40°C was recorded as part of a heatwave which exceeded previous records by a large margin, it was also the warmest year in records back to 1884. The world's longest running instrumental temperature series dating back to 1659, the Central England Temperature (CET) record, also recorded its hottest year on record. It wasn't only the unprecedented hot summer, but all months of 2022 except December were warmer than the 1991-2020 average.

Met Office studies found both the record warm year and July heatwave were made more likely by human induced climate change². With the top-10 warmest years for the UK in the series from 1884 have occurred in the 21st century.

June 2023 was the UK's hottest June on record, beating the previous record set in 1940, as well as June 1976 with sustained heat both day and night with an average monthly temperature of 15.8°C³. June was also the fourth sunniest in a series since 1910, and the sunniest since 1957.

Cities feel the heat

Living in a city can increase vulnerability to heat. Many deaths during heatwaves occur because of the combined effect of high temperatures and the urban micro-climate. In addition to background warming an additional factor facing city residents is the urban heat island effect, the combined effect of the built environment as compared to more natural, rural environments.

URBAN HEAT ISLAND PROFILE

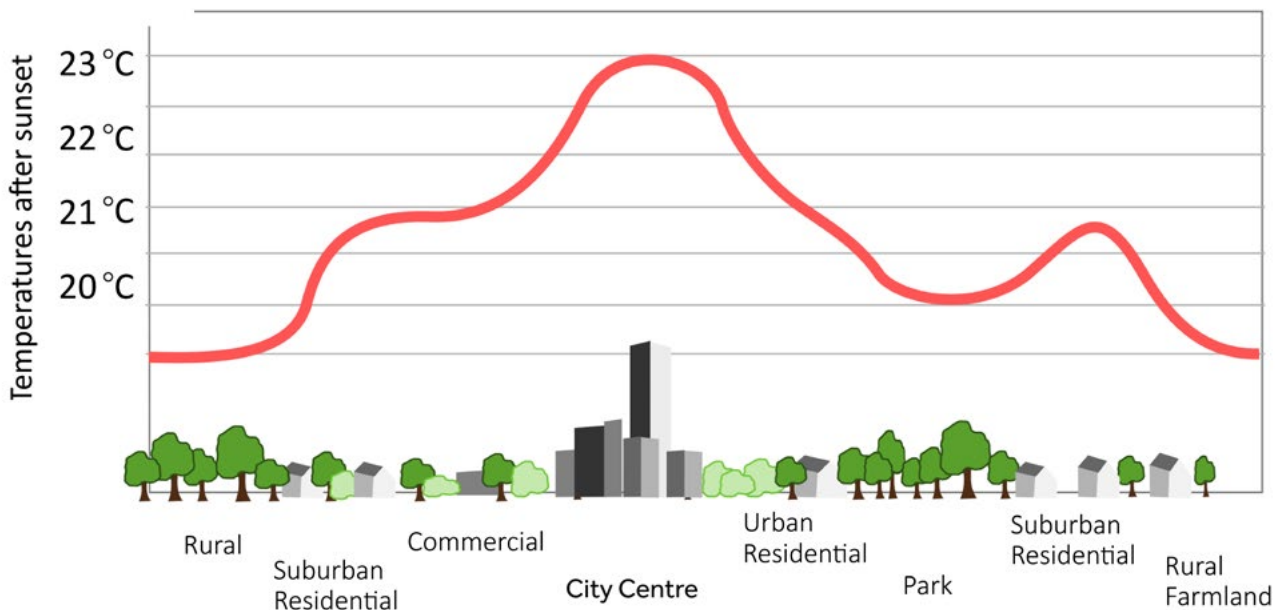


Figure: The Urban Heat Island effect (Wikimedia Commons)

Urban environments warm-up for a variety of reasons:

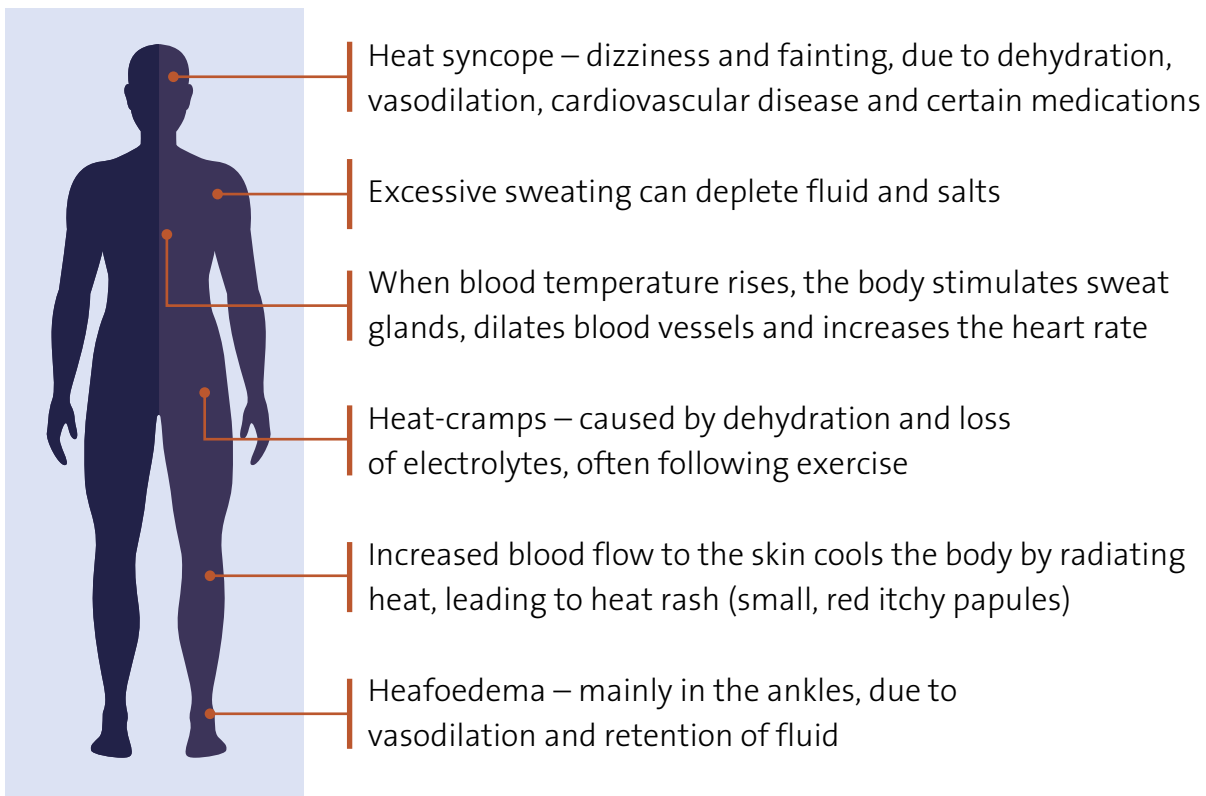
- The dominance of hard surfaces like roofs, roads, and concrete which absorb and retain heat more easily than natural features, typically releasing this heat slowly at night. This prevents cities from cooling as much or as fast as rural areas during the evening.
- The arrangement of buildings and streets (otherwise known as the 'cityscape') where heat can become trapped on narrow 'street canyons' lined by tall buildings.
- The addition of waste heat emissions from buildings, vehicles, and other activities such as industrial processes.

Natural features, or living infrastructure, such as green spaces, trees and water bodies can all help reduce the Urban Heat Island through their natural cooling effect. As water evaporates from leaves, soil and water features it removes energy or heat from the urban environment.

Effects of heat

We are familiar with the positive images of hot weather but less so with the often-hidden negative impacts on health and other city systems. Our body temperature must remain within the narrow band of 36.5°C to 37.3°C in order to stay healthy. When people are unable to maintain a safe body temperature, they become vulnerable to heat stress. This can result in heat stroke, a worsening of existing health conditions and death if not treated quickly enough.

In the same way the performance of our buildings, railways, roads etc are all affected when temperatures stray outside certain boundaries or operational norms, leading to rooms overheating, rails buckling and road melt. Similarly the natural environment also has its own limits which affect species, biodiversity, and habitats.



Health effects of heat

The main causes of illness and death during a heatwave are respiratory and cardiovascular diseases. Additionally, there are specific heat-related illnesses including:

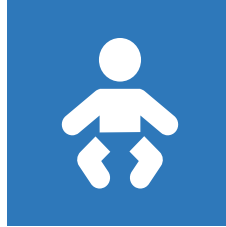
Heat Exhaustion		Heatstroke	
• Nausea or irritability	• Headache	• Hot, dry skin or profuse sweating	• Seizures
• Dizziness	• Fatigue	• Confusion	• Very high body temperature
• Muscle Cramps or weakness	• Heavy sweating	• Loss of consciousness	
• Feeling faint	• High body temperature		

Effects of Heat continued

Rising temperatures affect all populations. However, some populations are more exposed to, or more physiologically or socio-economically vulnerable to physiological stress, exacerbated illness, and an increased risk of death from exposure to excess heat¹. These include²:



People aged 65+



Babies and young children



People who have a severe physical or learning disability or have limited mobility



People with chronic and underlying health conditions



People with alcohol or drug addiction



People with a mental health condition



Economically or socially marginalised groups



People who are pregnant



Outdoor and manual workers



People who are homeless



People who live alone or are socially isolated



People who live in care settings

¹ [Heat and Health \(who.int\)](#)

² [UK heatwave risk report | British Red Cross](#)

Case for action

As we have witnessed this year in southern Europe heat can cause wildfires especially when whipped up by windy conditions.

Extended periods of excessive heat can have a negative impact on trees and food by reducing the amount of available moisture. This can result in leaves shedding and food ripening too early. Intricate food chains can be disrupted as insect populations reduce and soil dries up.

UK preparedness for climate change

The latest assessment by the Government's independent advisor the Committee on Climate Change found 'very limited evidence of the implementation of adaptation at scale needed to fully prepare for climate risks facing the UK across cities, communities, infrastructure, economy, and ecosystems'¹. In summary it concluded that both 'buildings and overheating' and 'health protection from climate change' both suffered from limited policies and plans as well as mixed progress, unevaluable actions, and/or insufficient actions.

Bristol Corporate Strategy 2022–2027

The council's corporate strategy sets out our contribution to the city and is our main strategic document and provides the overarching context for the Framework.

Below are the most relevant Priority Action Areas under their corresponding themes for the Framework:

Theme 1 Children and Young People:

CYP4 Intergenerational equity

Children and families living and growing up in low-income households are the most vulnerable to adversities and have the least resources to overcome them.

Theme 2 Economy and Skills:

ES1 Regeneration

Enable the growth, development, and regeneration of the city in an inclusive, sustainable, healthy, and resilient way.

Theme 3 Environment and Sustainability:

ENV4 Climate Resilience

Minimise our contribution to future shocks and stresses and invest in infrastructure and systems that cool the city and help us adapt to the effects of climate change. Do this in ways that provide inclusive, sustainable economic growth.

Theme 4 Health, Care and Wellbeing:

HCW1 Transforming Care

Work with partners to implement an Integrated Care System – transforming adult social care and joining up health, care, education, skills, and community activities.

¹ [Progress in adapting to climate change - 2023 Report to Parliament - Climate Change Committee](#)

Theme 5 Homes and Communities:

HC1 Housing Supply and HC2 Low and Zero Carbon

Healthy, resilient, and inclusive neighbourhoods with fair access to decent, affordable homes.

Theme 6 Transport and Connectivity:

TC4 Physical Infrastructure

Plan, prioritise and begin a refreshed and long-term (25-year+) programme of maintenance, repair, and renewal of the city's infrastructure, such as roads and bridges. This will help make sure that the city is safer, more climate-resilient, nature-friendly, and able to grow its economy in an inclusive and sustainable way.

Theme 7 Effective Development Organisation

ED04 Data Driven

Improve our ethical and inclusive use of research, data, insights, and information to become more data-driven and evidence-led when making decisions.

ED06 Estate Review

Review our operational estate to ensure we have the right amount and right quality of workspaces. Make sure they are carbon neutral by 2025, as well as climate resilient.

Corporate risk management

Mitigating urban heat risks through improving our preparedness for heatwave events and building longer-term resilience addresses:

- Communities/social risks: e.g. making neighbourhoods more resilient to urban heat risks through awareness raising on heatwave preparedness and physical changes to homes and the outdoor environment.
- Environmental risks: e.g. using passive cooling to tackle hot weather and heatwaves which reduces carbon emissions from active cooling such as air conditioning.
- Financial loss: e.g. gathering corporate intelligence on the financial impact of heatwave events on the council's functions.
- Infrastructure risks: e.g. highways specification – coping with high temperatures and making contributions to urban cooling and mitigating urban heat island effect.
- Legal risks: e.g. fulfilling statutory duties as a social housing landlord and ensuring homes are fit-for-purpose.
- Personal health and safety risks: e.g. ensuring council facilities are comfortable for the workforce during hot weather and heatwave events.
- Reputational risks: e.g. delivering tangible progress in meeting 2030 goal for a climate resilient city and maximising co-benefits for net zero and nature recovery.
- Service delivery risks: e.g. ensuring delivery of critical services through business continuity planning and emergency preparedness.



Developing the framework

We have co-developed this framework with experts funded through the UK Climate Resilience Programme. This funding enabled us to work with a dedicated Embedded Researcher with expertise in heat vulnerability analysis from the Tyndall Centre for Climate Change Research, and the Met Office's urban climate services team.

At the heart of the document is Bristol's first citywide baseline assessment of urban heat risks. We've explored how risks to health vary across the city in three key ways: using the latest climate data to explore future extreme heat trends, the creation of a Heat Vulnerability Index (HVI) which looks at risks today and neighbourhood-level feedback from Bristol's Quality of Life survey on homes overheating.

The climate data and HVI can be accessed through the Keep Bristol Cool mapping tool¹ and Met Office Heat Pack². The Quality-of-Life data can be viewed using the interactive dashboard³. For those who are interested in the finer detail of the evidence base please see the technical information at the end of this report.





We also worked closely with colleagues within the council and wider stakeholders. We used structured workshops and conversations with stakeholders to explore with them what this new evidence base tells us about urban heat risks, including areas which require further investigation. By exploring the 'problem' through this data, it's allowed us to identify 'solutions' – with four priority themes for action, specific goals for each theme and a set of 20 objectives for implementation over the next two to three years.

[1 Keep Bristol Cool mapping tool](#)

[2 Met Office Bristol Heat Pack](#)

[3 Bristol Quality of Life Dashboard](#)

Our four strategic goals

Strategic Goal	Urban heat resilience
 <p>1. Protecting vulnerable people, the public, council employees and council services during heatwaves</p>	<p>Protecting people’s health and wellbeing during heatwave events including maintenance of critical public services</p>
 <p>2. Future-proofing growth and city regeneration</p>	<p>Building urban heat resilience into new pieces of city, city infrastructure and new developments</p>
 <p>3. Tackling overheating risk in people’s homes</p>	<p>Making people’s homes safer and more comfortable when building new homes and retrofitting existing properties</p>
 <p>4. Using green and blue infrastructure for cooling streets and public spaces</p>	<p>Making places safer and more comfortable for communities, visitors, and workers when creating new places and retrofitting existing neighbourhoods</p>

In developing the framework we looked at cities within the UK, Europe and further afield to see what progress is being made to tackle the growing threat of extreme heatwaves including London’s Cool refuge initiative, Vienna’s Cool Streets project, Sydney’s Turn Down the Heat Strategy, and cross-cutting guidance like the UNEP’s Beating the Heat: A Sustainable Cooling Handbook for Cities.

This framework isn’t an evaluation of current activities which are contributing to Bristol’s urban heat resilience.



Our baseline assessment of urban heat risks

The creation of Bristol's first citywide baseline assessment of urban heat risks is the foundation for this framework. These insights into how heat risks may vary across the city and the key driving forces behind this vulnerability, helps to direct interventions such as:

- Concentrating emergency planning efforts during a heatwave to protect clusters of vulnerable people,
- Prioritising retrofit programmes for vulnerable communities who live in high-risk areas with poorly adapted homes, or
- Increasing tree planting, wildlife habitats and soft landscaping in city hotspots.

This assessment brings together sources of data which look at heat risks from three different perspectives:

1. Met Office analysis using the latest climate projections to assess changes in extreme heat events this century.
2. The creation of a Heat Vulnerability Index to identify those areas of the city where extreme heat could have the biggest impact on people's health and wellbeing.
3. Using feedback from Bristol's Quality of Life survey¹ to explore perceptions and spatial patterns for homes which overheated during the last three years.

The following section outlines the methodology for generating this baseline assessment and our summary findings.

¹ [Quality of life in Bristol](#)

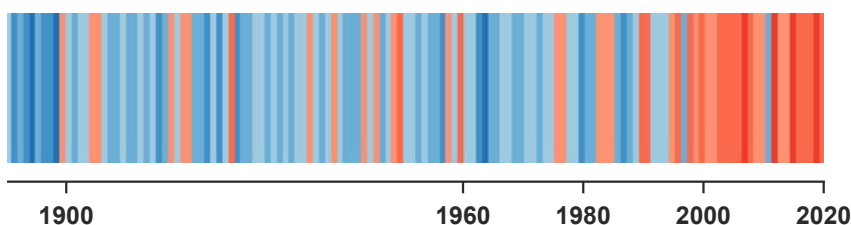
Bristol's warming climate and extreme heat trends

Bristol's temperature has already increased significantly over the last century. Most of this warming has occurred in the past twenty years and is projected to continue throughout this century due to climate change. Unique climate stripes have been created which clearly show how annual temperatures are getting warmer with time¹. This shows visually how annual average temperatures have changed since 1887, compared to a baseline or reference period of 1981 to 2000.

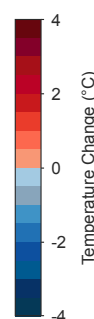
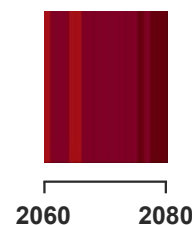
Figure: Bristol's climate stripe (© Met Office)

Annual average temperature change in Bristol compared to 1981-2000

Observed since 1884:



Modelled (high emission scenario):



Concept from Prof. Ed Hawkins [#ShowYourStripes](#)

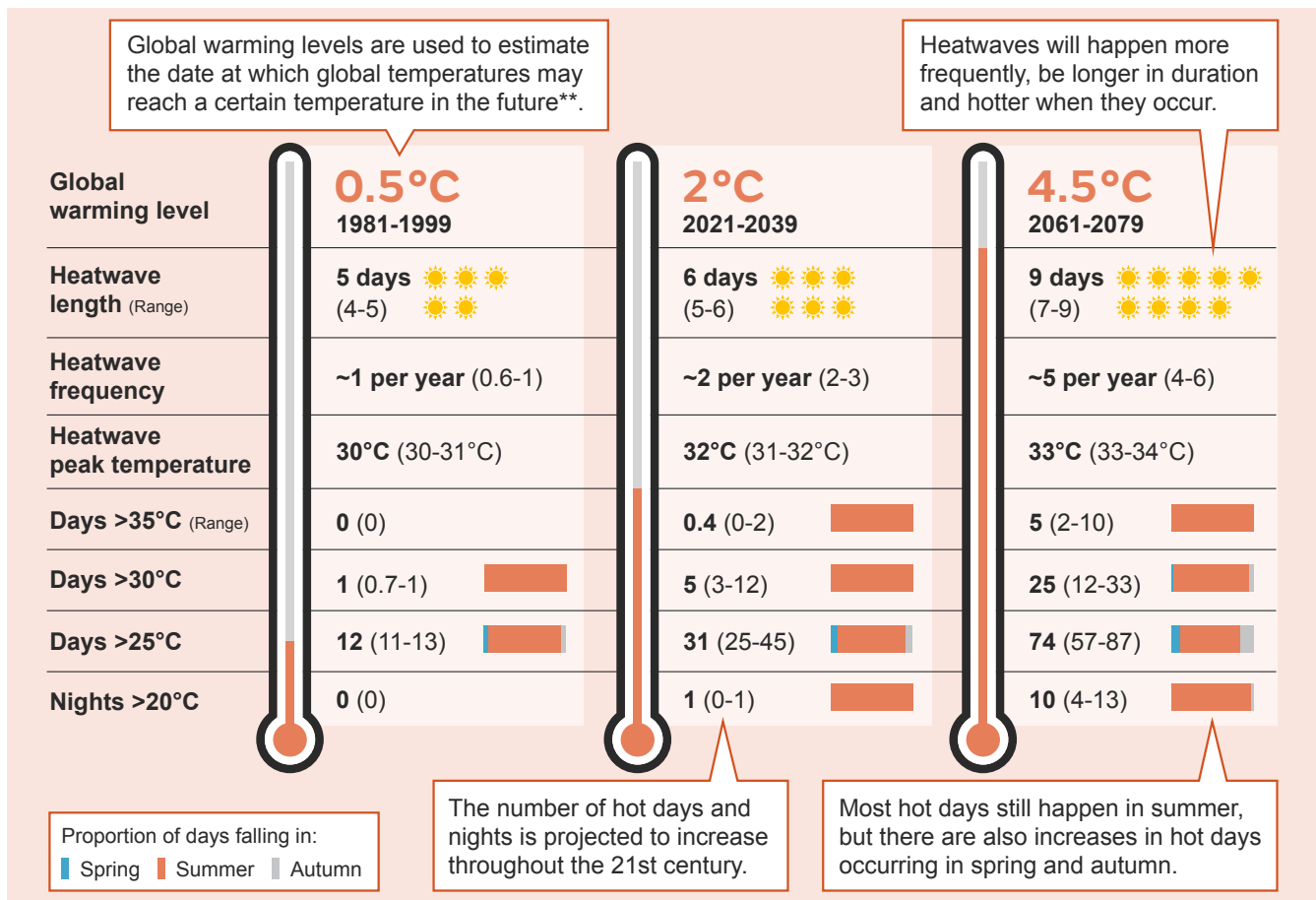
The Met Office used the latest UK Climate Projections to look at Bristol's warming climate this century. They looked into how air temperatures are gradually increasing and the number of days when temperatures are reached that negatively affect health and wellbeing, infrastructure and building performance. Data was produced for the city as a whole and mapped to show differences between neighbourhoods and Bristol's urban heat island effect. They also looked into how heatwaves are changing in frequency, severity, and duration this century. The Met Office define a Bristol heatwave as three or more consecutive days where maximum daily temperatures exceed 27°C.

The Met Office climate model used to generate this data works on a similar scale to those used for weather forecasts and includes a

more detailed representation of urban land surface than previously used in climate modelling. The modelling is based on a future outlook where greenhouse gas emissions continue to grow unabated (and would mean that some existing climate policies in some countries would be reversed). This would lead to about a 4.5°C global temperature rise by the end of the century. Under this scenario, we would pass the upper Paris target of 2°C during the 2030s (2021-2039) which is earlier than some other models.

The values in the table below present the results from the climate model simulations for Bristol based on a 4.5°C global temperature rise by 2100. The main value shows the mid-point or 50% 'central estimate' alongside the range for the climate projections (10% lower end and 90% upper end).

Figure: Future extreme heat trends for Bristol during the 21st century¹



So if global greenhouse emissions do continue to fall short of reduction targets as the century progresses, summers will continue to get hotter with more extreme heatwaves. We are also already locked-into a period of inevitable climate change due to historic emissions.

In Bristol over the next 20 years we could see average summer temperatures between 1.0°C and 2.2°C² warmer than the end of the 20th Century. Heatwaves will also be getting more frequent, severe, and longer.

By the 2080s, average summer temperatures could increase by between 3.1°C and 7.6°C when compared to the end of the 20th Century³. By this point about 1 in 5 days

could be hotter than 25°C, with one in 15 over 30°C. Heatwaves could have more than doubled in frequency when compared to the 2030s to five times a year, representing a five-fold increase on the 1980s and 1990s. A typical heatwave could last for 9 days, reaching a peak temperature of 33°C⁴.

Mapping this temperature data for Bristol shows the city's own unique urban heat island where the central and eastern areas tend to be warmer than other parts of the city. Data was mapped for MOSAs (Middle Layer Super Output Area) which are similar in size to electoral wards.

1 © Met Office



2 Met Office Bristol City Pack SPF City Pack editable template

3 Met Office HadUK-Grid provides climate information for the UK derived from a UK network of weather stations

4 Met Office Bristol Heat Pack CSSP City pack Bristol



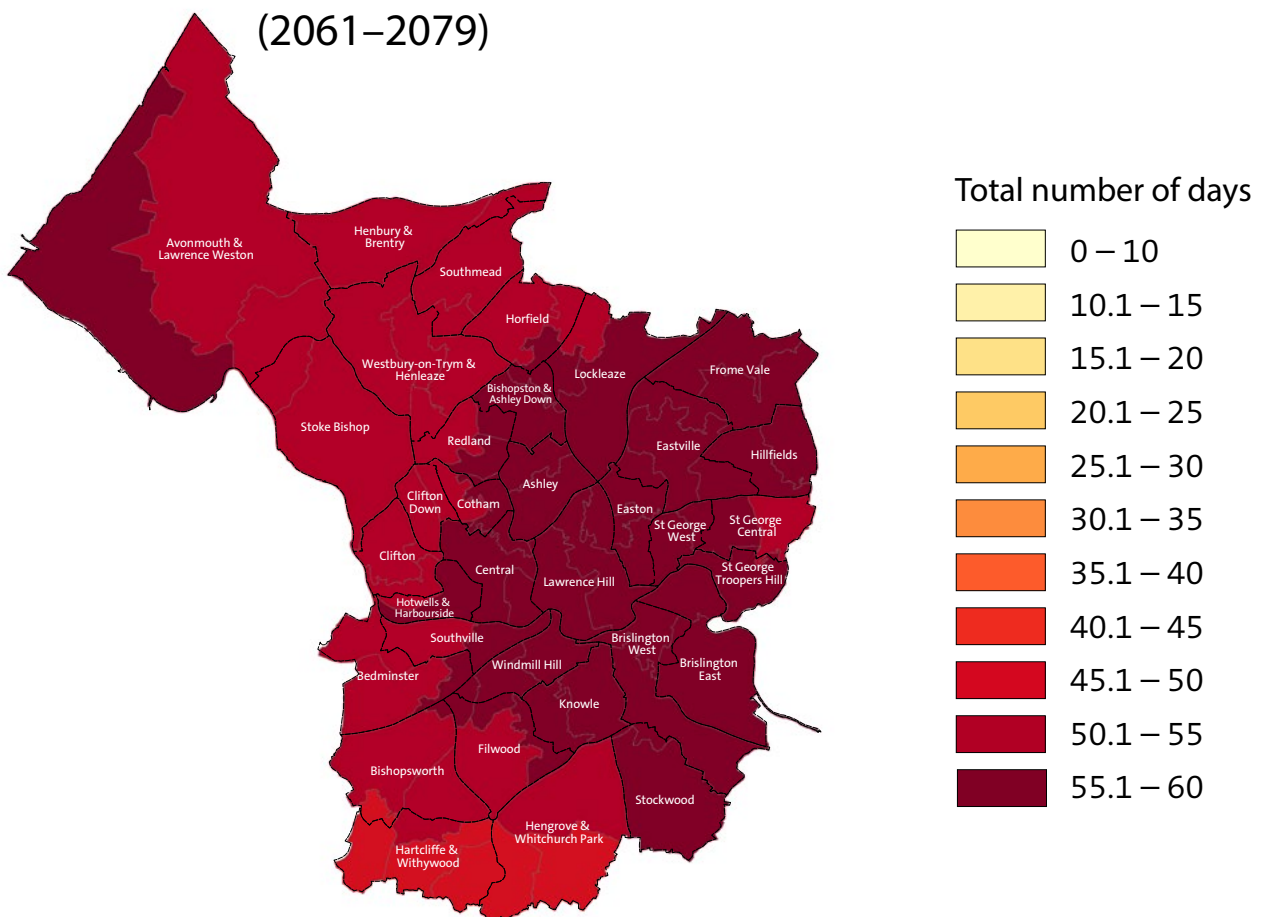
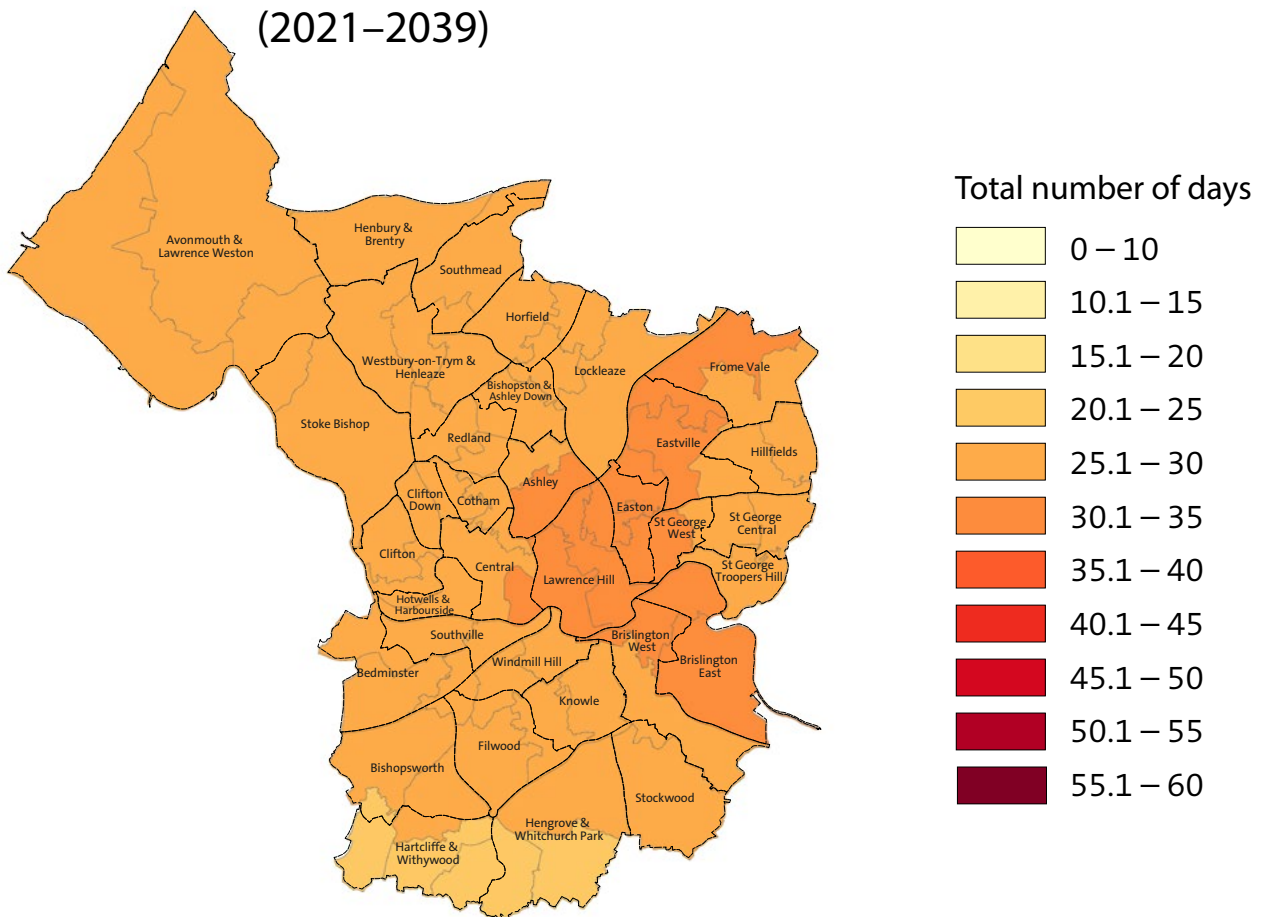
Table: Urban heat island patterns for Bristol

 <p>Daytime</p>	<p>The central and eastern areas of Bristol will experience the highest number of warm (above 25°C) and hot days (above 30°C).</p> <p>The centre is heavily urbanised with several retail and business parks with hard surfacing which may cause these areas to heat-up more intensely than surrounding areas.</p> <p>The eastern parts of the city are also further away from any cooling effect from coastal sea breezes during the day. The prevailing westerly winds can pick-up and transport heat from the urban heat island creating a downwind effect to the east of the city.</p> <p>Areas at a higher elevation to the north-west and south are generally cooler than central city areas.</p>
 <p>Night-time</p>	<p>There are more tropical nights (above 20°C) concentrated in the low-lying and more built-up central regions of the city.</p> <p>In these areas an urban heat island effect can be seen where the heavily built-up areas of the city absorb energy from the sun during the day and release heat back into the atmosphere at night preventing temperatures in the city centre from cooling down.</p>

Bristol’s climate data should be treated as an approximation where a number of factors can influence the results. These include the natural variability of our climate and the fact that the climate model can’t represent some small-scale local climate processes.

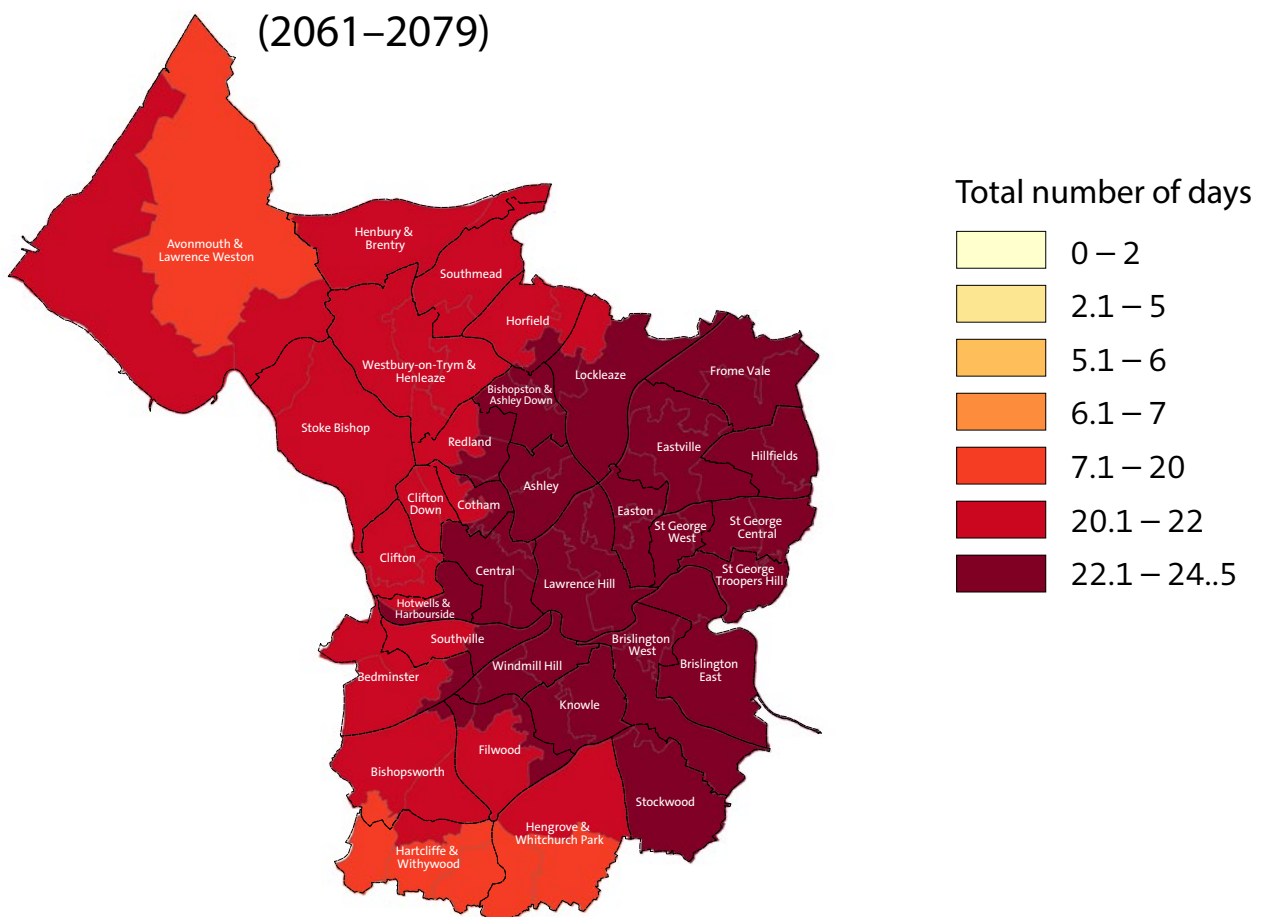
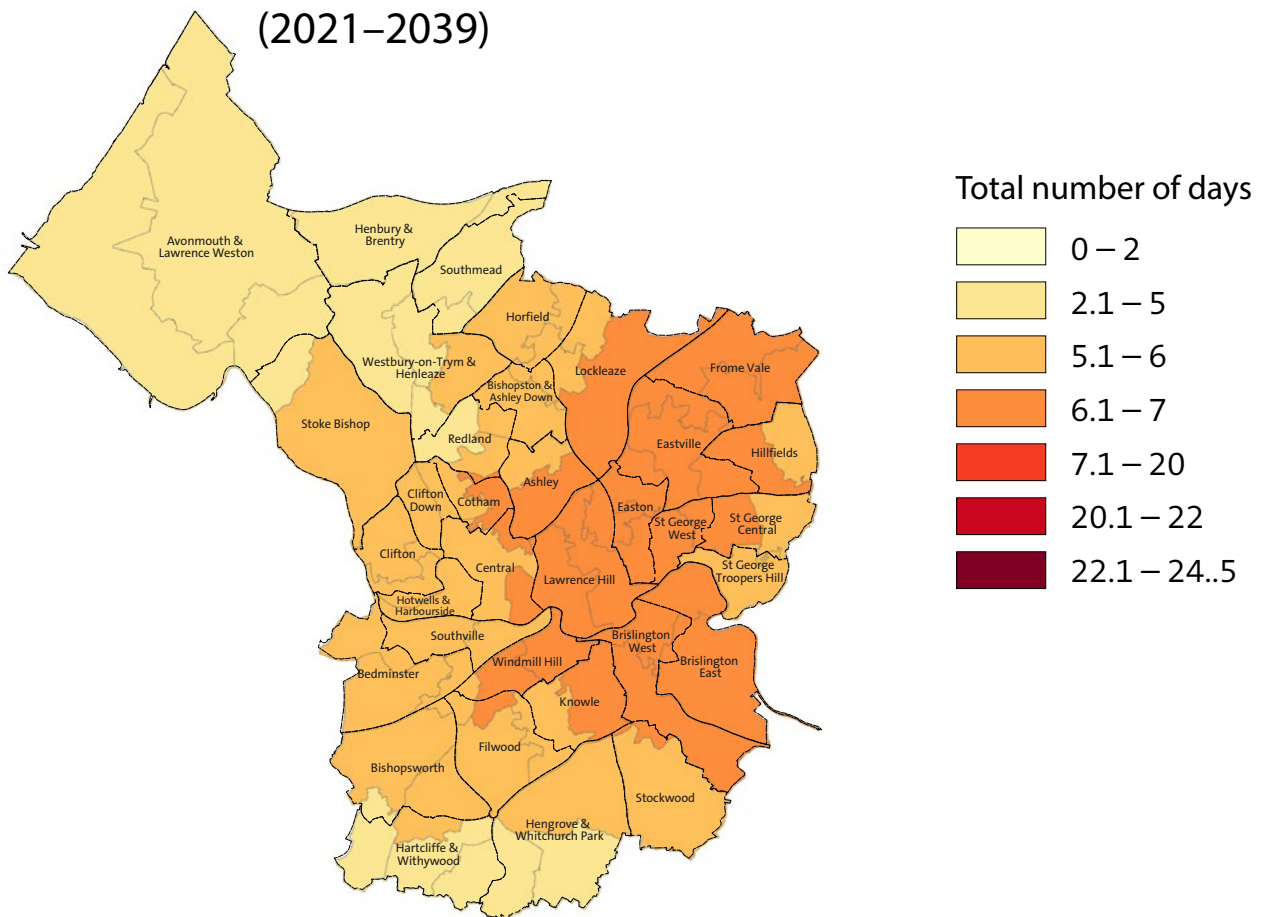
Using the Met Office’s climate model to drive UKCP Local means that the projections explore a narrower range of future outcomes and generates results on the warmer end of the climate response.

Figure: Average number of summer days above 25°C (© Met Office¹)



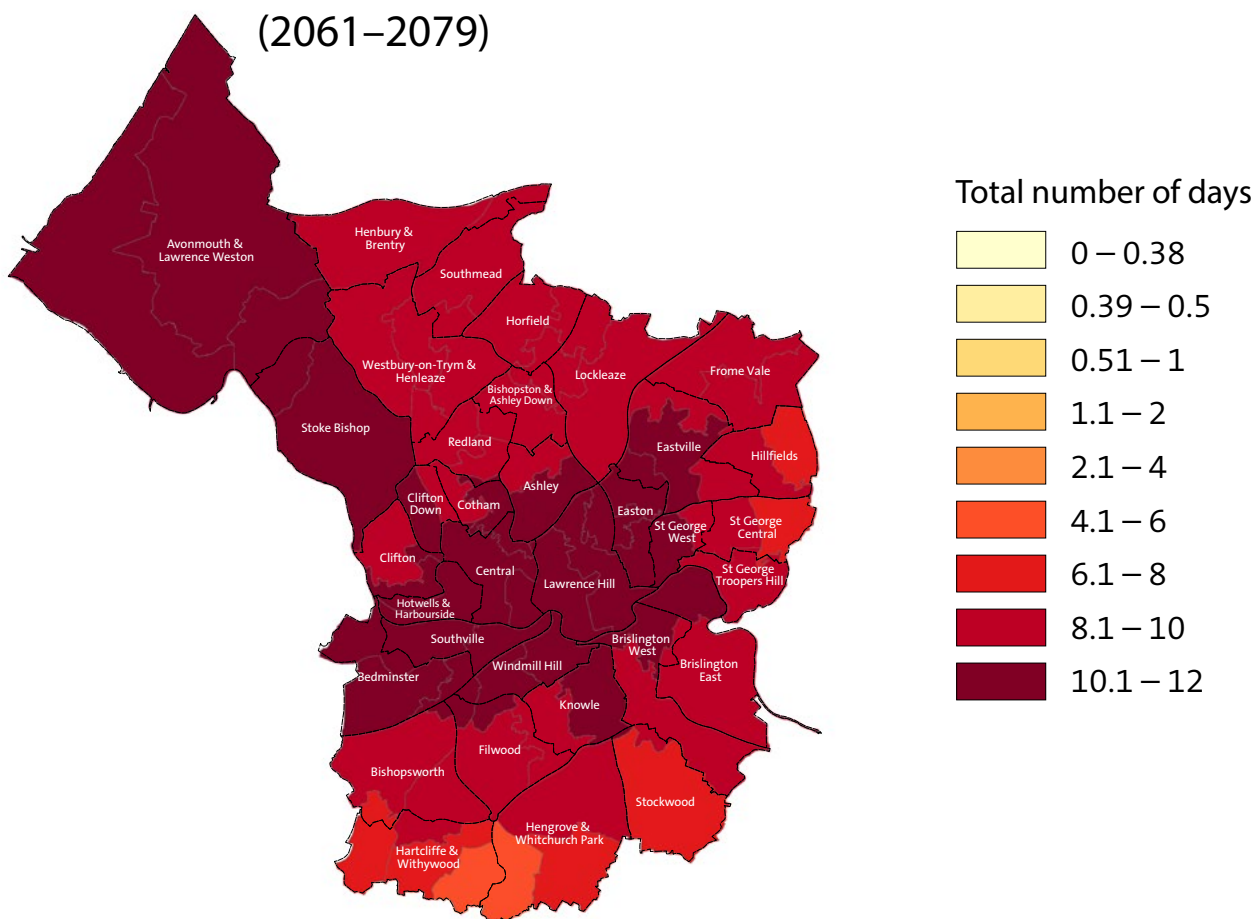
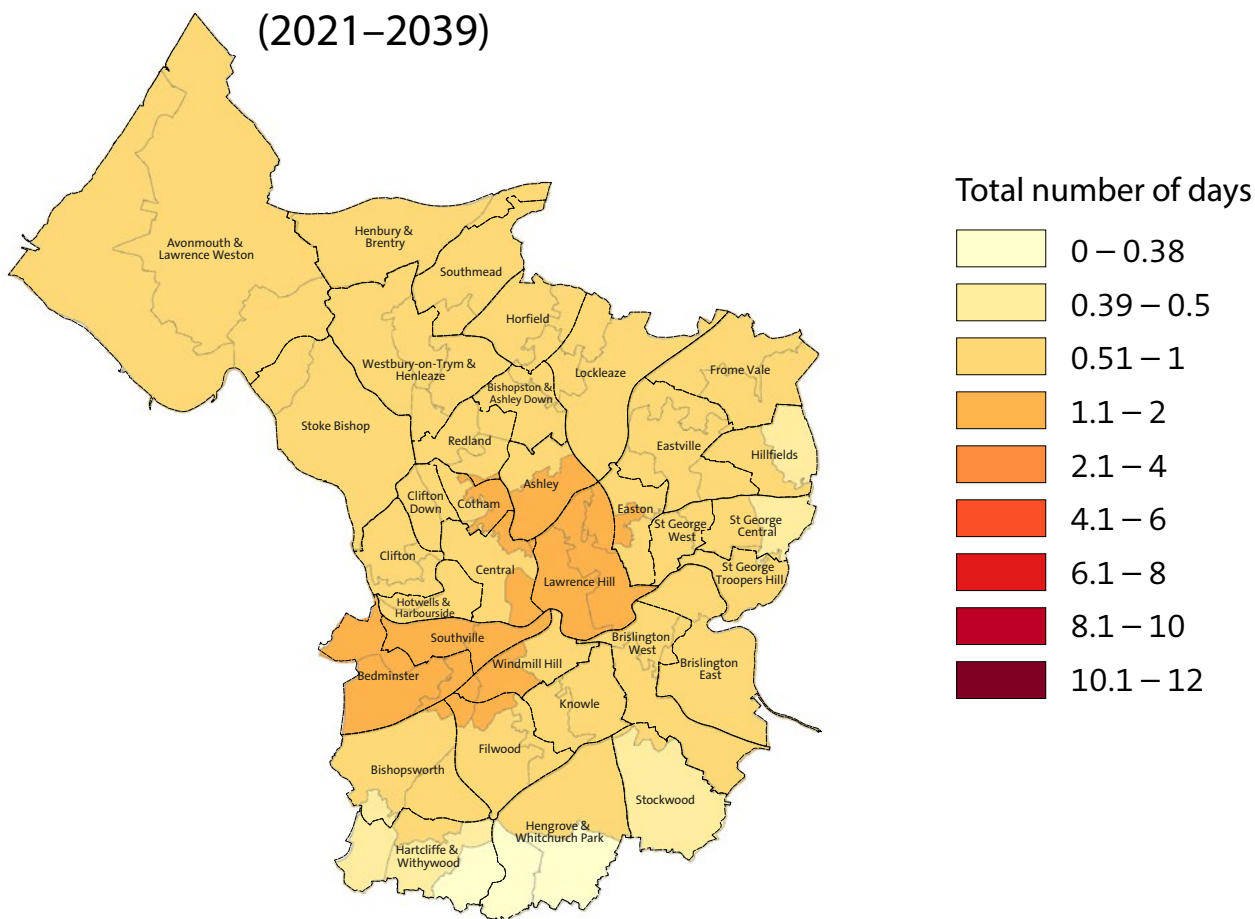
1 © Crown Copyright and database right 2023. Ordnance Survey AC0000807971

Figure: Average number of days for summer days above 30°C (© Met Office)



1 © Crown Copyright and database right 2023. Ordnance Survey AC0000807971

Figure: Average number of nights for summer nights above 20°C (© Met Office)



1 © Crown Copyright and database right 2023. Ordnance Survey AC0000807971

Bristol's Heat Vulnerability Index

Countries and cities around the world are using the power of spatial mapping to explore the impacts of climate change on places, and to develop responses that build the climate resilience of cities, neighbourhoods, and people.

Determining people's vulnerability to high temperatures is complex as it depends on many factors. The development of a Heat Vulnerability Index (HVI) can help us to understand these variations across a city by mapping those factors which increase heat-health risks, using the best available information to describe individuals, their neighbourhoods, their homes, and the local environment. Sources of information to describe these characteristics can include census data, satellite imagery, modelled data, the Index of Multiple Deprivation, information about local land use and land cover (proxies for the Urban Heat Island effect), information on population density (a proxy for waste heat emissions), as well as data on housing characteristics. Proxies are data which acts as substitutes for direct measurements.

These factors can then be layered and combined to create an index to help understand these variations in heat risks. This enables different parts of a city to be compared to one another, as well as identifying the most at-risk areas.

A Heat Vulnerability Index has been developed for Bristol which brings together spatial information on Bristol's population, people's homes, and their local environment. This index helps us identify those areas of the city where extreme heat could have the biggest impact on people's health and wellbeing.

Knowing who is most vulnerable to urban heat risks in a city and where they live, provides important evidence to help build resilience to both current and future heat. The negative impacts of heat on human health do not occur equally across a population.

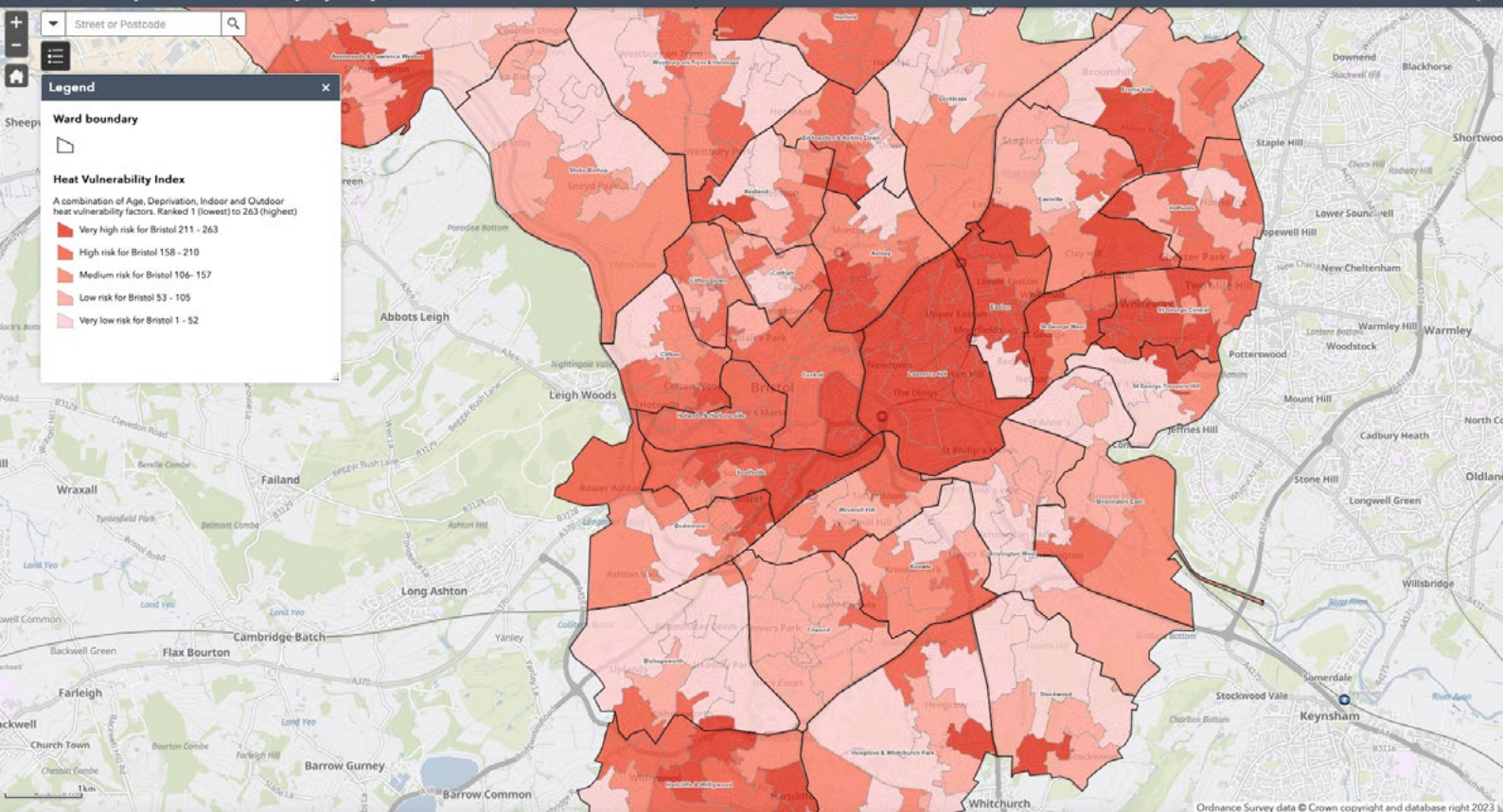
The causes of this vulnerability are complex, but generally fit into four key aspects:

1. A person's sensitivity to heat such as age (especially over 65s and under 5s) and any health conditions.
2. A person's ability to adapt to high temperatures, which is influenced by factors such as income, employment, and education.
3. A person's exposure to high outdoor temperatures because they live in an area with a strong Urban Heat Island effect e.g. a very urban environment with limited green space and tree cover.
4. A person's exposure to high indoor temperatures because their home is more prone to overheating e.g., south-facing property with large windows.

Table: Bristol’s Heat Vulnerability Index

KBC Mapping	Construction	Heat Vulnerability Aspects	Bristol
Heat Vulnerability Index	<p>Ranked score combining four layers – age, IMD, outdoor and indoor exposure.</p> <p>LSOAs ranked 1 (least vulnerable) to 263 (most vulnerable).</p> <p>34 factors.</p>	<p>A person’s sensitivity to heat stress</p> <p>A person’s ability to adapt to reduce exposure to high temperatures</p> <p>Exposure to high indoor temperatures</p> <p>Exposure to high outdoor temperatures</p>	<p>The HVI identifies the most heat vulnerable locations in the city, combining all four vulnerability layers.</p>
Age-related vulnerability layer	<p>5 factors:</p> <ol style="list-style-type: none"> 1. Population aged 0–1 2. Population aged 2–5 3. Population aged 65–74 4. Population aged 75 plus 5. Population aged 64 plus and living alone 	<p>A person’s sensitivity to heat stress</p>	<p>This layer identifies the most vulnerable locations in the city due to age-related factors which affects a person’s sensitivity to heat stress.</p>
Deprivation vulnerability layer	<p>One index: IMD – income, employment, education, health, crime, barriers to housing and services and living environment</p>	<p>A person’s ability to adapt to reduce exposure to high temperatures</p>	<p>This layer identifies the most vulnerable locations in the city due to deprivation which affects a person’s ability to adapt to reduce exposure to high temperatures.</p>

KBC Mapping	Construction	Heat Vulnerability Aspects	Bristol
<p style="text-align: center;">Indoor exposure vulnerability layer</p>	<p>13 factors:</p> <ol style="list-style-type: none"> 1. High glazing areas 2. Modern homes 3. Flats 4. Terraced homes 5. Poor roof energy efficiency 6. Very poor roof energy efficiency 7. Poor glazing energy efficiency 8. Very poor glazing energy efficiency 9. South-facing homes 10. Southwest-facing homes 11. Overcrowding 12. Good wall energy efficiency 13. Very good wall energy efficiency 	<p>Exposure to high indoor temperatures</p>	<p>This layer identifies the most vulnerable locations in the city due to home-related factors which affects a person's exposure to high indoor temperatures.</p>
<p style="text-align: center;">Outdoor exposure vulnerability layer</p>	<p>15 factors:</p> <ol style="list-style-type: none"> 1. Mean land surface temperature 2. Normalised Difference Vegetation Index 3. % homes near busy roads 4. Population density 5. Air pollution (NOx) 6. Air pollution (PM10) 7. Air pollution (PM2.5) 8. Building height 9. Land covered by buildings 10. Mean distance to green space 11. Normalised Difference Built-up Index 12. Greenspace 13. Blue space 14. Urban 15. Suburban 	<p>Exposure to high outdoor temperatures</p> <p>A person's ability to adapt to reduce exposure to high temperatures</p>	<p>This layer identifies the most vulnerable locations in the city due to outdoor environment factors which affects a person's exposure to high outdoor temperatures.</p>



The HVI has been used to develop the Keep Bristol Cool mapping tool, which is available online.

The tool is for policy makers and practitioners such as urban designers, landscape architects, or emergency planners to explore:

- how current heat vulnerability varies across different neighbourhoods
- how climate change may increase temperatures in the future

The tool

gives insights into how urban heat risks vary across the city and within communities



identifies the areas where high temperatures and heatwaves could have the biggest impact on people's health and wellbeing



The following pages show heat vulnerability trends for Bristol for the Overall HVI and the four vulnerability layers used to build the index, listing those Wards ranked in the highest category of 'very high risk for Bristol'.



Heat vulnerability trends for Bristol

Heat Vulnerability Index



The most vulnerable Wards in the Bristol are all located in the central and eastern parts of the city based on a combination of four vulnerability layers:

1. Lawrence Hill
2. Easton
3. St George Central
4. Central
5. Hillfields
6. St George West

The Lawrence Hill Ward is ranked as the most vulnerable ward in the city. It has a very high-risk rating for deprivation levels, number of homes at risk of overheating and the exposure of residents to high outdoor temperatures which all contribute to high levels of heat vulnerability and risks to health.

Age



Looking at age-related vulnerability the following are considered the most vulnerable Wards in the city:

1. St George Troopers Hill
2. Bedminster
3. Westbury-in-Trym and Henleaze
4. Hengrove and Whitchurch Park
5. Stoke Bishop
6. Hillfields
7. Stockwood

The St George Troopers Hill Ward has a very high- or high-risk rating for a range of factors which increase the sensitivity of the population to heat stress, including higher numbers of very young children (aged 0-1) and older people (aged 65+ including those living alone).

Index of Deprivation



Looking at deprivation-related vulnerability the following are considered the most vulnerable Wards in the city:

1. Hartcliffe and Withywood
2. Lawrence Hill
3. Filwood
4. Southmead
5. Lockleaze
6. Avonmouth and Lawrence Weston
7. Easton

The Hartcliffe and Withywood Ward has the highest Index of Multiple Deprivation rating in the city. The IMD combines datasets on income, employment, education, health, crime, barriers to housing and services and living environment.

Homes



Looking at indoor exposure-related vulnerability the following are considered the most vulnerable Wards in the city:

1. Hotwells and Harbourside
2. Central
3. Clifton
4. Redland
5. Clifton Down
6. Cotham
7. Lawrence Hill

The Hotwells and Harbourside Ward has a very high- or high-risk rating for a range of factors which increase the likelihood of homes overheating, including a significant percentage of the housing stock classified as modern homes, flats, and properties with large and/or energy inefficient glazing areas.

Urban environment

Looking at outdoor exposure-related vulnerability the following are considered the most vulnerable Wards in the city:

1. Central
2. Lawrence Hill
3. Bishopston and Ashley Down
4. Easton
5. Ashley
6. Clifton Down
7. Southville

The Central Ward has a very high- or high-risk rating for a range of factors which indicate a strong Urban Heat Island effect. It's a built-up, dense urban environment with tall buildings and has a general lack of greenness and greenspace.

High air pollution levels will also reduce the likelihood of people opening their windows, which can cool homes when done at the right time.



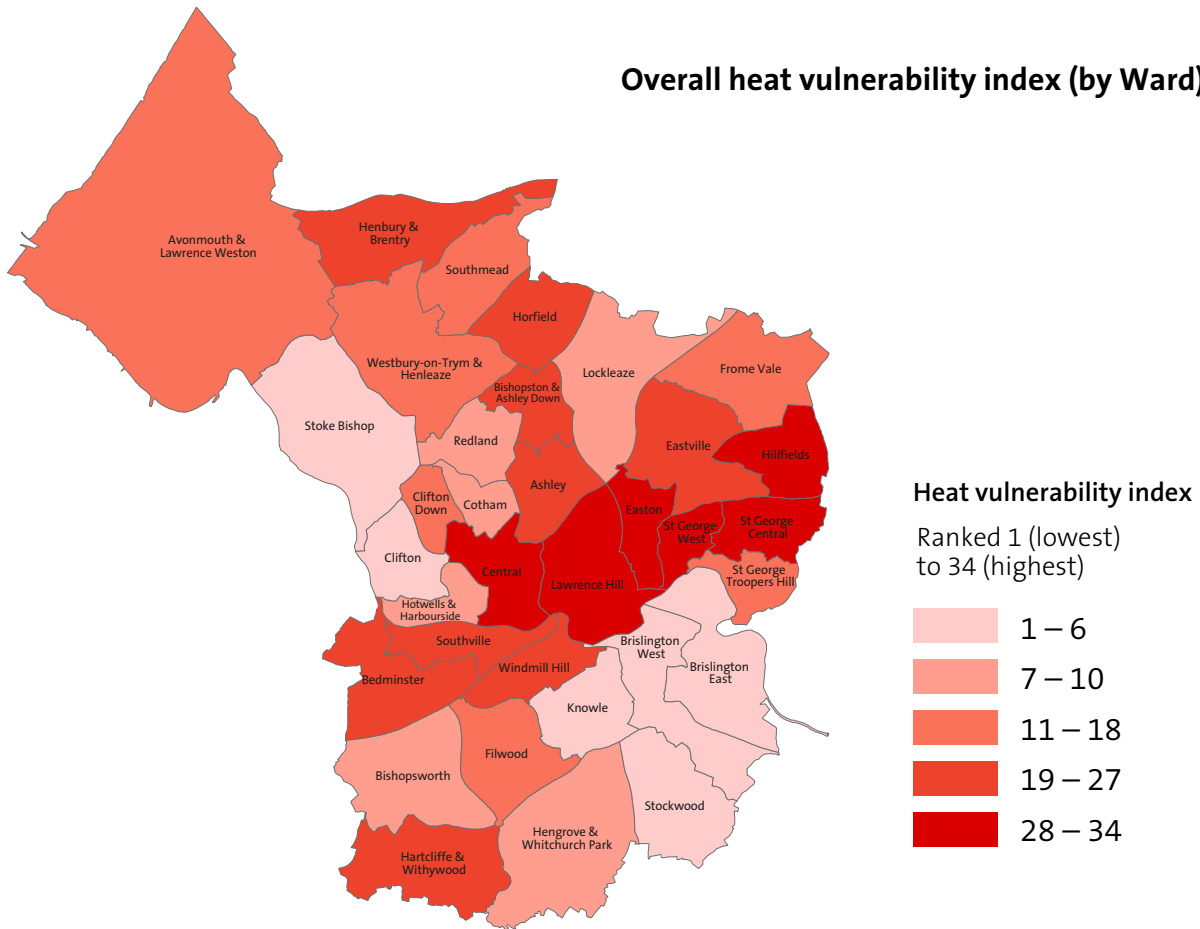


Summary of limitations:

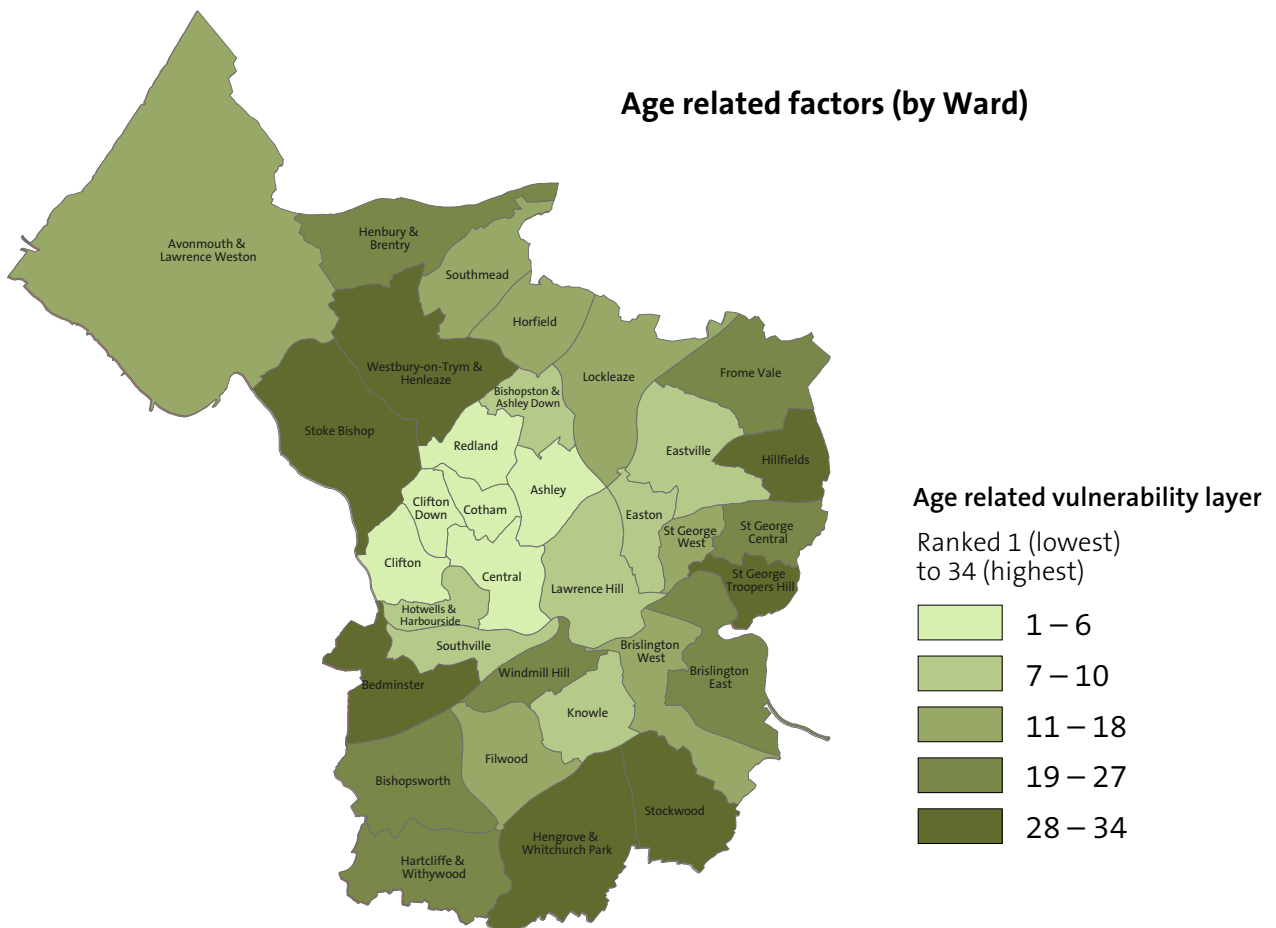
- The index is a relative measure of vulnerability, where an aggregation of data helps reveal patterns and picks-up trends, which assists the prioritisation of interventions. The mapping is based on ranking the wards or LSOAs from low to high, with the shading being based on the position in the ranking. This is particularly relevant for the indoor and outdoor exposure layers. For example, a neighbourhood identified as ‘low risk for Bristol’ in outdoor exposure could still be high risk if compared to countryside village.
- The index averages spatial data over a whole Ward or LSOA so this doesn’t capture variability within these areas. So areas identified as ‘very low risk for Bristol’ will still include people, homes and locations that are vulnerable to heat risks. It does not provide a household or building-level assessment.
- The outdoor exposure vulnerability layer is based on location-specific factors which affect both the Urban Heat Island effect and window opening due to noise and air pollution levels. The indoor exposure vulnerability layer only includes building-specific factors which affect the likelihood of a home overheating. This enables a separation between public and private domains.
- The construction of the index has been limited by the availability of robust, open source data at the right geographic scale. So other factors known to affect heat vulnerability were excluded where data was unavailable e.g. loft conversions. The indoor exposure vulnerability layer was also heavily reliant on EPC data (Energy Performance Certificates) which is known to have weaknesses because many simplifying assumptions are made in calculations for existing homes. For example, window dimensions are not measured but are instead calculated automatically based on the age band of the home and the measured wall area.
- The index does not tell us about the impacts of urban heat for example how many homes will overheat or how many individuals may become ill as a result of exposure to high temperatures.
- The index was constructed using data from 2021 or earlier using Ward, LSOA and LSOA boundaries that were correct at the time of production.

Figure: Heat vulnerability layers for wards

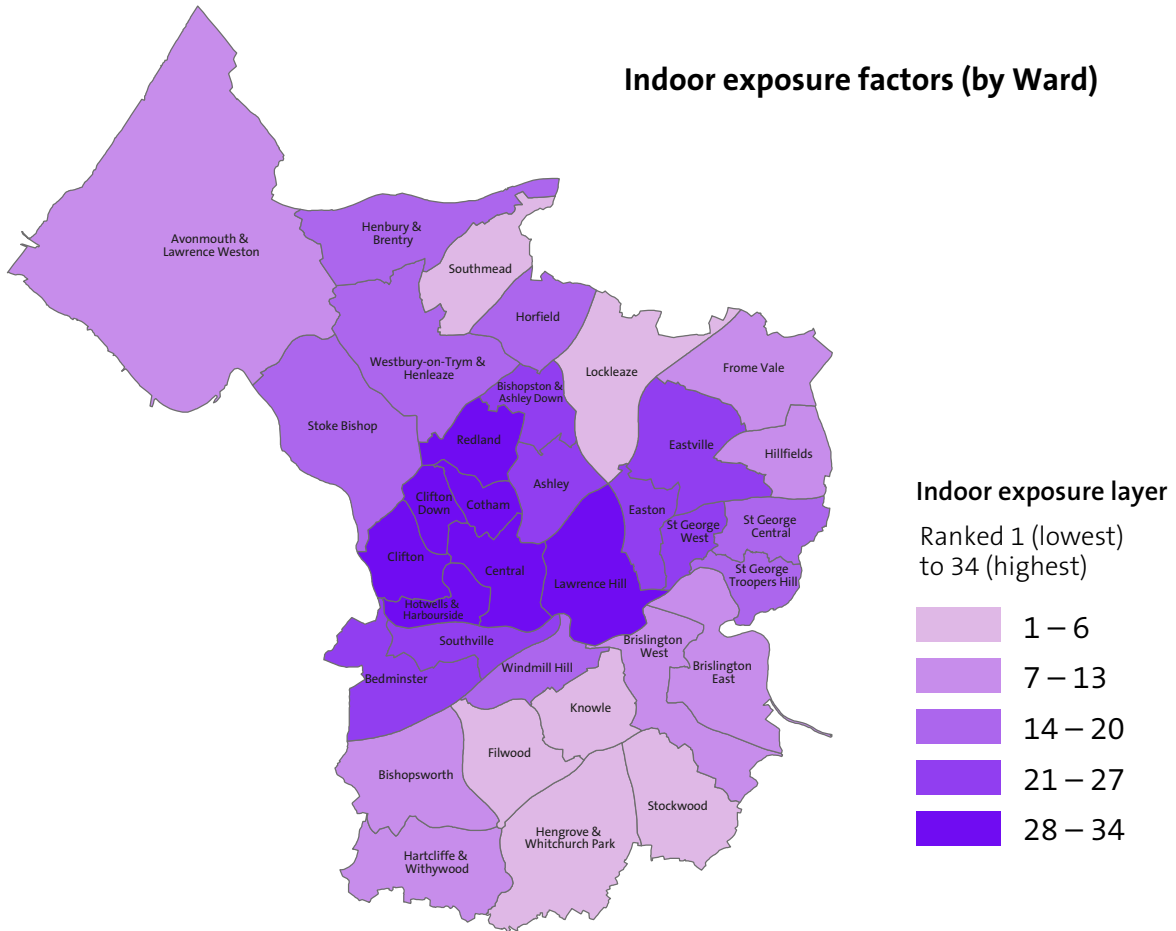
Overall heat vulnerability index (by Ward)



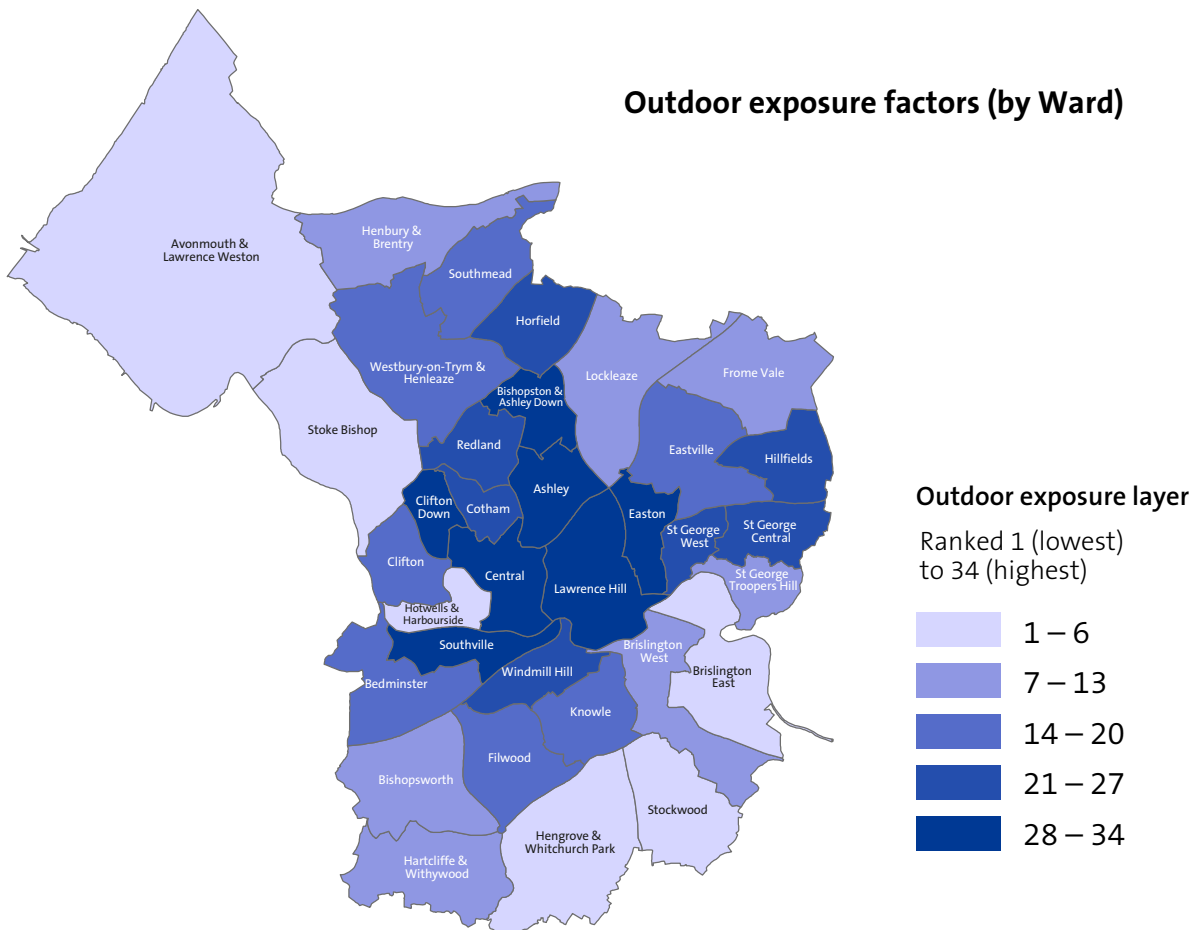
Age related factors (by Ward)



Indoor exposure factors (by Ward)



Outdoor exposure factors (by Ward)



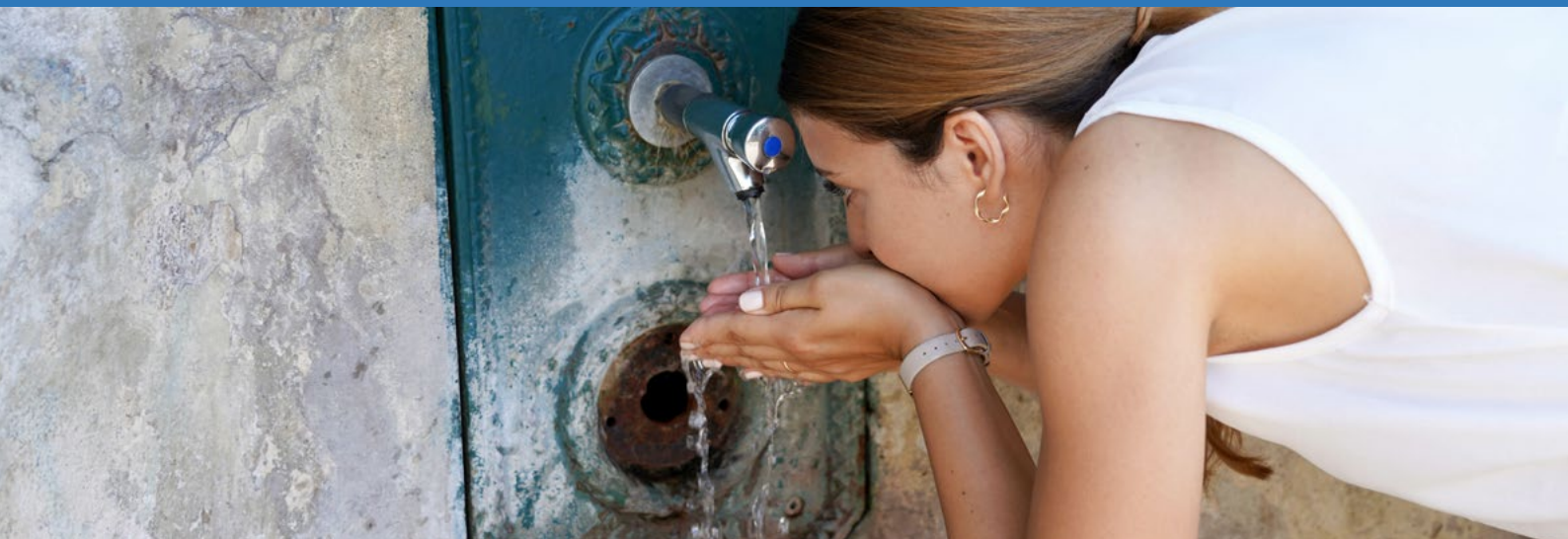


Bristol's Quality of Life Survey, 2022

The Quality of Life Survey provides an annual snapshot on the quality of life in Bristol. It is the council's main tool for providing neighbourhood-level statistics and public perception information. The statistics are analysed at a ward-level and for equalities groups such as age, sex, and ethnicity. The data provides valuable insights that help the council, health services and other public sector partners to help plan local services, track change, and improve the quality of life in Bristol.

The survey has been running since 2001 with some of the questions changing over time. Data across approximately 180 indicators is collected through the survey including ones specifically about climate change. Over the last three years, local residents have been asked whether their homes had suffered from overheating during the last 12 months.

By exploring the 'problem' through this data, it's allowed us to identify 'solutions' – with four priority themes for action, specific goals for each theme and a set of 20 objectives for implementation over the next two to three years.



The Quality of Life survey shows that about 1 in 2 people living in the city centre wards of Hotwells & Harbourside and Central reported that their homes overheated last year. This is a dense urban area with access to the waterside but limited green space which is in high demand during hot weather. The city centre also has a high concentration of flats including purpose-built student accommodation.

Looking at the spread across equalities groups, younger people (aged 16 to 24 years) and people in private rented accommodation were most likely to report overheating (at 57% and 50% respectively). Younger people, in general, also tend to live in private-rented accommodation more than other groups. This demographic could also explain why LGB+ (Lesbian, Gay and Bisexual+) and Trans reporting levels are also so high (at 53% and 55% respectively)¹.

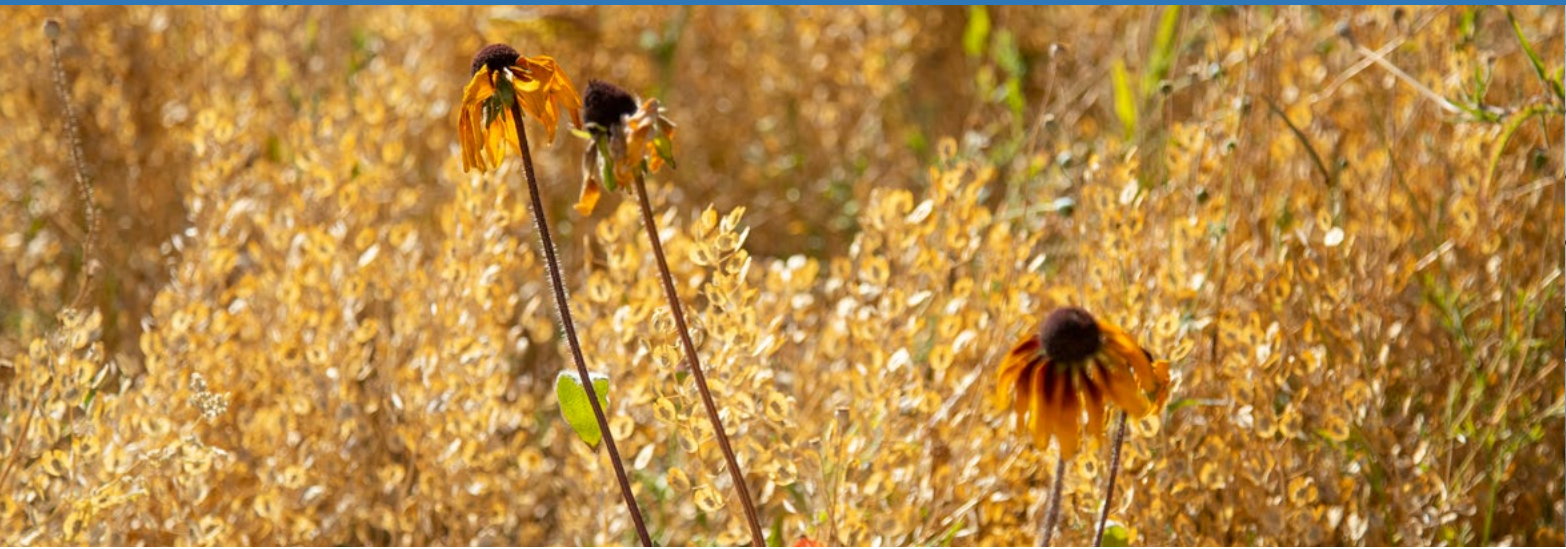
There are between 60–800 caravan dwellers in Bristol that will be vulnerable to heat. These are situated across the city, most are aged 25–49 years, but the oldest is 79 years old. The majority do not have access to

clean drinking water, or water for washing clothes or showering. Their vans heat up during hot weather so can be uncomfortable to live in, and with no showers they cannot cool down easily. Those without roofs and/or are homeless, will face similar problems and be especially vulnerable to heat.

At a national scale, the British Red Cross briefing on heatwaves in the UK looked into public perceptions of heatwaves² based on a survey of 2,000 adults during the summer of 2021. While most adults see heatwaves as a potential risk to other people's health, some of the most vulnerable groups underestimate the risk to their own health. Over half of people aged 75+ did not consider themselves vulnerable to the impact of heatwaves. Other at risk groups who did not consider themselves vulnerable included people: with a heart condition (31%), with a lung condition (28%), those living in a top-floor flat (30%) and those working outdoors 30+ hours a week (34%). Four in 10 adults also think heatwaves are a normal part of summer, with over a third of people believing that they are a problem of the future, not the present.

¹ LGB+ and Trans definitions from [Equality Strategy 2018–2023](#)

² [British Red Cross report on heatwaves in the UK](#)



Our work to tackle the climate and ecological emergency

This framework builds on and supports ongoing initiatives to tackle the twin climate¹ and ecological² emergencies. Details of these can be found in our Action Plans and our website.

Vision and Principles

The One City Climate Strategy sets out our vision and principles,

‘In 2030, Bristol is carbon neutral and climate resilient. We have collectively achieved a fair and inclusive transition; capturing the opportunities for new jobs and investment, improved health, wellbeing and education, and a better environment for local people. We have helped lead the way to a safer global climate.’

The vision includes five principles which have been applied to this framework and the issues it contains:

Evidence based

Our work will be informed by robust evidence from leading climate science and practitioners.

Learning

All council decisions will consider the risks of overheating so that we work towards making our policies, plans and services more climate resilient.

Transformative and Collaborative

We will produce and implement a Keep Bristol Cool Action Plan guided by this framework working inclusively and collaboratively with organisations and the community.

Action will be prioritised in areas with the greatest heat vulnerability.

Action will be prioritised to protect the most vulnerable people.

Fair

We will ensure that our commitment to social justice remains at the heart of what we do.

¹ [Climate emergency](#)

² [Ecological emergency](#)



Our strategic Goals and Themes for urban heat resilience

Taking the evidence base, case for action, and our current work around the climate and ecological emergency, we've created four high-level strategic goals that Bristol's urban heat resilience should strive towards.

These are live goals, which will need to be regularly readdressed and reassessed to ensure we're making progress toward them in the best way possible. A future action plan will use these goals as a starting point to create and assign actions towards making Bristol more urban heat resilient.

Specific actions will also be underpinned by the specific themes that sit under each goal. Many of these themes are cross-cutting in nature, but for the purpose of this framework have been allocated to their most relevant goals.



Goal 1: Protecting vulnerable people, the public, council employees and council services during heatwaves

Protecting people's health and wellbeing during heatwave events including maintenance of critical public infrastructure and services.

Themes:

1. Improving severe weather planning
2. Using latest evidence to warn and inform
3. Improving heatwave preparedness
4. Trialling the monitoring of heat impacts
5. Providing cool places



Goal 2: Future-proofing growth and city regeneration

Building urban heat resilience into new pieces of the city, city infrastructure, and new developments.

Themes:

1. Local Plan climate adaptation policies
2. Using latest evidence to inform regeneration frameworks
3. Understanding resilience of city council infrastructure
4. Working with infrastructure providers to understand their heat vulnerability
5. Engaging citizens with visions of the future



Goal 3: Tackling overheating risk in people's homes

Making people's homes safer and more comfortable for communities, visitors and workers when building new homes and retrofitting existing properties.

Themes:

1. Understanding resilience of care settings
2. Taking an integrated approach to retrofitting homes
3. Ensuring the council's new homes do not overheat
4. Working with the wider housing sector to improve resilience
5. Awareness raising with home-owners



Goal 4: Using blue green infrastructure for cooling streets and public spaces

Making places safer and more comfortable for communities, visitors, and workers when creating new places and retrofitting existing neighbourhoods.

Themes:

1. Defining a potential cool corridors network
2. Understanding the resilience of major public spaces
3. Trialling nature-based solutions
4. Improving community resilience
5. Harnessing citizen science

Goal 1: Protecting vulnerable people, the public, council employees and council services during heatwaves

Improving severe weather planning

Heatwaves are being increasingly common we will need to ensure our severe weather plans and processes are heat wave ready. The national Adverse Weather and Health Plan¹ provides guidance and recommendations on how local authorities can improve their preparedness and response plans.

Using latest evidence to warn and inform

The latest urban heat evidence base, such as the Keep Bristol Cool mapping tool, can help identify high-risk communities and vulnerable groups. This will enable better targeting of information and advanced warning of heat waves.

Improving heatwave preparedness

Improving how prepared the council, education institutions, workplaces and community facilities are for heatwaves is important for achieving this goal. This could include raising awareness, preparing business continuity plans and signing up to weather warnings.

Trialling the monitoring of heat impacts

There is currently limited data available on the impacts of heatwaves and extreme heat on key council functions, such as building closures, critical service delivery and asset performance. Through collecting more data, we can better plan actions to improve resilience.

Providing cool places

The Welcoming Spaces Network was set up in October 2022, initially to support residents over autumn and winter, and many spaces have continued to operate following the initial period. These spaces can provide support during heatwaves, such as drinking water, guidance on keeping homes cool, details on shaded local greenspaces, and information from partners on relevant services.



¹ [Adverse Weather and Health Plan - GOV.UK](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/103111/Adverse_Weather_and_Health_Plan.pdf)

Goal 2: Future-proofing growth and city regeneration

Local Plan climate adaptation policies

The revised Local Plan will guide development in the city over the next 20 years. During this time, the frequency and duration of heat waves are likely to increase, and average and peak summer temperatures will be higher. Climate change adaptation policies within the Local Plan will help ensure new development is resilient to increased temperatures and contributes to wider city resilience.



Using latest evidence to inform regeneration frameworks and masterplans

Areas of the city will undergo significant change over the next 20 years and regeneration frameworks and masterplans are being developed for these areas to guide development. The latest urban heat evidence base, such as the Keep Bristol Cool mapping tool, can be used to inform the production of the frameworks and masterplans to provide the foundations for heatwave ready development.



Understanding resilience of City council infrastructure

Bristol City Council is responsible for a large amount of infrastructure that is vital for the city to function, including highways, energy, ICT, drainage and flood risk assets. Understand how resilient these assets are to increased heat will help guide future asset management and upgrade works.

Working with infrastructure providers to understand their heat vulnerability

Much of the city's vital infrastructure, such as electricity and water supply, is managed by third parties. Understanding the vulnerability of the city's infrastructure systems requires a coordinated approach – identifying common challenges, interdependencies and priorities. These infrastructure networks are regional, so addressing this will involve collaborating with our neighbouring local authorities and the West of England Combined Authority.

Engaging citizens with visions of the future

Co-creating a positive vision for a climate resilient future with citizens can help build support for changes to our buildings, streets, neighbourhoods and open spaces. This theme would involve working with our academic, arts, culture and community partners.

Goal 3: Tackling overheating risk in people's homes



Understanding resilience of care settings

Adult and children's care facilities, including residential, day-care and specialist units, could be particularly affected by heat waves. Understanding more about the resilience of our facilities will be important to make operational, asset management and future-proofing decisions.



Taking an integrated approach to retrofitting homes

We are undertaking an ambitious programme to retrofit our council homes. The primary aim of this programme is to improve the energy efficiency and reduce the carbon emissions of the homes but it is also an opportunity to implement measures that reduce overheating risk. Learning from initial projects can inform later stages of the retrofit programme.



Ensuring the council's new homes do not overheat

New council homes should provide for the comfort, health and wellbeing of occupiers throughout the year and include measures for reducing overheating risk over their lifetime. There are also opportunities for the developments to benefit the surrounding environment's climate resilience, through providing green infrastructure.

Working with the wider housing sector to improve resilience

Increased heat will affect all housing in the city so working with housing sector partners to raise awareness and knowledge share will be a vital part of tackling overheating across the city.

The Bristol Living Rent Commission, alongside other issues, highlighted limitations in the council's and private tenants' power to improve the quality of private rented housing sector across the city, which includes the adaptations needed to combat global heating. Therefore, this framework looks at the actions that can be taken within the council's control in regard to housing, while ensuring information campaigns around the issue are pertinent to all of Bristol's citizens.

Awareness raising with home-occupiers

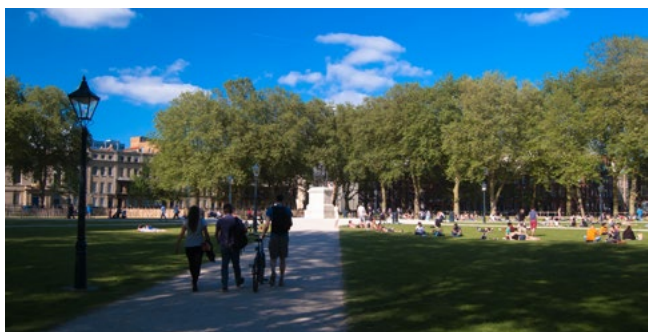
It will be important to that people have access sound and consistent advice on how to keep their homes cool during hot weather and heatwaves. This will involve working with healthcare and social housing partners.

Goal 4: Using blue and green infrastructure for cooling streets and public spaces



Defining a potential cool corridors network

A strategic network of cool corridors (e.g. river walkways or shaded avenues) can provide resilient routes for active travel through city during hot weather. This could be defined within the Bristol Green and Blue Infrastructure Strategy and then delivered through new developments, the management of council assets, and working in partnership with key landowners and Business Improvement Districts.



Understanding the resilience of major public spaces

Major public spaces in the city centre, such as Lloyds Amphitheatre, Millennium

Square, Castle Park and Queen Square, are often heavily used during the summer, including for events. Understanding the current resilience of these spaces to heat can inform future operations, assess management and future-proofing.



Trialling nature based solutions

Nature based solutions, such as sustainable urban drainage systems, can deliver multiple benefits, improving flood risk, wellbeing and nature, as well as heat resilience. Trailing and monitoring these systems can help build the evidence base for wider use in the city.

Improving community resilience

Green infrastructure, such as trees, can be used to improve the resilience of neighbourhoods. The Keep Bristol Cool Mapping Tool can help identify the most vulnerable neighbourhoods in the city and direct the focus of green infrastructure improvements to improve community resilience.

Harnessing citizen science

Citizen science and co-design can be used to build a story of place, which generates insights into the lived experience of different communities during heatwaves. There are opportunities to work with city partners, including academia and community organisations, on initiative to support this.



Next steps

We are already making progress towards the achieving goals within this framework, with work underway across many of the themes. There is more work to do across all the themes within the framework. Following the publication of the Keep Bristol Cool framework, the council will develop an action plan over the coming year to support achievement of these goals, working with its team, wider partners and the community.

Monitoring and reporting

We will review progress annually and seek input from external partners and advisors such as the Bristol Advisory Committee on Climate Change as appropriate.



Acknowledgements

The support of our funders: UK Research & Innovation (UKRI) Strategic Priorities Fund UK Climate Resilience Programme and the council's Climate and Ecological Emergency Programme.

The Keep Bristol Cool project team (past and present): Sustainable City Team Bristol City Council, Embedded Researcher Dr Charlotte Brown, Tyndall Centre for Climate Change Research (University of Manchester), Met Office Urban Climate Services Team, and Sarah Toy Consulting.

Those who laid the foundations for this work: Cabot Institute University of Bristol, 4 Earth Intelligence, Growth and Regeneration

Scrutiny Commission, Forest Research, and all participants at our Heat Vulnerability in a Changing Climate practitioner workshop.

Our partners, contributors, reviewers, testers and co-authors: colleagues across Bristol City Council; West of England Combined Authority; Healthier Together - Bristol North Somerset & South Gloucestershire Sustainability & Health Group, Bristol Resilience Group (Avon & Somerset Local Resilience Forum), Bristol Advisory Committee on Climate Change, West of England Sustainability Group, Social Housing Decarb Forum, Landsmith Associates, Core Cities Adaptation Working Group, and everyone else who helped along the way.

Appendix Glossary

GIS: Geographical Information Systems is a technology that allows data to be visualised on a map. It is an efficient tool for exploring spatial data and investigating place-based questions such as how heat vulnerability varies across a city.

Heat Vulnerability Index: The HVI brings together spatial information on Bristol's population, people's homes, and their local environment with a focus on heat-health risks.

Index of Multiple Deprivation: This combines datasets on income, employment, education, health, crime, barriers to housing and services and living environment as a way of ranking each small area of England from the most deprived to the least deprived area.

LGB+: This stands for Lesbian, Gay, and Bisexual with a plus sign to include Genderqueer, Non-Binary, Questioning, Intersex and Asexual etc.

LSOA: A Lower Layer Super Output Area is a geographical unit commonly used for the collection and reporting of data on populations and households in cities. There are 263 of these areas in Bristol.

MSOA: A Middle Layer Super Output Area is a geographical unit commonly used for the collection and reporting of data on populations and households in cities. There are 55 of these areas in Bristol.

Normalised Difference Built-up Index: A Normalised Difference Built-up Index (NDBI) is a way of estimating the density of built-up areas using satellite images. It measures the difference between shortwave-infrared light (strongly reflected by built-up areas) and near-infrared light

(strongly absorbed by less built-up areas). The index ranges from +1 to -1 with higher values representing more built-up areas.

Normalised Difference Vegetation Index: A Normalised Difference Vegetation Index (NDVI) is a way of estimating the density of vegetation in an area using satellite images. It measures the difference between near-infrared light (strongly reflected by vegetation) and red light (strongly absorbed by vegetation). The index ranges from +1 to -1 with higher values representing more greenspace.

NOx: This refers to a combination of nitrogen dioxide (NO²) and nitric oxide (NO). Together they are often referred to as oxides of nitrogen (NOx). NOx is produced by combustion processes. Health effects are associated with NO₂. Short term exposure to high levels of NO₂ can cause irritation to the respiratory system causing inflammation. Studies have shown long term exposure is associated with reduced lung development and respiratory infections in childhood and effects on lung function in adulthood. In building the Heat Vulnerability Index, NOx data has been used as a proxy for window opening, alongside other pollutants and noise levels.

PM: Particulate matter is everything in the air that isn't a gas, a suspension of particles which are solid, liquid or somewhere in between. It can come from natural sources such as pollen, sea spray and desert dust, and human-made sources such as smoke from fires, soot from vehicle exhausts, dust from tyres and brakes, as well as emissions from industry. PM is often classified according to size and referred to as 1) coarse particles known as PM₁₀ (particles that are less than 10

microns (μm) in diameter) or 2) fine particles known as PM_{2.5} (particles that are less than 2.5 μm in diameter). There is an extensive body of evidence that long-term exposure to PM increases mortality and morbidity from cardiovascular and respiratory diseases. In building the Heat Vulnerability Index, PM data has been used as a proxy for window opening, alongside other pollutants and noise levels.

Proxy: This is information or data which acts as a substitute for direct measurements. For example, using noise and air pollution data as a 'proxy' for people opening their windows because higher levels are likely to act as a deterrent. Another example is using land surface temperatures taken from satellites and information on population density as 'proxies' for the Urban Heat Island effect.

Trans: This is an umbrella term to describe people whose gender is not the same as, or does not sit comfortably with, the sex they were assigned at birth. Trans people may describe themselves using one or more of a wide variety of terms, including (but not limited to) transgender, transsexual, gender-queer (GQ), gender-fluid, non-binary, gender-variant, crossdresser, genderless, agender, nongender, third gender, bi-gender, trans man, trans woman, trans masculine, trans feminine and neutrois¹.

UK Climate projections: This is a set of tools and data that shows us how the UK climate may change in the future. UKCP Local provides information at a city-level on what these changes might look like.

Urban Heat Island: This describes a phenomenon where the urban environment of a city experiences higher temperatures than more rural surroundings. Each city has its own unique pattern.

¹ [List of LGBTQ+ terms](#)

Research and innovation

We invite academia and technology partners to investigate:

1. Monitoring Bristol's urban climate using a citywide meteorological network either as a dedicated system or through existing infrastructure assets.
2. Waste heat contributions to Bristol's urban heat island and key interventions.
3. Smart Apps which could assist Bristol's heatwave response.
4. Methods for capturing, processing and visualising organisational-level data on the impacts of heatwave events.
5. Hierarchy of options for changing surfaces at roof and ground level e.g. cool pavements, green roofs etc to reduce Bristol's urban heat island.
6. Permitted Development Rights monitoring data for tracking higher-risk conversion of buildings from non-residential to residential and home improvements such as loft conversions and extensions.
7. Estimation of greening levels for a +2°C 2080 and +4°C 2080 climate scenario taking into account areas where higher levels may be needed to address the urban heat island effect.
8. Retrofit packages for private-rented accommodation including occupancy-level mitigations and landlord interventions.
9. Adapting Bristol's historic environment for higher temperatures and heatwaves.
10. Neighbourhood-level lived experience of people during heatwaves, including mining social media.