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Policy brief
Cities, climate change and chronic heat exposure

Headline issues

- Chronic heat exposure can seriously affect health and productivity; climate change will amplify the duration and magnitude of exposure.
- Developing countries are especially vulnerable to sustained high temperatures, due to their location, urban design and poverty levels.
- Decisions on infrastructure investment in urban areas are central to managing chronic heat exposure and to avoiding it in the future.

Policy briefs provide analysis on topical issues, presenting specific recommendations to inform ongoing policy debates. Drawing on the Grantham Research Institute's expertise, they summarise either our research findings or the state of knowledge about a particular issue.

This policy brief has been written by **Patrick Curran, Christian Siderius** and **Tanya Singh**.

Summary

Exposure to high temperatures over long periods can have serious implications for human health, productivity and infrastructure. Many of these impacts are already being felt. Under countries' current commitments to climate change action, the world is set for 3–4°C of warming, which could mean an increase in prolonged exposure to extreme heat and exacerbation of these impacts.

Developing and emerging economies are particularly vulnerable because most are located partially or entirely in tropical regions, and because they are urbanising. Urban areas face additional risks from heat because their density amplifies temperatures through the urban heat island effect, and because of the conditions in and the design of unplanned 'informal' settlements, which create conditions that exacerbate heat risks while their residents lack the financial means to mitigate the impacts. The risks are especially high for the elderly, children and the infirm.

The ability to avoid, manage and build resilience to chronic heat exposure in the future will depend on decisions taken now. Urban design and infrastructure investment, socioeconomic inequality and climate change risks have to be managed simultaneously. Necessary actions include reforming building standards, undertaking vulnerability reviews, and investing in infrastructure that is built to withstand, as well as minimise, chronic heat exposure, particularly in informal, vulnerable areas.

> "Climate change will lead to increases in the occurrence of *chronic* heat exposure over longer durations and there is an urgent need to focus on managing the risks this poses."

Heat exposure, lives, livelihoods and development

With current temperatures at around 1°C above the pre-industrial average, already there are climate change impacts being felt. One of these is the increased frequency, duration and intensity of heatwaves (Coumou et al., 2013). The adverse impacts of heatwaves on mortality, morbidity and livelihoods are felt most acutely in developing countries and by society's most vulnerable (the poor, elderly, children, and people in ill health). Climate change will lead to increases in the occurrence of *chronic* heat exposure over longer durations – for weeks or even months – and there is an urgent need to focus on managing the risks this poses, as well as the immediate risks from shorter-lived heat events.

The cumulative effects of being exposed to temperatures that exceed high-risk thresholds over long periods, at both day and night, can compound pre-existing risks to physical health. Prolonged exposure, even for an acclimatised human body, can decrease the capacity of individuals to work or be productive, leading to decreased efficiency, more employee absenteeism and increasing the risk of illness or injury (Shuang et al., 2019; see also Box 1).

Factors that amplify the risks and threats include poor housing conditions, working in the informal sector which brings with it uncertain income and limited savings (acting as a barrier to affording mitigating measures), working outdoors, and having a pre-existing health condition. All of these factors are more likely to affect lower-income groups. In contrast, higher-income groups can more readily adopt technological or behavioural changes (albeit up to a point), so for this group the costs of heat are more likely to be financial than health-related: they include the costs of air conditioning and costs to ensure energy or water security.

Therefore, chronic heat exposure can also aggravate existing inequalities and developmental challenges. It can limit access to water (because it can both reduce availability and cause system failures), damage transport infrastructure (which disrupts mobility), and place additional strain on electricity grids due to increased demand (for cooling) or supply-side failures. The health and personal safety implications can also overwhelm limited social services such as healthcare and education, leading to their potential disruption.

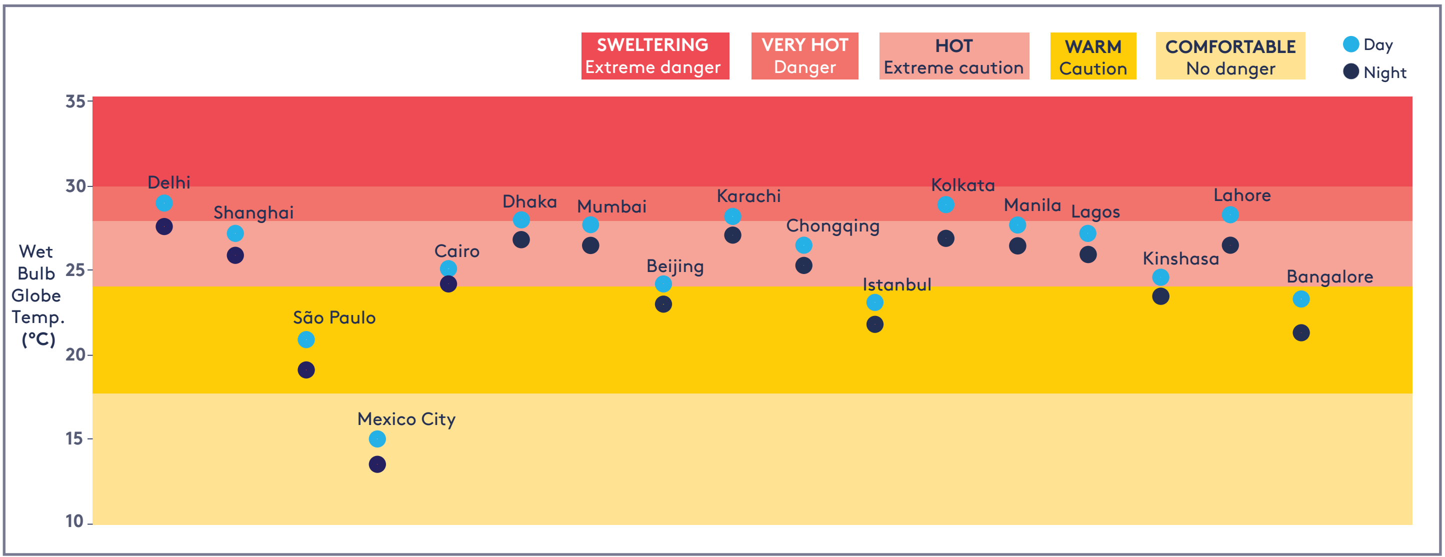
Box 1. Indices for assessing the danger of heat exposure

The impact of heat on humans is determined through several environmental variables, including air temperature, humidity, wind speed and exposure to solar radiation.

Different indices are used for different purposes but each has the aim of determining the risk of climatic conditions to human health (thermal stress) (e.g. the Wet Bulb Temperature – WBT) and the ability to continue activities (thermal comfort), such as the Physiologically Equivalent Temperature (PET), and the Wet Bulb Globe Temperature (WBGT). In this brief we refer to WBGT thresholds, which represent the potential impact of heat from continuing to undertake physical activities: this is the index most frequently used for workplace assessments. For a WBGT above 18°C it is recommended to keep alert to signs of heat stress; for a WBGT above 30°C it is dangerous to continue physical activity (Blazejczyk et al., 2012).

There is no specific indicator or threshold for sleeping conditions that considers prolonged extreme heat exposure. However, multiple concurrent warm nights are increasingly seen as a cause of heat risk and stress (see Obradovich et al., 2017).

Figure 1. Levels of heat exposure in the largest cities in developing countries in 2018



Developing countries: at the centre of heat exposure

Developing countries (including some emerging economies) are particularly vulnerable to heat impacts. All the Small Island Developing states (SIDs), 43 of the 47 least developed countries (LDCs), and most of the nations with the lowest incomes are located either entirely or partly in tropical regions (State of the Tropics, 2017), with most of these located in South Asia and equatorial Africa. Approximately 3.5 billion people live in these countries, around 40 per cent of the global population, and they are already facing hotter average temperatures due to global warming (Herold et al., 2017).

Developing countries are also home to 17 of the 20 largest cities in the world, accounting for nearly 300 million people (UN Population Division, 2018), significant because of the higher temperatures that urban areas experience in comparison with rural areas, as explained below.

Figure 1 illustrates the heat conditions currently experienced by these 17 cities. Seven cities experienced heat stress indicators either in, or bordering on, the 'Very hot (danger)' ranges. A further six cities experienced average Wet Bulb Globe Temperatures [see Box 1] in the 'Hot (extreme caution)' range, with the rest falling within the 'Warm' and 'Comfortable' range. However, within the 'Warm' range many were bordering on 'Hot' levels.

In 11 of the cities the heat stress indicators remained within the 'Hot (extreme caution)' range at night time, to the extent that the average exposure to heat stress at night over the summer months was only slightly below the exposure experienced during the day. The cities that currently experience temperatures at which 'caution' surrounding heat is advised both in the day and at night are home to around 280 million people in total. Of these, around 50 per cent live in temperatures during the summer months at which 'extreme caution' during both the day and night is recommended.

It is important to note that Figure 1 only illustrates heat stress during the three warmest months. In many of the cities shown, particularly those in South Asia, temperatures

Figure 1 notes and data sources: Represents average Wet Bulb Globe Temperature (WBGT) during day and night time during the three summer months of 2018, calculated by the authors using data using World Meteorological Organization (WMO) station data and the WBGT calculator from Climate CHIP (www.climatechip.org/heat-stress-index-calculation). WBGT is calculated assuming indoor conditions or in shaded areas; it therefore assumes no direct sunlight and limited wind speed (Lemke and Kjelstrom, 2012). Heat stress levels and categories are based on Blazejczyk et al. (2012). The data in Figure 1 are collected from meteorological stations, which by regulation should be surrounded by open green space thereby shielding them from any urban heat island effect on measurements. 2018 was the fourth warmest year on record (see WMO, 2019: https://library.wmo.int/doc_num.php?explnum_id=5789).

> “The cities that currently experience temperatures at which ‘caution’ surrounding heat is advised both in the day and at night are home to around 280 million people.”

generally start rising in early March, and remain high until the onset of the monsoon in June or early July, after which high humidity adds to the WBGT. Indeed, it is often only in early October that the risk of heat exposure significantly reduces. These temperatures are also likely to represent the lower estimates, as air temperatures in densely built-up areas are likely to be higher due to the urban heat island effect (UHI) (discussed below).

Urbanisation and its implications

Some of the largest countries in developing regions are projected to see over half of their population living in urban areas by 2050 (UN Population Division, 2018), with growth expected in major cities but also in small and medium-sized cities. While heat impacts people in rural areas too, residents of cities are especially vulnerable, both because there are increasing numbers of urban residents and because the risks from heat are further amplified by the urban heat island (UHI) effect (see Figure 2 for the example of Delhi). The UHI can add between 2°C and 7°C-plus to the air temperature (Shahmohamadi et al., 2011).

Factors that amplify or ameliorate heat in cities include the presence of vegetation (for shade and evapotranspiration), proximity to water, building density and height, presence of air pollution, and the orientation of streets and buildings in relation to prevailing winds and solar radiation. In general, the features that mitigate heat are unevenly spread, with higher-income areas having a greater presence than lower-income areas, and thus being cooler (see Box 2 for a description of how this occurs in three South Asian cities, and Figure 2 on Delhi).

Box 2. Exposure to extreme heat conditions in informal neighbourhoods

The exposure of areas of different income levels to outdoor heat in Delhi (India), Dhaka (Bangladesh) and Faisalabad (Pakistan) have been explored by Jacobs et al. (2019). The study took temperature and thermal exposure measurements between April and June 2016 in each city.

In Dhaka, daily peak temperatures exceeded the Wet Bulb Globe Temperature (WBGT) threshold of ‘Very hot (danger)’ (28°C) on all of the days that measurements were taken, and on 95 per cent of these days these temperatures were in the ‘Sweltering (extreme danger)’ risk category (above 30°C). In Delhi and Faisalabad, the WBGT temperatures breached the highest risk (‘Sweltering’) category on 97 and 98 per cent of the days, respectively.

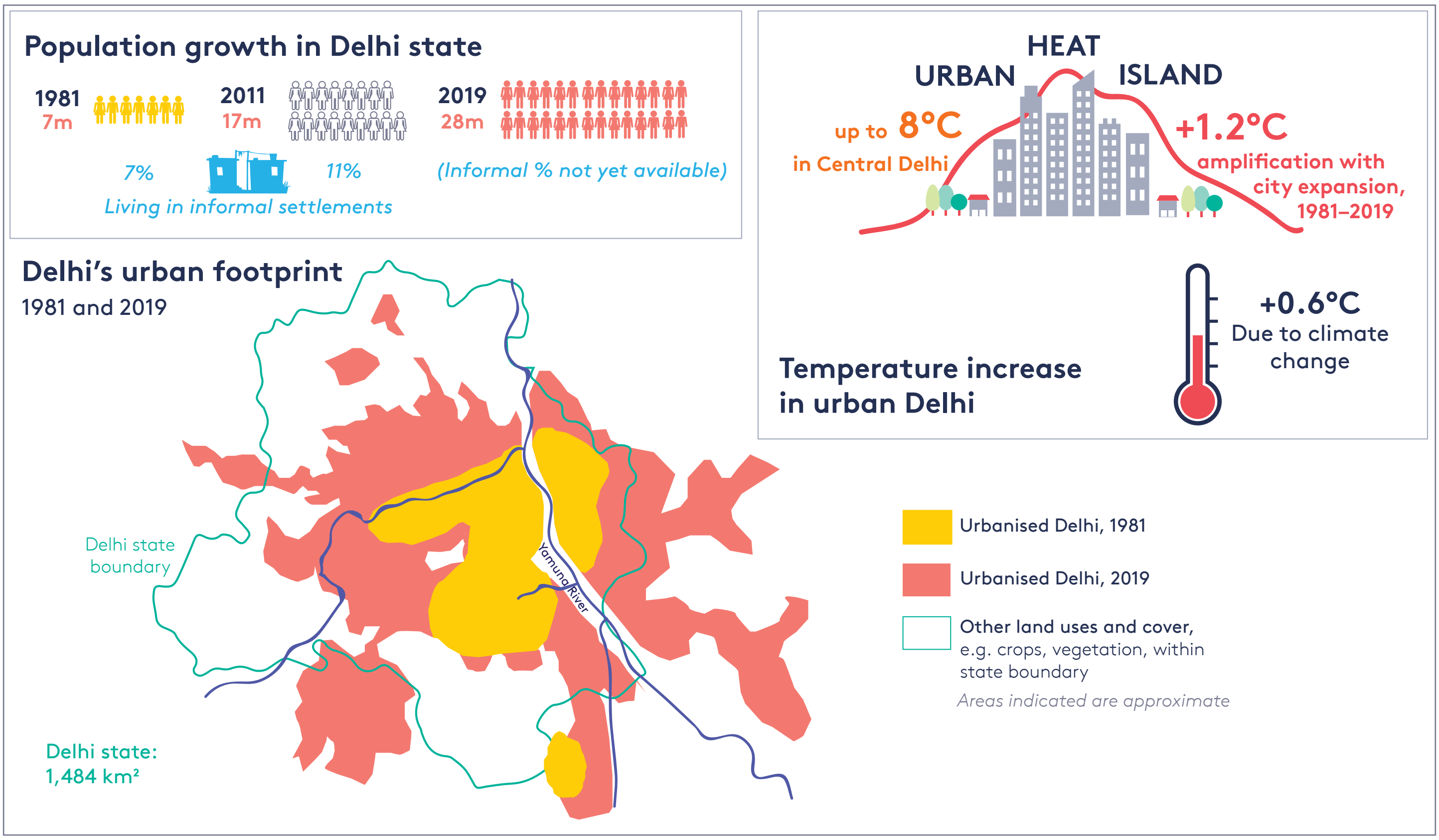
However, the heat characteristics varied depending on the neighbourhood:

- In general, higher income neighbourhoods were more likely to have conditions, including shading from trees or buildings at street level or more green space, that reduced heat storage and provided a cooling effect.
- More densely built low-income neighbourhoods did have some shade during the day, but their dense nature meant greater exposure to high temperatures, particularly at night.

Further, in Delhi and Dhaka, a typical house in an informal neighbourhood (see p5) could be up to 8°C warmer at night than the officially recorded outdoor temperature, because of its construction of single brick walls with tin roofs. In contrast, in higher-income neighbourhoods, insulation, ventilation and typical roofing materials tend to reduce the difference between indoor and outdoor temperatures, and air conditioning provides further cooling.

Source: Summarised from Jacobs et al. (2019)

Figure 2. Increased vulnerability and exposure to chronic heat: example of demographic and urban changes in Delhi, India, 1981–2019



The risks of chronic heat exposure are particularly pronounced in 'informal' areas of cities – those that are unplanned, or where citizens live with no tenure rights. This is due to underinvestment in or limited access to water, energy and transport infrastructure, less access to social support such as healthcare, or features that amplify heat exposure, such as unfavourable building materials or location (see Box 2). Informal areas of cities are still prevalent in many countries that could be exposed to chronic heat conditions. For example, in Bangladesh and Nigeria around 50 per cent of urban residents live in informal settlements (World Bank, 2019).

Climate change and future heat exposure in urban areas

The risks of heat and the ability to manage the impacts in urban areas could also be exacerbated by climate change. Coffel et al. (2017) project that between 2060 and 2080, parts of southern India, central Africa, south-east Asia, and Central and South America may experience between 50 and 150 days a year with temperatures at levels considered dangerous to human health. This projection assumes that temperatures are stabilised at around 2°C above pre-industrial levels. However, countries' current commitments under the Paris Agreement put the world on track for warming of around 3–4°C by 2100. In this scenario, exposure to extreme heat could more than double to between 100 and 250 days per year towards the end of the century (ibid.) – in other words, near-constant dangerous heat for a significant portion of the year.

Figure 2 notes and data sources:
The urban heat island effect was estimated by the authors based on the population and rural–urban temperature difference from Oke (1973) for illustration purposes. Delhi has changed not only in size but also in shape over time: these effects were not taken into account in this estimation. In 2011 87 per cent of Delhi's population did not have access to air conditioning (Desai et al., 2015), largely due to affordability issues. Population figures from Census of India (1981 and 2011); informal settlement data from Chakrabarti (2001) and Census of India (2011); anthropogenic contribution to surface temperature change from Ross et al. (2018). Image by Georgina Kyriacou.

"Choices made now on how urban infrastructure is constructed and planned could either exacerbate the challenges posed by extreme heat and climate change or build resilience to them."

The importance of infrastructure decisions

New investment in infrastructure is needed mostly to provide access to housing and basic services for the most vulnerable populations, and to enable growth and development. Choices made on how this urban infrastructure is constructed and planned – in terms of building materials, protection of existing green space and water resources, and the building of network infrastructure (transport, energy, waste) – could either exacerbate the challenges posed by extreme heat and climate change or build resilience to them (New Climate Economy, 2016). These decisions have to be made in a way that enables productivity and at the same time reduces exposure to urban heat island and climate change impacts.

For example, if the increased installation and use of air conditioning is prioritised as a heat adaptation strategy, this could ultimately exacerbate the risk of heat exposure if it is electrified through the combustion of fossil fuels that will emit further greenhouse gases. Air conditioning can also have more immediate impacts on neighbourhood heat, as the evacuation of heat from buildings raises the temperature at street level, sometimes by around as much as 1°C (Salamanca et al., 2014).

Neighbourhood or citywide decisions can also result in trapping heat by creating microclimates. For example, supporting road transport infrastructure that perpetuates the emissions of particulate matter and heat can amplify the UHI effect; and choosing to remove trees and water sources to provide space for building reduces the day and night time cooling benefits that these features bring. But sensible choices can be made, as the example of Singapore shows (Box 3).

Policy recommendations

To prepare for and manage chronic heat exposure, we recommend the following actions for the stakeholders named below:

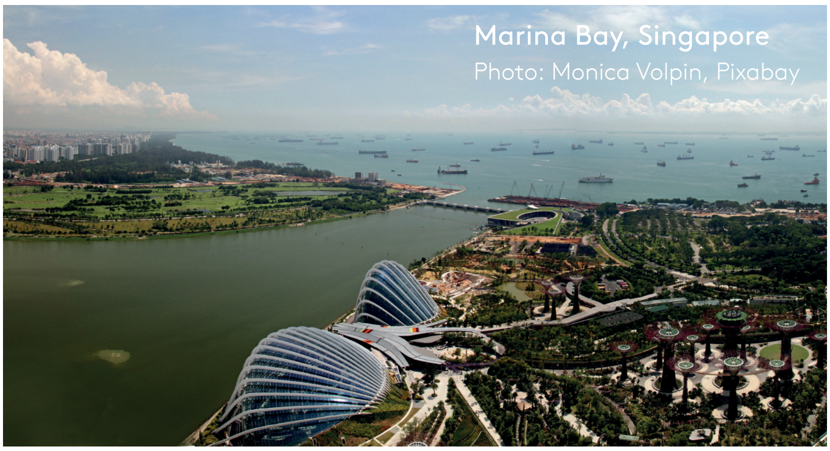
National and regional governments

- Update development policies to reflect the risks of chronic heat exposure to health, infrastructure and productivity. Heat management solutions should be integrated into resource

Box 3. Heat management in Singapore

In the past 20 years Singapore's population has increased by nearly 50 per cent but urban planning decisions have led to green cover increasing by 11 per cent.

The authorities have prioritised cooling, including through mandatory tree planting requirements, providing financial support for demonstration of passive cooling on buildings (green walls and roofs), and effective management of green space (Tan et al., 2013).


Marina Bay, Singapore
Photo: Monica Volpin, Pixabay

allocation and activities of all departments, including those responsible for urban planning, housing, transport, health, water and energy.

- Reform housing and building standards (where responsible) to mandate passive heat management techniques (e.g. green roofs) for new buildings. Technological heat management solutions, such as air conditioning, must be combined with mandatory energy efficiency standards and corresponding investment in renewable energy.
- Introduce support programmes for existing buildings to incorporate heat management technologies, including insulation, roofing and natural ventilation.

Local governments and utilities

- Set minimum requirements for housing developments to incorporate city- and neighbourhood-wide heat management techniques, including around shading, tree planting, preservation of natural features, provision of green space, and street-level orientation that minimises heat retention.
- Undertake a vulnerability review of current public infrastructure, both physical (energy, water, transport and housing) and social (health), to manage and continue operation under different levels of extreme, chronic heat conditions.
- Invest in a combination of the appropriate grey infrastructure (e.g. public transport, flexible energy grids, water distribution) and green infrastructure (e.g. permeable pavements, wetlands, water bodies) to address the energy, water, transport, waste management and communication needs of informal, vulnerable areas. This infrastructure must be designed, planned and built to withstand, as well as minimise, chronic heat exposure.
- Collaborate with representatives of informal areas (e.g. slum-dwellers' organisations, housing associations) to identify appropriate and low-cost heat management solutions and raise awareness and disseminate information on chronic heat management options (behavioural and technological).

Property developers and investors

- Property developers must integrate climate change scenarios and thermal heat indices (such as the WBGT) into project evaluation and design processes. The criteria should assess risks to the thermal comfort of users and to the operational lifespan of projects. Investment should integrate solutions to allow for continuous use, protection of users, and avoid activities that exacerbate heat (materials, fossil fuel combustion).
- Public and private finance investment institutions should undertake a risk assessment of existing portfolios of infrastructure to climate change impacts, including both prolonged heat and heatwaves, to fully understand and reflect risks to operations, returns and users.

Development support and finance organisations

- Develop and fund support programmes in partnership with local governments to identify, develop and implement management techniques for chronic heat exposure, and protect natural areas within urban boundaries, prioritising the expansion and integration of green infrastructure options.

"Public and private finance investment institutions should undertake a risk assessment of existing portfolios of infrastructure to climate change impacts."

- Work with community-based organisations to develop support programmes, including funds and investment vehicles that enable the development and dispersal of appropriate low-cost heat management information, techniques and technologies.
- Create specific research grants and programmes that focus on the link between chronic heat related to climate change and urban development in developing countries to gain a broader understanding of the associated risks and the most effective combination of technological, behavioural and policy solutions to manage exposure.

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