



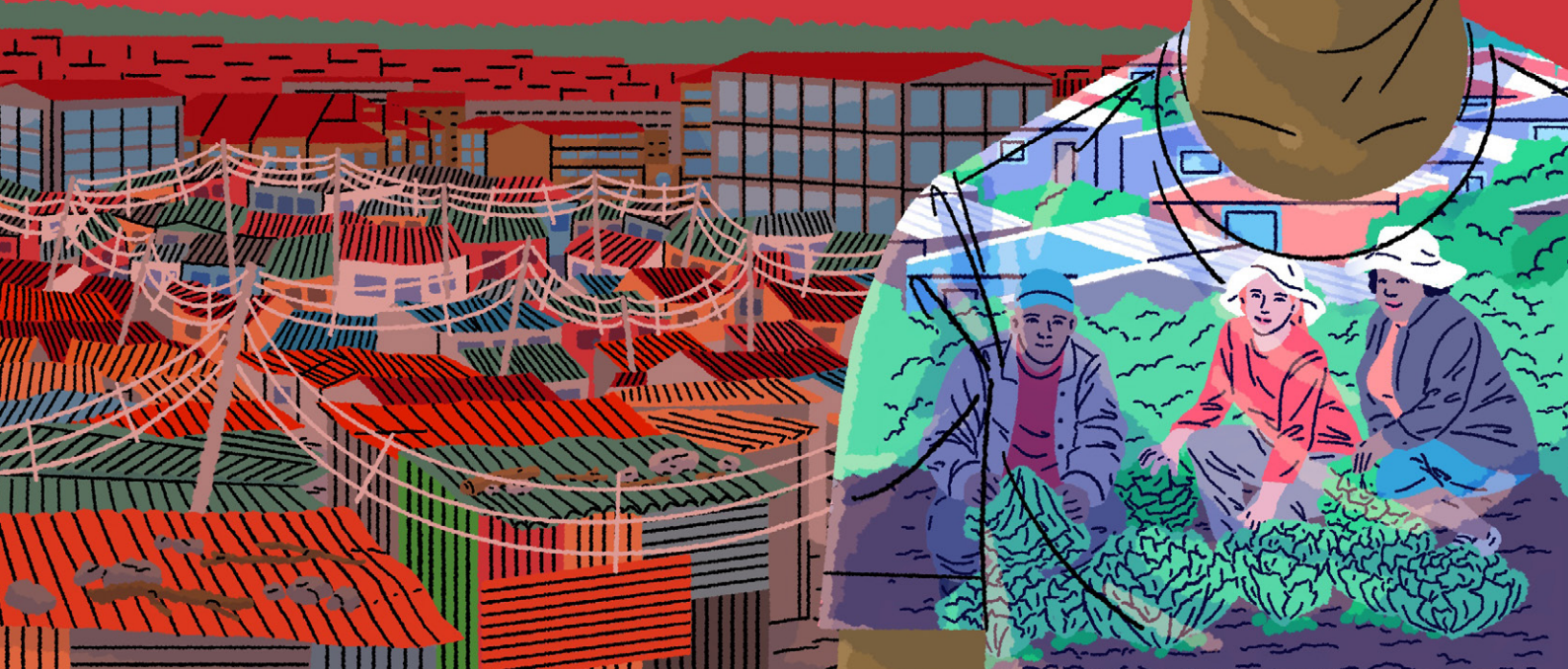
**national treasury**

Department:  
National Treasury  
REPUBLIC OF SOUTH AFRICA

**clTiEs** SUPPORT PROGRAMME

# URBAN HEAT IN JOHANNESBURG AND EKURHULENI

## Impacts and Mitigation Options



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# FOREWORD



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Historical temperature trends in Johannesburg have shown clear signs of increase. There are indications as well that extreme temperatures are on the increase. This suggests possibilities of heatwaves and/or warm spells. Potentially this has severe health impacts for the City's residents, particularly the poor, those with low adaptive capacity, the elderly and those living with pre-existing medical conditions.

The City's adaptation plan review process highlighted the need for the City to prioritize development of a heat plan. Furthermore, under the Climate Action Plan (CAP), Goal focusing on "A Climate Resilient City by 2050", under the theme- "Healthy Communities" has a specific action area, with a focus on the protection of communities from heat-related health effects. This will be done through provision of cooling areas during periods of excessive heat. These cooling areas will be achieved by creating a network of cool shelters, to protect community health and care for vulnerable groups. Moreover, rising temperatures can increase the risk of transmission of vector-borne and other diseases, for which supervision and control protocols will need to be established.

The urban heat assessment study undertaken, is important to the City as it will help enhance the City's plans towards providing communities with relief during periods of excessive heat. The assessment has been useful in coming up with suggested heat stress response actions to help the City in the acceleration of the implementation of the following heat-related actions:

- Awareness raising campaigns to educate citizens on how to remain cool during extreme heat days;
- Development of more green spaces to reduce heat; and
- Understanding of heat-related mortality and morbidity.

The measures suggested in the heat assessment report are however not exhaustive, which then opens the City to investigating more options.

**Lebo Molefe**

**Director**

Air quality, Climate Change and Energy  
Environment and Infrastructure Services Department (EISD)

# FOREWORD



Cities continue to be key contributors to climate change, through greenhouse gas emissions from sectors like built environment, energy, transport, and waste. The effects of climate change such as flooding, storms, drought, and heatwaves are already being experienced globally. The City of Ekurhuleni (CoE) like other cities in the global south, remains more vulnerable to these impacts due to existing environmental, social, economic, and political challenges. This makes the need for climate action and building climate resilience very important.

The City of Ekurhuleni is committed to being a carbon-neutral (Net Zero) City region by 2050. To support this, the CoE has established a Climate Change unit within the Environmental Resource and Waste Management Department that is focused on building climate resilience in the City. The work of this unit is guided by the Council approved Climate Change Response Strategy (2017) that details the City's climate change vision and targets. Furthermore, the CoE has finalised its Green City Action Plan (2022) that seeks to support the achievement of its mitigation goals. These strategic policy frameworks are promoted by the City's active engagement in National and International Networks such as C40 Cities, ICLEI, Global Covenant of Mayors, South African Cities Network and National Treasury's Cities Support Programme.

The urban heat island assessment that has been undertaken with support from the National Treasury's City Support Programme provides a spatial view on heat across the City, thereby addressing the long-term heatwave risks. This report is a crucial policy informant as it provides scientific data and a clear policy directive on urban heat impacts in the City. The adaptation measures laid out in this report will then be implemented to build climate resilience and reduce the impacts of heat in the CoE.

A handwritten signature in black ink, appearing to read "FWotshela".

**Ms Faith Wotshela**

**Head of Department**

Environmental Resource and Waste  
Management  
City of Ekurhuleni

# ACKNOWLEDGEMENTS

This study was prepared by a core team comprising staff of the World Bank, VITO and PlanAct, in collaboration with the National Treasury of South Africa and its Cities Support Programme, and the Metropolitan Municipalities of Johannesburg and Ekurhuleni.

The World Bank team was led by Nicholas Jones (Data Scientist), Monyake Moteane (Urban Specialist), Ross Eisenberg (Disaster Risk Management Specialist), Nerali Patel (Consultant) and Andrew Nell (Consultant) with technical inputs from Boris van Zanten (Disaster Risk Management Specialist) and Steven Rubinyi (Disaster Risk Management Specialist).

Design of the field measurement campaign, technical supervision of fieldwork, climate modeling and report drafting were led by the VITO team comprising Koen de Ridder, Niels Souverijns, Nele Veldman, Raf Theunissen and Filip Lefebre. Implementation of the citizen science field measurement campaign was led by the PlanAct team comprising Frederic Kuzambizi-Kiingi, Wetu Memela, Mike Makwela, Bafana Tshabalala and Siphwe Segodi.

The study was produced under the overall guidance and leadership of Eric Dickson (Senior Urban Development & Disaster Risk Management Specialist), Peter Ellis (Practice Manager, Urban and Disaster Risk Management - Eastern and Southern Africa) and Niels Holm-Nielsen (Practice Manager, Global Facility for Disaster Reduction and Recovery).

The project team thanks Anthea Stephens (National Treasury) for her leadership and strategic guidance. The team gratefully acknowledges Lebo Molefe and Mzukisi Gwata (City of Johannesburg) and Is'haaq Akoon and Nokuthula Dubazane (City of Ekurhuleni) for their guidance and contributions.

Support for publication and dissemination was provided by Yoko Kobayashi (GFDRR) and Chris Morgan (Fundi Films). The study was made possible through funding from the Swiss State Secretariat for Economic Affairs, the Global Facility for Disaster Reduction and Recovery and the City Resilience Program.

# EXECUTIVE SUMMARY



In South Africa's Highveld region, which hosts the metropolitan areas of Johannesburg and Ekurhuleni, climate change has so far led to a temperature increase by more than 1.5°C, relative to pre-industrial values. Because of the urban heat island phenomenon, both metros are facing even higher temperatures, and a consequent additional exposure to excessive heat.

A detailed modelling study was conducted to assess this, the results showing that the excess night-time temperature in both urban areas is higher by up to 6°C compared to nearby rural areas, especially in dense neighbourhoods such as Soweto, Alexandra, Tembisa and Katlehong. During daytime also, these neighbourhoods are characterized by high levels of heat stress, largely because of

the lack of green vegetation and the shadow it provides, but equally because of the widespread occurrence of low-cost dwellings, for which a community-based monitoring study found excess temperatures by 10°C and more.

From an analysis involving maps of socio-economic characteristics, a picture emerges of excessive temperatures primarily occurring in densely built neighbourhoods that are lacking in green vegetation and that are home to majority black and low-income communities living in low-cost dwellings; in fact, largely reflecting apartheid-era urban planning patterns.

Excessive heat stress is expected to become considerably worse with climate change, regional projections showing an additional temperature increase by 2.5°C to 5.9°C at the end of the century, compared to today. As a result, the number of tropical nights occurring in the urbanised areas of Johannesburg and Ekurhuleni will increase nearly five-fold and daytime heat stress will increase from 'strong' to 'very strong' and 'extreme'.

The ensuing upward exposure is expected to induce severe impacts. In particular, increasing heat will lead to enhanced morbidity and mortality, especially among the elderly, the very young, and those with underlying ailments such as tuberculosis or HIV. Moreover, excessive heat will adversely affect labour productivity – hence the overall economy – and will cause additional strain to the energy sector because of a higher cooling energy demand.

Yet, heat mitigation solutions are available. In particular, a field monitoring study involving a hundred community participants has revealed the cooling power of urban trees. The simple fact of dwelling in the shadow of a tree reduces heat stress considerably, from 'strong' down to 'moderate' or even 'limited' heat stress. Fine-scale modelling studies and thermographic photography campaigns confirm these effects, and add evidence concerning the cooling effects induced by other measures, such as roof whitening to reduce the heat load upon buildings from the sun.

Based on insights from the monitoring and modelling exercises conducted in Johannesburg and Ekurhuleni, and considering existing local and international heat mitigation policy, concrete recommendations are formulated to enhance the resilience of both metros to excessive heat. Among these recommendations, the 'greening of under-provisioned neighbourhoods' is important, as is the recommendation to substantially enhance heat-health early warning and awareness plans, which is considered a very efficient measure in terms of its cost-benefit ratio. Further recommendations concern cooling strategies for low-cost dwellings and for public spaces; the development of community cool spaces (shelters); measures to combat heat-related occupational health issues and labour productivity loss; and measures to reduce building cooling demand. Finally, to be successful, mainstreaming these recommendations across all city policies is crucially important.



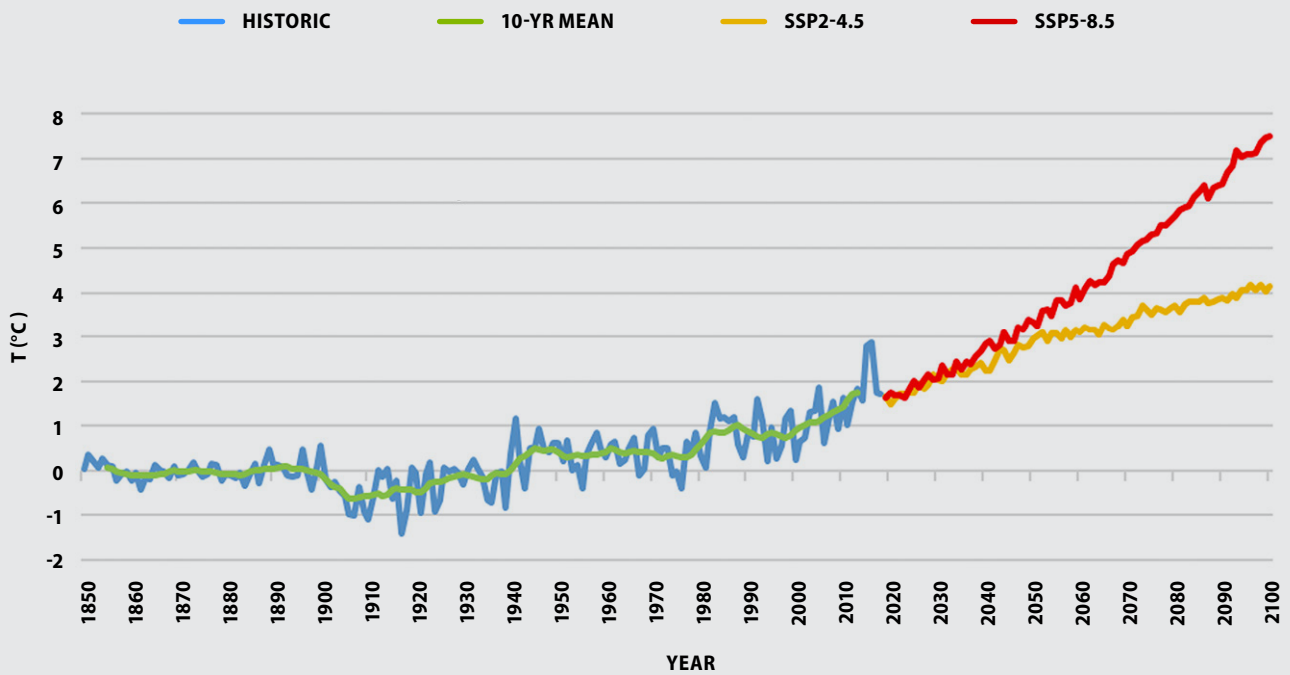
**T**o date, global temperature has increased by nearly 1.2°C relative to pre-industrial values. Atmospheric carbon dioxide concentrations have risen from 280 to 410 ppm. At the current pace of emissions, the carbon budget that is left to stay below the 2°C target of the Paris Agreement will be depleted in a few tens of years. For the 1.5°C target, this budget will be exhausted before the decade is out.

Regional impacts of global climate change are increasingly apparent in South Africa. Observations show that in Johannesburg and Ekurhuleni, temperature has increased by more than 1.5°C relative to the period 1850-1900 (Figure 11). This has caused a rise in the annual number of hot days and the associated adverse health effects. At the same time, the amount of precipitation has decreased, and the occurrence of dry spells has increased.

**FIGURE 1.1. HISTORIC (1850-2018) AND FUTURE (2019-2100) EVOLUTION OF ANNUAL MEAN AIR TEMPERATURE RELATIVE TO 1850-1900 AT 28.1°E, 26.2°S, (APPROXIMATE POSITION OF THE WIDER JOHANNESBURG-EKURHULENI AREA).**

The blue line shows historic (observed) values, the green line presenting a 10-year running mean. The yellow and red lines display temperatures for a medium (SSP2-4.5) and high (SSP5-8.5) climate scenario, respectively.

**Source:** HadCRUT4 filled-in historic data and CMIP6 future projections (ensemble mean), data retrieved from the KNMI Climate Explorer (<https://climexp.knmi.nl/start.cgi>).



According to the most recent climate projections (Figure 1.1), temperatures in the Johannesburg-Ekurhuleni area will continue to increase, by 1.2°C-1.7°C towards the middle of the century and by up to 5.9°C at the end of the century, relative to 2020 and depending on the climate scenario. At the same time, the projected reduced cloudiness will induce higher amounts of solar radiation at the surface, contributing to enhanced heat stress and drying out of the soil. Mean precipitation will further decrease, yet intense precipitation events are expected to become more intense still. Higher temperatures, more radiation and less precipitation will increase aridity. From this emerges a picture that, even though currently Johannesburg and Ekurhuleni may benefit from fairly temperate climate conditions, temperatures in the area will increase strongly under climate change.

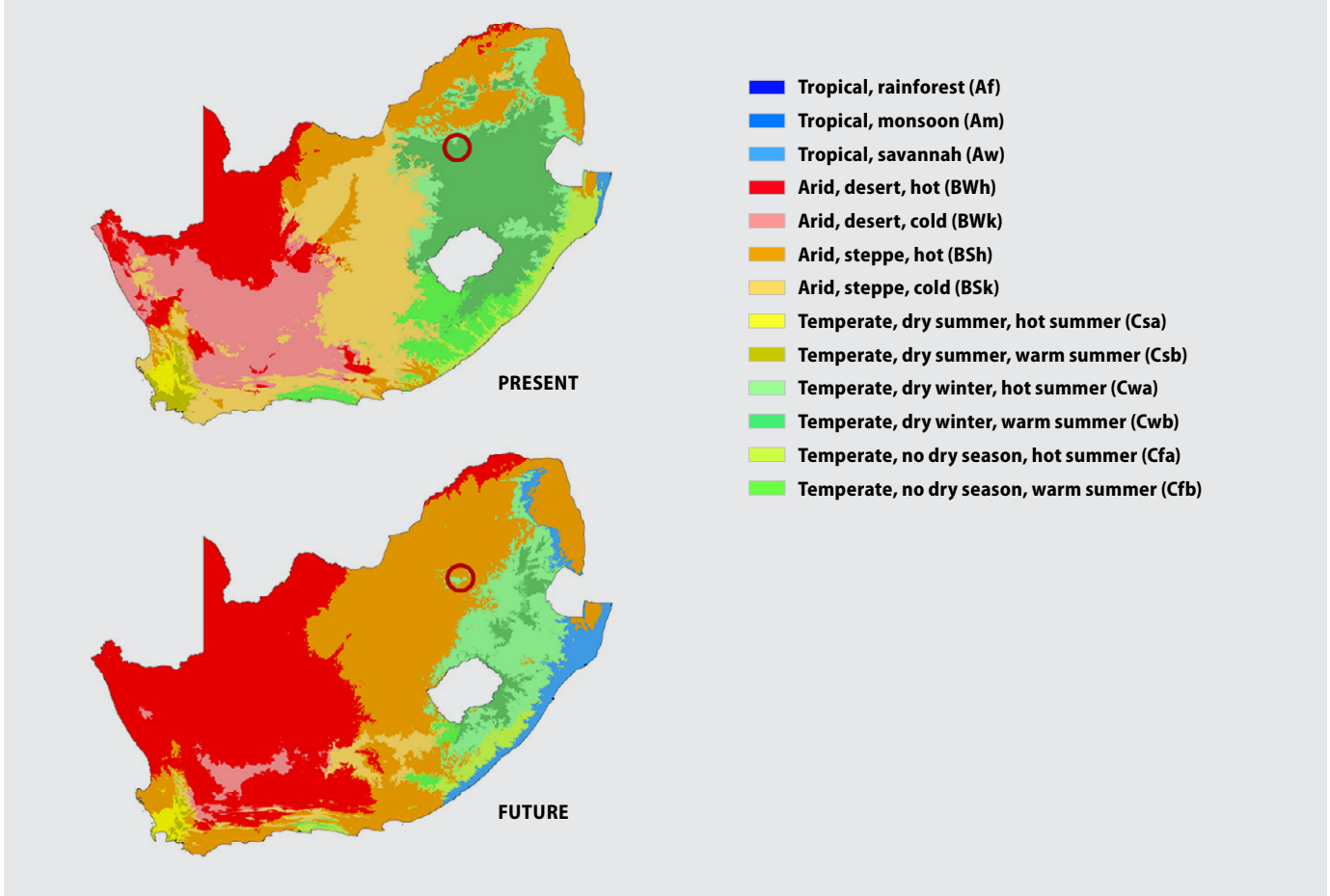
The regional climate shift towards a hotter and dryer future is also apparent in the projected change of the Köppen climate zones (Figure 1.2). Currently, the Johannesburg-Ekurhuleni area is categorized as a Cwb type of climate (temperate, dry winter, warm summer). Towards the end of the century, under a high climate scenario, the area will experience a shift to a BSh climate (arid steppe, hot) – currently restricted to the northernmost regions of the country (North West and

Limpopo provinces) – with some intermixtures of a Cwa climate (temperate, dry winter, hot summer). As a result, the future climate of the Johannesburg-Ekurhuleni area will be at par with the climate currently encountered in certain regions within India, North Australia, and areas close to the Sahel.

**FIGURE 1.2. PRESENT (1980-2016, TOP PANEL) AND FUTURE (2071-2100 AND HIGH CLIMATE SCENARIO, BOTTOM PANEL) CLIMATE ZONES OF SOUTH AFRICA ACCORDING TO THE KÖPPEN CLASSIFICATION.**

The red circle is centred on the position of Johannesburg and Ekurhuleni.

Source: data from Beck et al. (2018), figure adapted from Wikipedia ([https://en.wikipedia.org/wiki/Climate\\_change\\_in\\_South\\_Africa](https://en.wikipedia.org/wiki/Climate_change_in_South_Africa)).



Moreover, since both metros are highly urbanised, exposure to extreme heat is exacerbated by the urban heat island phenomenon, i.e., the fact that cities tend to be warmer than nearby rural areas. While the average urban-rural temperature difference is of the order of a few °C, under specific conditions this difference may reach 7-8°C and more.

Realising that some level of climate change has become unavoidable, it is important to direct considerable actions and resources to adaptation. In this report, adaptation options to excessive heat are derived for Johannesburg and Ekurhuleni, accounting for the outcome of a heat mapping exercise and considering the urban character and socio-economic context of both metros.

The remainder of this report starts with the description of the spatial patterns of urban heat in Johannesburg and Ekurhuleni, using results from participatory field campaigns and urban climate modelling. The ensuing maps are analysed in conjunction with socio-economic data to identify the city quarters and population groups that are exposed most to excessive heat. Finally, a set of adaptation recommendations is provided to enhance resilience to present and future excessive heat in the municipalities of Johannesburg and Ekurhuleni.

Details of the heat mapping exercise are provided separately in a *Scientific Report* (Souverijns et al., 2022). Moreover, the present report is accompanied by a Technical Annex (De Ridder et al., 2022), which elaborates on certain methodological aspects of the study.



CHAPTER

# 2.

# URBAN HEAT IN JOHANNESBURG AND EKURHULENI



05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 00 01 02 03 04



30° 31° 32° 33° 34° 35° 36° 37° 38° 39° 40° 40° 39° 38° 37° 35° 33° 31° 30° 30° 30° 30° 30° 30°

## • 2.1.

### CITY NEIGHBOURHOODS FACE SHARP DISPARITIES IN HEAT INTENSITY

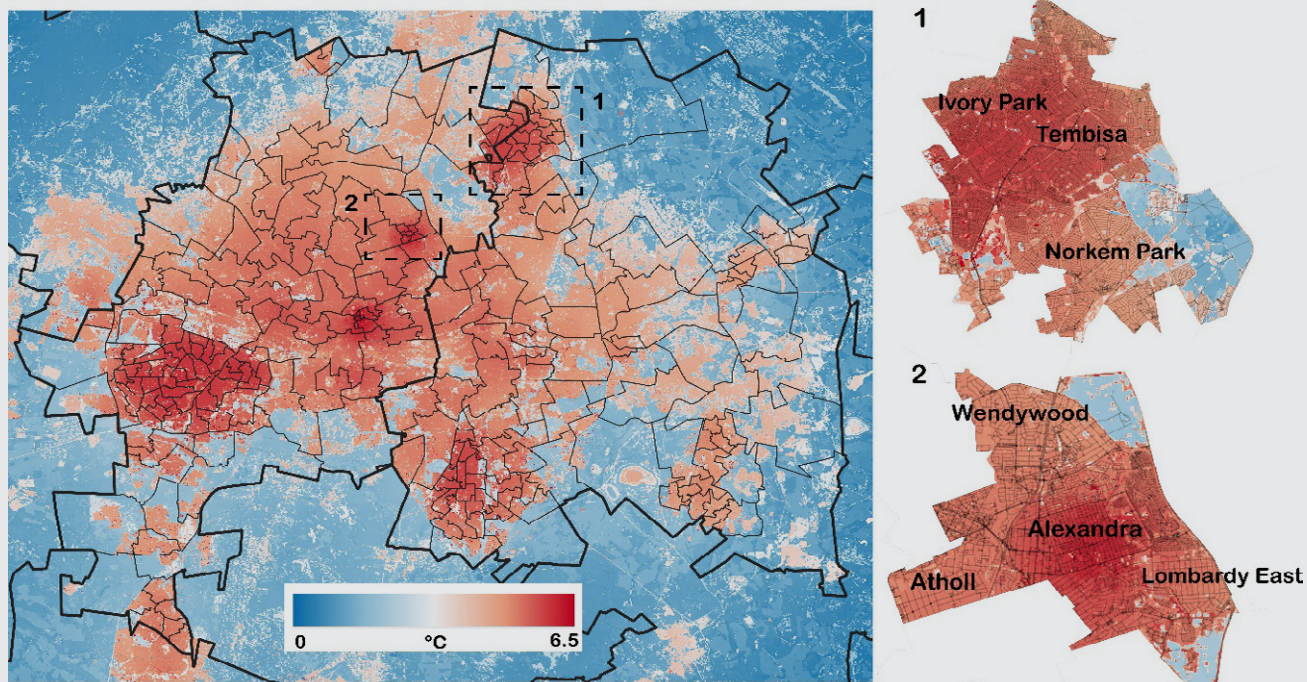
\* Note that, generally, the urban heat island is at its strongest during the night, when heat stored throughout the day is slowly released from the urban fabric.

Based on advanced urban climate simulations (Souverijns et al., 2022), a map of the night-time\* urban heat island intensity (urban-rural temperature difference) was produced (Figure 2.1.). The spatial extent of the urban agglomerations of Johannesburg-Ekurhuleni is clearly visible, large portions exhibiting excess temperatures amounting to 3-4°C, in some areas rising to 6°C. The highest urban

heat island intensity occurs in a few large townships, such as Soweto, Katlehong, Tembisa and Alexandra. Johannesburg’s Central Business District also stands out clearly.

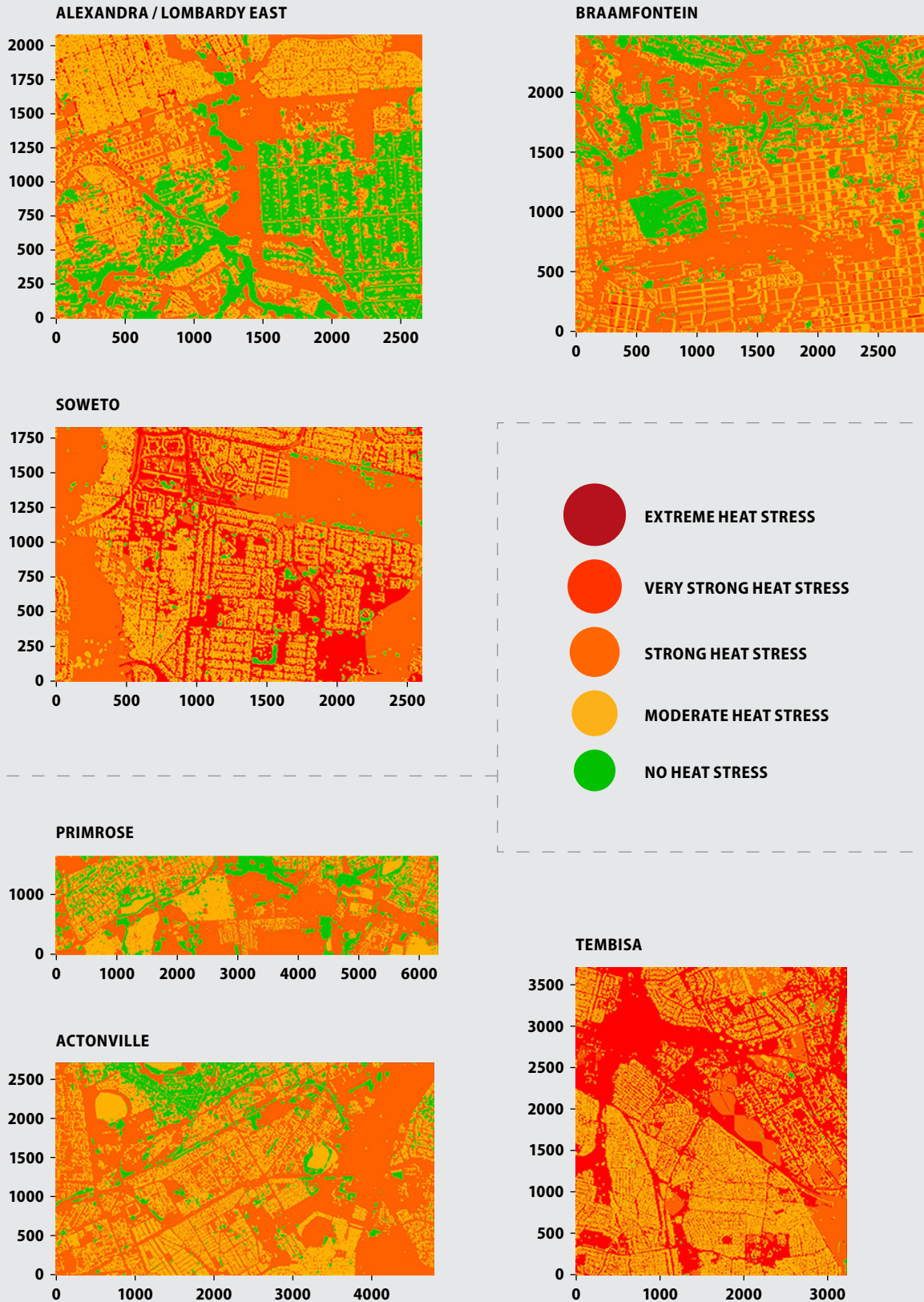
**FIGURE 2.1. URBAN HEAT ISLAND INTENSITY CORRECTED FOR OROGRAPHICAL (TERRAIN HEIGHT) EFFECTS.**

The rightmost panels show detailed views for areas centred on Tembisa (upper panel) and Alexandra (lower panel).

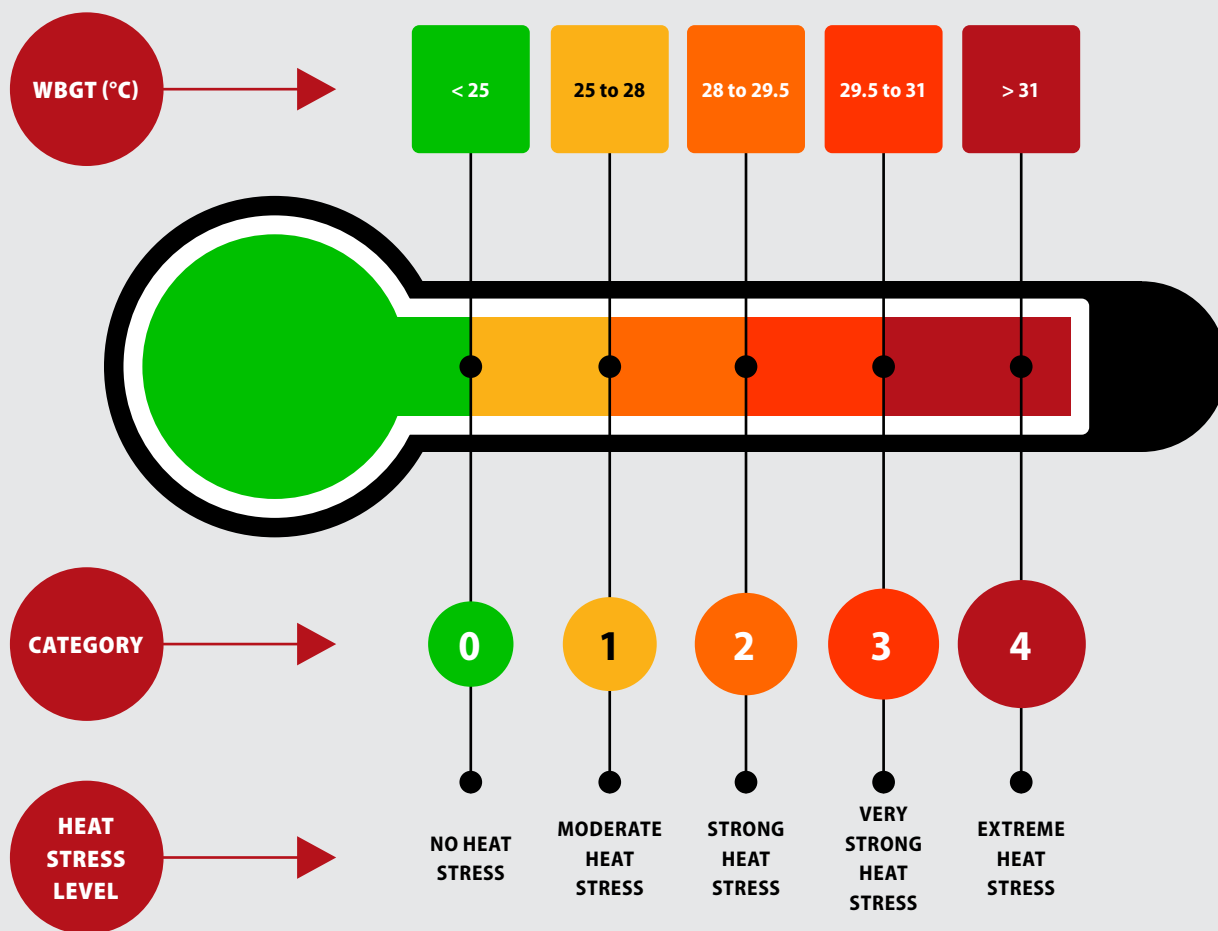


At a finer scale, spatial disparities in heat stress are also apparent. Figure 2.2 shows the simulated heat stress levels for six neighbourhoods in Johannesburg and Ekurhuleni – using the wet bulb globe temperature (WBGT, see Table 2.1) as a heat indicator – for the extremely hot day of 6 January 2016 at 15:00, when air temperatures in the area soared to 40°C. Overall, strong to very strong heat stress is encountered, especially in densely built city quarters as Soweto and Tembisa, and in open, sun-exposed areas. Conversely, thanks to the cooling effect of trees, green residential areas often fall in the ‘no heat stress’ category. The cooling effect of tall and shady vegetation is clearly expressed in low values of the WBGT, as the latter incorporates the effects of solar and thermal radiation.

**FIGURE 2.2. HEAT STRESS LEVELS SIMULATED FOR THE HEATWAVE DAY OF 6 JANUARY 2016 AT 15:00 LOCAL TIME FOR SIX NEIGHBOURHOODS IN JOHANNESBURG (UPPER PANELS) AND EKURHULENI (LOWER PANELS), BASED ON THE WET BULB GLOBE TEMPERATURE (WBGT).**



**TABLE 2.1. HEAT STRESS LEVELS FOR DIFFERENT RANGES OF THE WET BULB GLOBE TEMPERATURE (WBGT) VALUES.**



In fact, the WBGT incorporates effects of humidity, wind, and radiation, alongside air temperature, constituting a better proxy for human heat stress than air temperature alone. Designed to represent heat impacts in occupational health settings, it is subject to international standards (ISO, 2017); it is also included in South Africa’s occupational health regulations<sup>1</sup>. A word of caution is in order regarding the interpretation of WBGT values: even though this indicator is expressed in common units of degrees Celsius (°C), it cannot be compared to regular air temperature. For instance, while an air temperature value of 31°C may be tolerable (e.g., in dry and shady conditions), a WBGT this high represents a considerable heat stress with a hefty demand on human thermoregulation capacities.

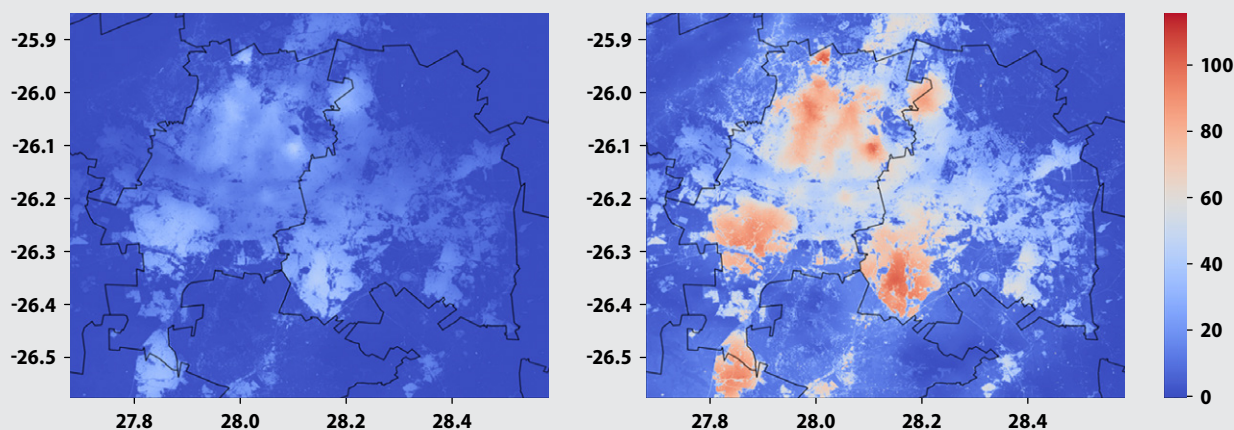
1 Act 85 of 1993, Environmental Regulations for Workplaces, updated 7 March 2003 (GoN R307, G. 2496), available at [http://www.saflii.org/za/legis/consol\\_reg/erfw428.pdf](http://www.saflii.org/za/legis/consol_reg/erfw428.pdf).

## 2.2.

# URBAN HEAT WILL INCREASE SUBSTANTIALLY BY 2050

Previously, Figure 11 showed that, in a high climate scenario, by 2050 the projected temperature increase in the Gauteng region relative to today will reach 1.2-1.7°C, which is expected to lead to an enhanced frequency of extreme heat events. Urban climate simulations do confirm a substantial increase of the occurrence of excessive heat in the Johannesburg-Ekurhuleni area, among other indicating that the average number of heatwave days – using the definition by the South African Weather Service (SAWS) – will increase from a current value of 1.3 days per year (period 2001-2020) to 8.4 days per year (2041-2060, high climate scenario), i.e., a more than six-fold increase. Yet, the number of heatwave days is affected only moderately by urban patterns: not only is the definition of a heatwave day only based on daily maximum temperature (which does not differ much between urban and rural areas); the topographical gradients within the domain obscure the urban patterns, having a dominant effect on temperature during the day.

**FIGURE 2.3. NUMBER OF TROPICAL NIGHTS (DAILY MINIMUM TEMPERATURE > 20°C) FOR PRESENT CONDITIONS (2001-2020, LEFT PANEL) AND FOR 2050 (AVERAGE FOR 2041-2060 UNDER A HIGH CLIMATE SCENARIO, RIGHT PANEL).**



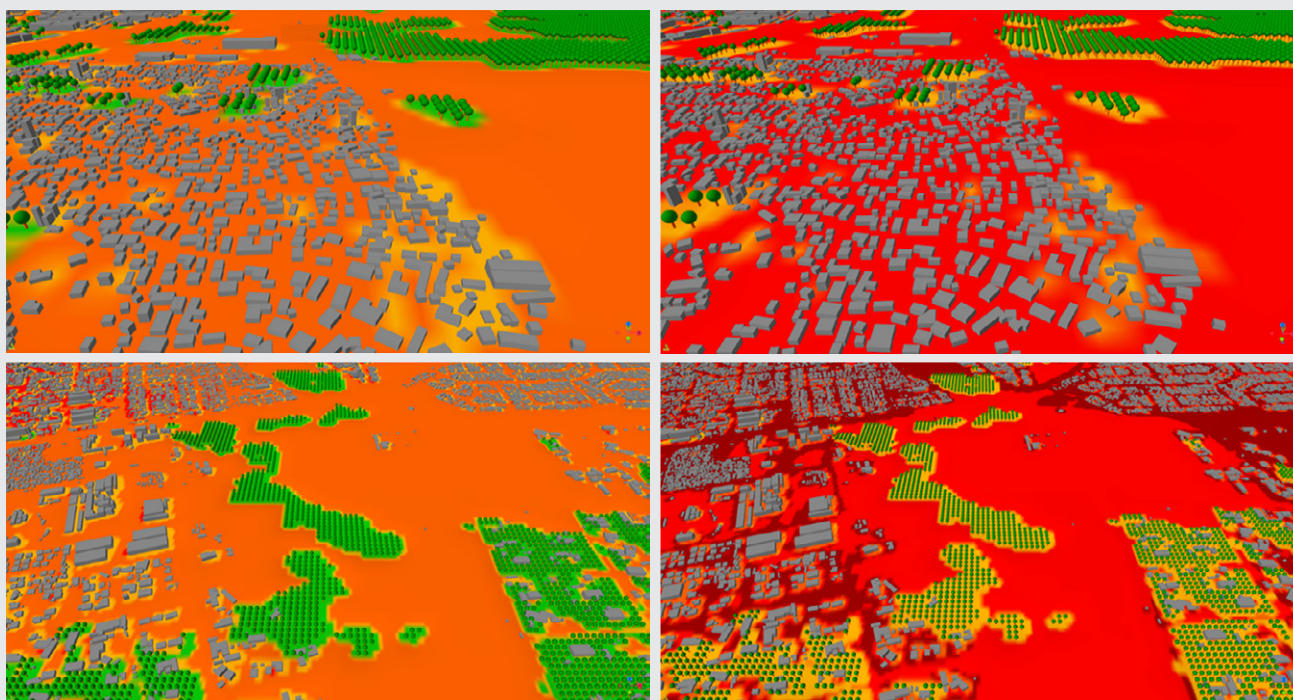
The effect of urban areas on night-time temperature is much more pronounced. For instance, the average number of tropical nights per year (Figure 2.3) – i.e., the number of nights per year when the minimum temperature exceeds 20°C – displays a distinct urban pattern. The simulation results also show that this quantity will increase substantially. While the annual number of tropical nights today is in the range of 5-10 over most of the agglomeration, areas exhibiting high building densities exhibit a figure of around 40 nights per year.

This changes towards 2050, when the number of tropical nights increases to 40-50 over large portions of the city, and to a value of approximately 100 in densely built areas devoid of vegetation. This increase in the number of tropical nights will have a clear health impact, since the lack of night-time cooling adversely affects people's capacity to rest and recover from daytime heat exposure.

A series of fine (metre-scale) modelling results confirm this tendency towards sharply increased heat stress conditions. As an example, Figure 2.4 shows current and mid-century heat stress maps for Primrose and Alexandra / Lombardy East on a heatwave day. It is found that, between the current situation and 2050, the heat stress in the open (sun-exposed) areas within the domain shift from 'strong' to 'very strong' and 'extreme' heat stress. Outdoor workers, such as construction workers or waste pickers, will be on the forefront of exposure to these extreme heat conditions. This will not only entail a high risk to their health, such levels of heat stress will invariably lead to a reduced labour productivity, thus impacting the economy.

**FIGURE 2.4. HEAT STRESS LEVELS IN PRIMROSE (UPPER PANELS) AND ALEXANDRA/LOMBARDY (LOWER PANELS) FOR THE HEATWAVE DAY OF 6 JANUARY 2016 AT 15:00 UNDER PRESENT-DAY (LEFT PANELS) AND FUTURE (2050, HIGH CLIMATE SCENARIO, RIGHT PANELS) CONDITIONS, FOR THE LATTER TAKING THE SAME PERCENTILE VALUE IN THE FUTURE TEMPERATURE PROBABILITY DISTRIBUTION AS THE PRESENT-DAY VALUE.**

The colour coding follows the scheme of Table 2.1 Maps for these and other neighbourhoods can be accessed and interactively manipulated at <https://bit.ly/3OeabxW>.



Conversely, once again, the cooling effect of trees shows very clearly, their shadow creating conditions of ‘no heat stress’ today and ‘moderate heat stress’ in 2050. From Figure 2.4 it is also clear that the shadow cast by buildings (yellow zones near the buildings) produces higher heat stress levels than tree shadow. This can be explained by the fact that tree crowns are generally cooler than building walls, thanks to the process of evapotranspiration taking place in the canopy.

## ● 2.3.

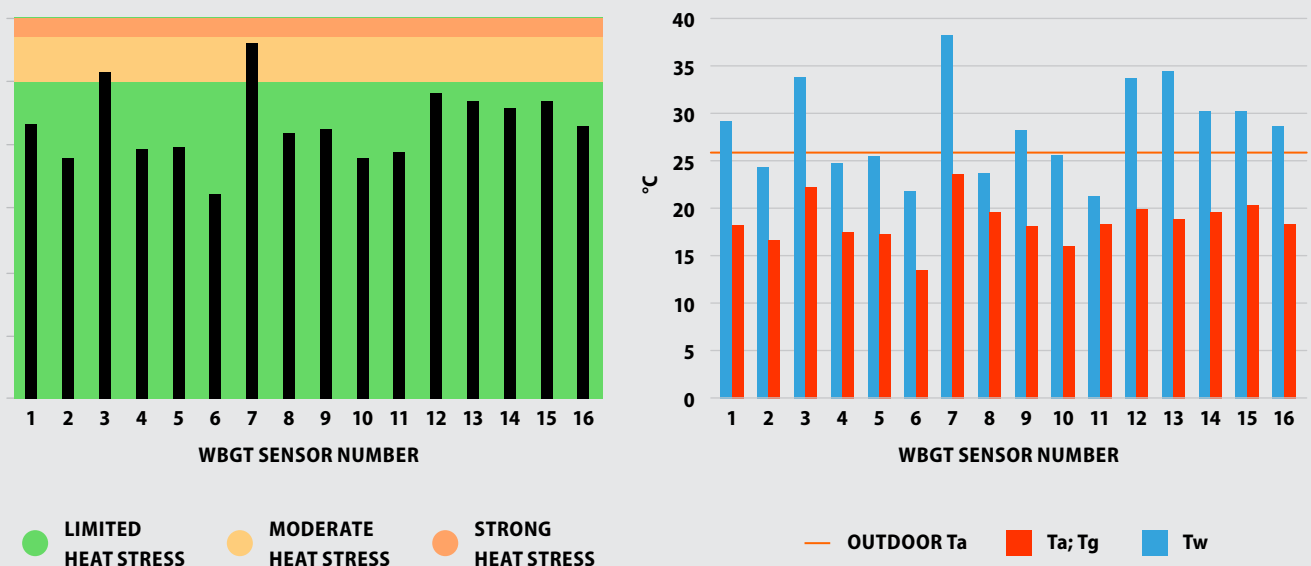
# LOW-COST DWELLINGS WILL FACE EXTREME TEMPERATURES

Indoor heat stress monitoring took place over a six-day period (23-28 March 2022), in the homes of 16 community participants, eight of them in each of the City of Ekurhuleni and Johannesburg. The participants had the WBGT loggers delivered to their homes and they were in charge of monitoring the device and the recording readings displayed throughout the week.

Depending on the measurement location and building type, a large variety of heat stress conditions was encountered (Figure 2.5), reflecting differences in air temperature and humidity, since the solar radiation component that normally contributes to heat stress was not relevant here, as the monitors were positioned in a way to avoid direct exposure to solar radiation through windows.

**FIGURE 2.5. WET BULB GLOBE TEMPERATURE MEASUREMENTS (LEFT) AND ITS COMPONENTS (AIR TEMPERATURE  $T_a$  AND WET BULB TEMPERATURE  $T_w$ , RIGHT) IN THE AFTERNOON OF 27 MARCH 2022, FOR THE 16 HOMES INVOLVED.**

(Note that the wet bulb temperature  $T_w$  is a measure for the degree of air humidity.)



A first notable result is that indoor air temperatures sometimes reach much higher levels than outdoor values. This is the case in more than half of the measurement locations, pointing to a quick warming-cooling cycle of the building, which carries the signature of limited or no insulation. Several locations reach indoor air temperatures well above 30°C (Figure 2.5), reaching up to 38°C at one location, even though the outdoor temperature was only 26°C. Since these warmer indoor environments were also found to be generally more humid – as reflected by the wet-bulb temperature (orange stacks in Figure 2.5) – the concerned homes featured an overall higher level of heat stress, two of them venturing into the ‘moderate heat stress’ zone, despite the outside air temperature not being very high. The concerned heat stress-prone buildings were found to be located in townships and to be characterized by poor design and a lack of insulation and ventilation, allowing heat on sunny days to accumulate inside. Often, such dwellings are constructed with corrugated iron sheets mounted on a light wooden frame, as shown in Figure 2.6 (right panel).

Considering that it never became really hot during the monitoring period (the highest outdoor temperature during the campaign not exceeding 26°C), it is clear that, when a heatwave does strike, thermal stress in these dwellings will become unbearable, likely reaching levels of very strong to extreme heat stress. The only way for residents living in these city quarters to get relief would be to find shade from nearby outdoor vegetation. Yet, the concerned neighbourhoods are often devoid of green infrastructure.

**FIGURE 2.6. CONTRASTING BUILDINGS WHERE THE HEAT STRESS DATA LOGGERS LABELLED WBG7 (LEFT) AND WBG6 (RIGHT) MONITORED INDOOR HEAT STRESS.**

(The numbering of the WBG7 data loggers corresponds to information in Figure 2.5). The left image shows a building constructed with bricks and concrete in Parktown North, Rosebank, Johannesburg, in a green residential area. The right image shows a home constructed of wood and corrugated iron sheets, in an informal settlement (Thembelihle, Lenasia, Johannesburg) characterised by a low vegetation abundance.



Finally, note that some of the measurements shown in Figure 2.5 feature indoor temperatures that are lower than the outdoor value of 26°C. The corresponding dwellings are usually located in city quarters with low population and building densities and a superior housing quality, with proper insulation and often equipped with an active cooling system. Apart from the higher cooling potential of those houses, they are generally also located in city quarters with a higher vegetation abundance, offering refuge from hot indoor temperatures if needed. This is the case, for instance, for monitoring location WBGT6, which yielded the lowest measured heat stress level (Figure 2.5, left panel).

## ● 2.4.

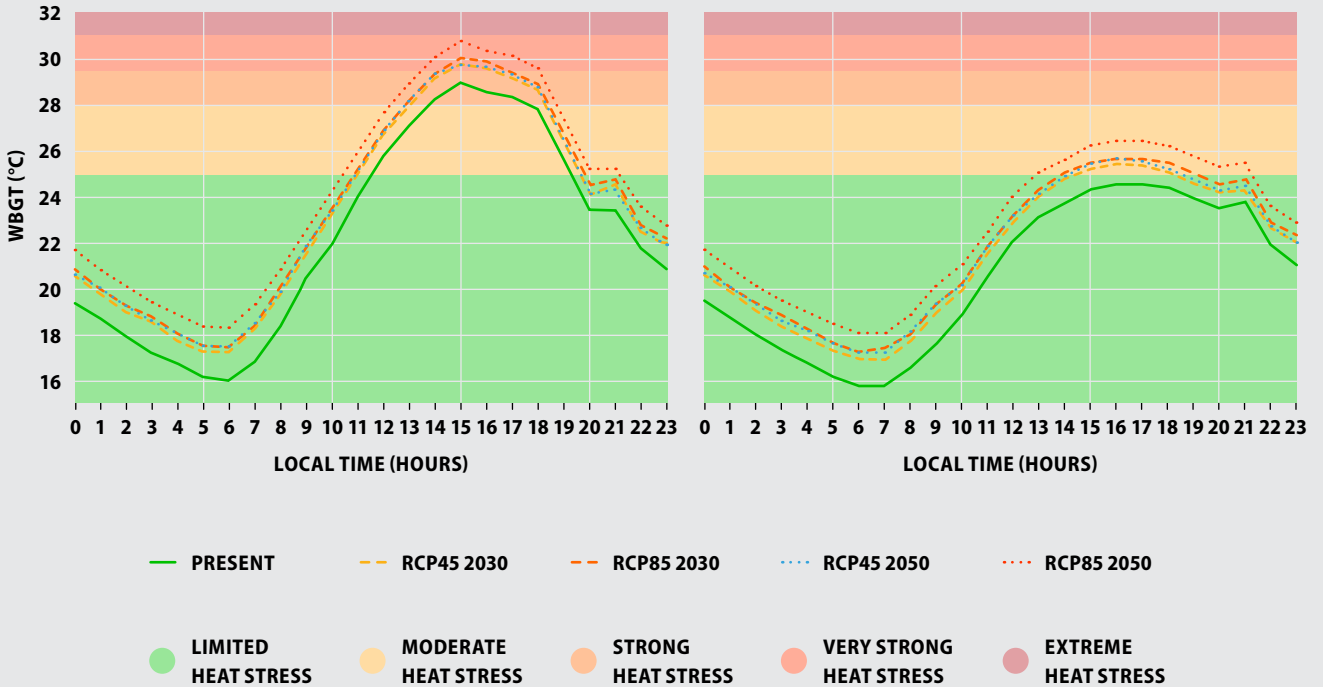
# VEGETATION AND COOL BUILDINGS MITIGATE EXCESSIVE HEAT

Several of the maps shown above (e.g., Figure 2.2, Figure 2.4) clearly demonstrate the cooling impact of vegetation at neighbourhood level. To show this in more detail, Figure 2.7 presents the simulated diurnal cycle of heat stress under present and future climate conditions, for two locations in the Alexandra / Lombardy East domain: one in the shadow of a tree in Lombardy East, and another at an open sun-exposed space in the township of Alexandra; again taking 6 January 2016 as the reference heatwave day. In the present climate and when benefiting from tree shadow, limited heat stress is experienced throughout the day. Conversely, strong heat stress is experienced in the open and sun-exposed area.

Towards the future, moderate heat stress will be present during several hours of the day, even in the shadow of a tree. In the open area, for most of the afternoon, strong to very strong heat stress persists, limiting any form of physical activity to a minimum to avoid heat-related health risks.

**FIGURE 2.7. MODELLED DIURNAL CYCLE OF HEAT STRESS UNDER PRESENT AND FUTURE CLIMATE CONDITIONS, FOR A LOCATION IN ALEXANDRA IN FULLY OPEN, UNSHADED TERRAIN (LEFT), VERSUS A LOCATION IN LOMBARDY EAST IN THE SHADOW OF A TREE (RIGHT).**

The colour coding shows the corresponding heat stress levels.



To complement this model-based information, heat stress measurements were collected, involving community participants and focusing on the contrasting heat stress levels found between shaded and sun-exposed locations (see Souverijns et al., 2022, for details). These urban heat monitoring campaigns aimed to measure the heat stress in six neighbourhoods in Ekurhuleni and Johannesburg, including informal settlements, central business districts, residential suburbs, and industrial areas, in order to build a comprehensive view of how temperature varies in different urban settings. The heat monitoring took place on six separate days (a different neighbourhood each day) spread throughout the summer months of January-February 2022. Altogether, the campaigns involved more than 100 community participants conducting the actual measurements.

**FIGURE 2.8. IMPRESSIONS OF THE WBGT MONITORING CAMPAIGNS CONDUCTED WITH COMMUNITY PARTICIPANTS IN JOHANNESBURG AND EKURHULENI, JANUARY-FEBRUARY 2022.**

The upper panels give an impression of the training sessions, which provided an overview of climate change and its impacts, followed by a practical training concerning the manipulation of the heat stress data loggers. The lower right panel shows the experimental set-up, one of the data loggers being in the sun while the other is in the shadow of a tree.

*Source: pictures by Planact.*



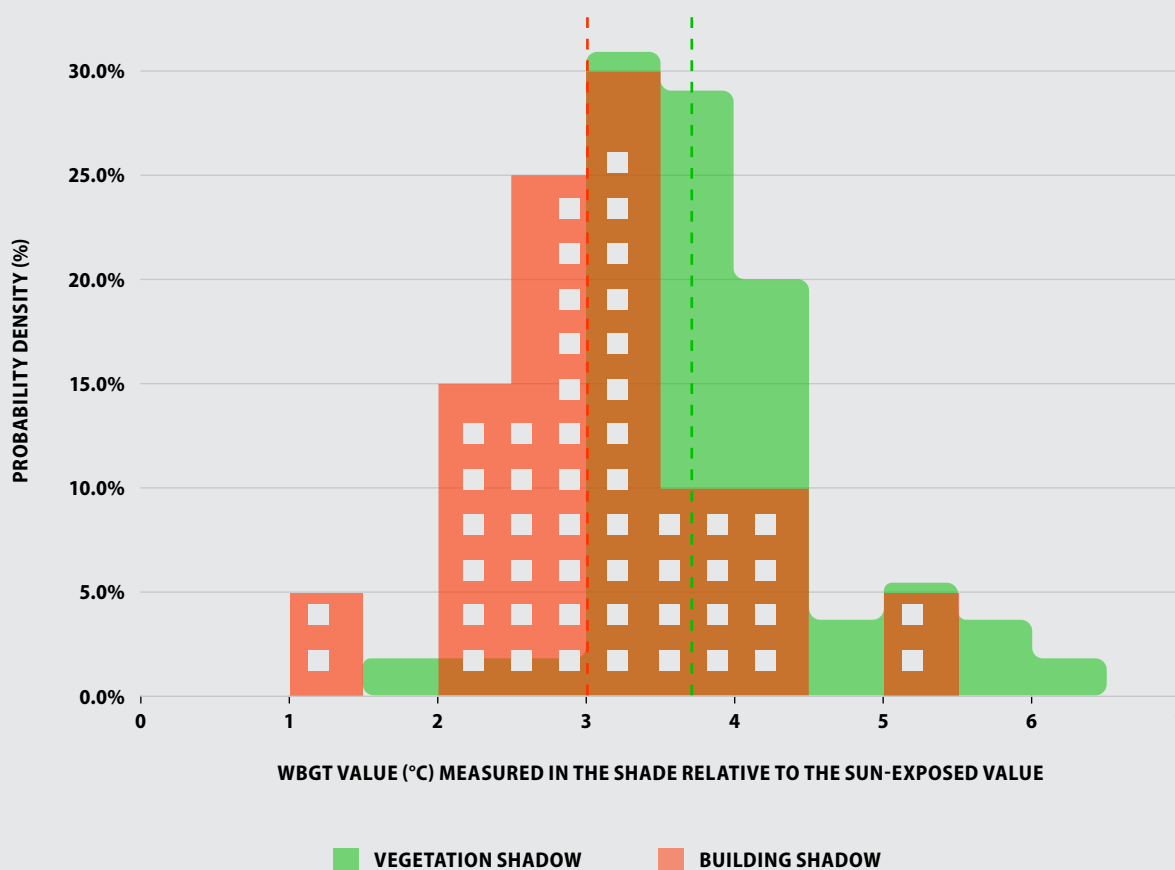
On each of the six campaign days, heat stress was measured in the early afternoon under as clear (cloud-free) and sunny circumstances as possible, to ensure that the peak heat stress was captured. Yet, the summer of 2022 being rather cool, rainy, and cloudy, ideal conditions were rarely encountered. Still, the monitoring campaigns produced very relevant insights.

In the City of Johannesburg, monitoring campaigns were conducted in Alexandra / Lombardy East, Braamfontein and Kliptown. Alexandra / Lombardy East contains a mixture of suburban and informal settlements, in strong contrast with Braamfontein’s high-rise, high-density locations. Kliptown, largely an informal settlement, presented the highest levels of human traffic and large and open public spaces.

In the City of Ekurhuleni, the project ventured into informal settlements in Tembisa and Primrose. Actonville brought in a new dynamic of measuring heat stress in a busy, low-density city quarter surrounded by heavy industrial activity. Both Primrose and Actonville contain large bodies of water and green city quarters with parks and leafy suburbs.

Within each neighbourhood, a diverse selection of measuring locations was chosen, so that the heat recordings would reflect as broad as possible a variety of urban landscapes and microclimates. Importantly, the focus of the measurement strategy was on monitoring heat stress differences between shaded and sun-exposed locations.

**FIGURE 2.9. FIELD MEASUREMENTS SHOW A GREATER COOLING EFFECT OF TREE SHADOW THAN BUILDING SHADOW, THE MEDIAN VALUE OF THE WBGT COOLING AMOUNTING TO 3°C IN BUILDING SHADOW (RED) AND TO 3.75°C IN VEGETATION SHADOW (GREEN).**



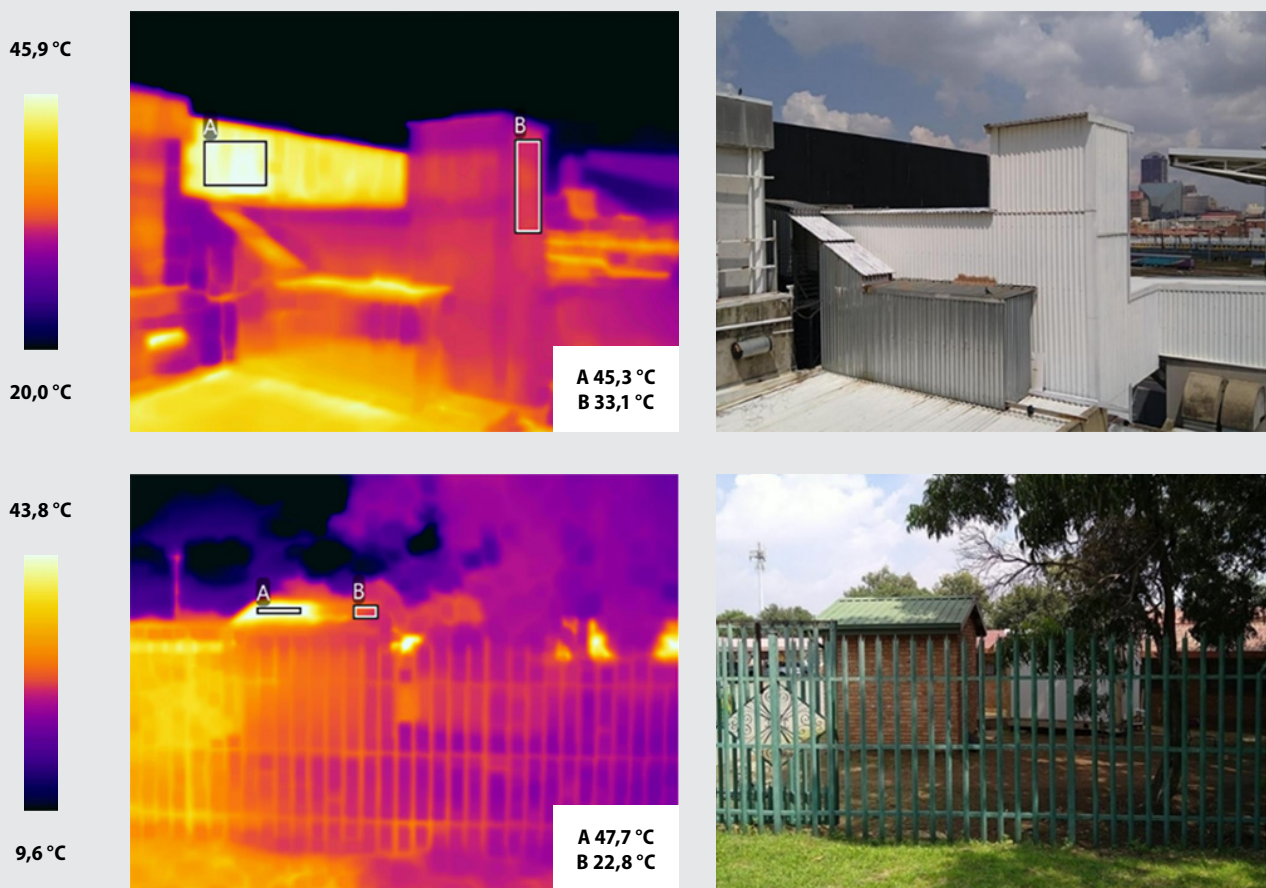
Results from the measurement campaign show that heat stress (as expressed through the WBGT, see Table 2.1) values in the shade are several degrees lower compared to values found at locations exposed to direct solar radiation (Figure 2.9). Moreover, shadow from vegetation yields a more efficient cooling (WBGT lowered by 3.75°C) than the shadow cast by buildings (WBGT lowered by 3°C), which may be attributed to the evaporative cooling effect displayed by active and green vegetation. These levels of heat stress reduction are substantial, often lowering thermal stress by two intensity levels (Table 2.1).

While the monitoring campaigns and modelling exercises showed the potential of urban vegetation elements to mitigate heat stress, an important caveat is that the cooling impact of vegetation is local, related largely to the shadow provided by urban trees to their immediate surrounding. The air cooling that is produced by vegetation through evapotranspiration is less efficient because of the strong dilution of the cooled air after leaving the source (i.e., the tree canopy). It is only when trees are planted in large numbers, forming extensive parks, that this cooling effect has the potential to affect the wider surroundings, and even then, the impact and spatial reach remain limited. Considering this, when implementing adaptation measures, it is important to aim for a spatially focused deployment of trees at those locations within the urban environment where they can achieve the largest reduction of exposure to excessive heat.

As a complementary source of insight, a series of thermographic images was acquired during the visit of the study team to Johannesburg and Ekurhuleni in March 2022. Such images provide a picture of the radiant temperature of objects, representing the heat one experiences when, e.g., getting near to surfaces heated by the sun. Exposure to this thermal infrared radiation substantially contributes to human heat stress, especially since radiant surface temperatures typically reach much higher values than air temperature. For instance, a dark surface in the full sun with limited ventilation (by the wind) may heat up to 50°C and more, even if the ambient air temperature in the nearby environment only reaches 25°C or so.

The upper panel of Figure 2.10. shows the cooling impact of urban trees when casting shadow on the roof of a low building. While the timing (well before noon) and meteorological conditions (a not particularly warm day) are not conducive of extreme temperature contrasts, the temperature difference between the sun-exposed and shaded portions of the building roof in this image amounts to 25°C. This example is highly relevant for many homes in Johannesburg and Ekurhuleni, given the abundance of low (and low-cost) buildings featuring a metal corrugated roof, among other in the townships and informal settlements. This thermal image also clearly demonstrates the above-mentioned local character of vegetation shadow-related cooling.

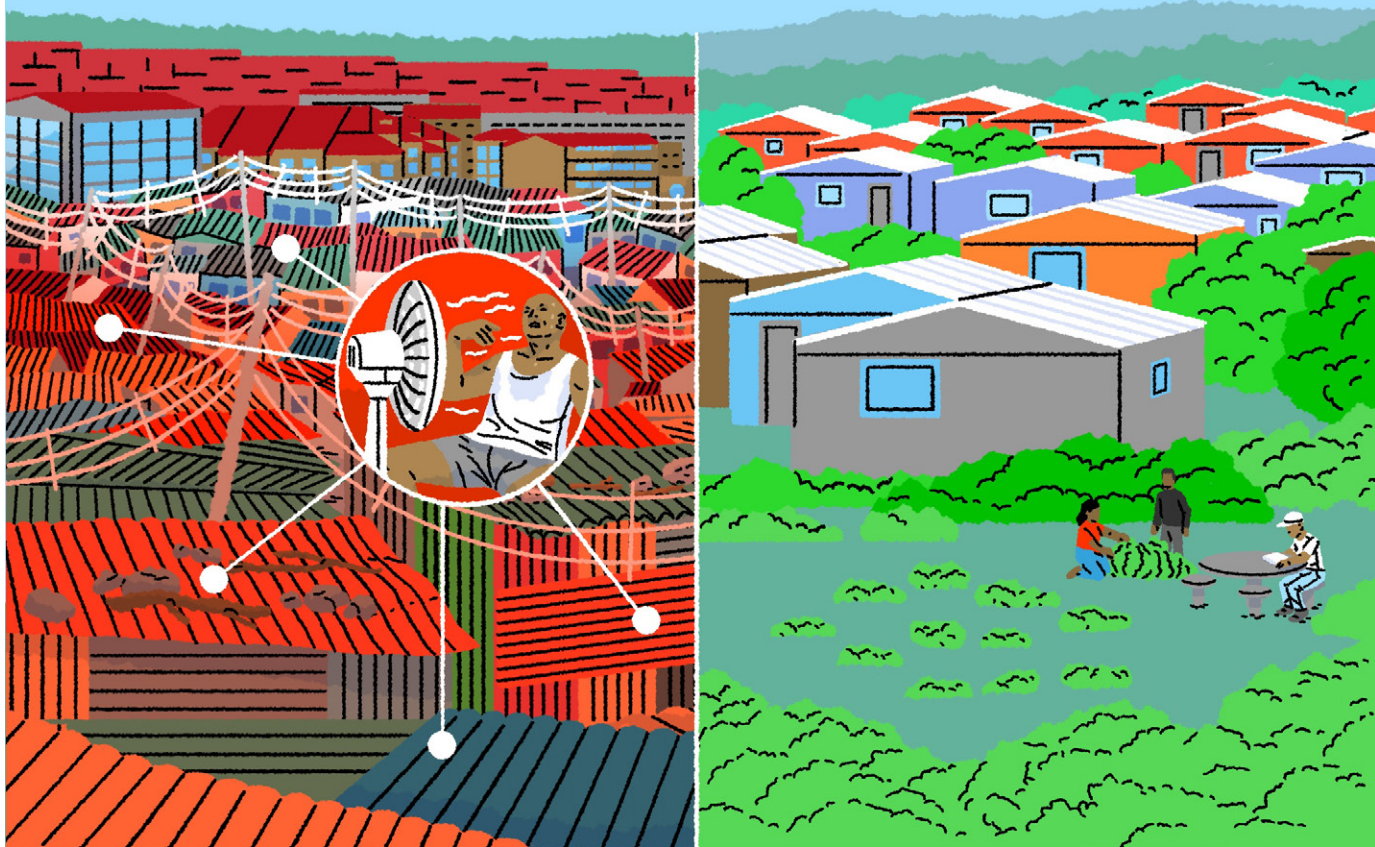
**FIGURE 2.10. THERMOGRAPHIC (LEFT) AND CO-LOCATED REGULAR (RIGHT) PHOTOGRAPHY, FOR A PARTIALLY SUNLIT ROOF ON A LOW BUILDING SITUATED AT THE CORNER OF SOFASONKE ST AND SENAONE ST IN ORLANDO EAST ON 10 MARCH 2022 AT 10:38 (UPPER PANELS) AND TAKEN FROM THE ROOF OF THE MATHS CENTRE (PLANACT) BUILDING, JUTASTREET, BRAAMFONTEIN, FACING A NEARBY BUILDING, 11 MARCH 2022, 13:43 (LOWER PANELS).**



The lower panel of Figure 2.10 demonstrates the distinct heating rates of differently bright (white versus black) surfaces, clearly demonstrating that black walls attain much higher surface temperatures than their white counterparts, by more than 12°C. Based on this, it is fair to conclude that cool (white) roofs constitute an effective adaptation measure, especially given the importance of heating through roof surfaces in single-storey low-cost dwellings covered with thin metal corrugated roofs, as in Figure 2.6.

CHAPTER

# 3. EXPOSURE, VULNERABILITY, AND IMPACTS



## ● 3.1.

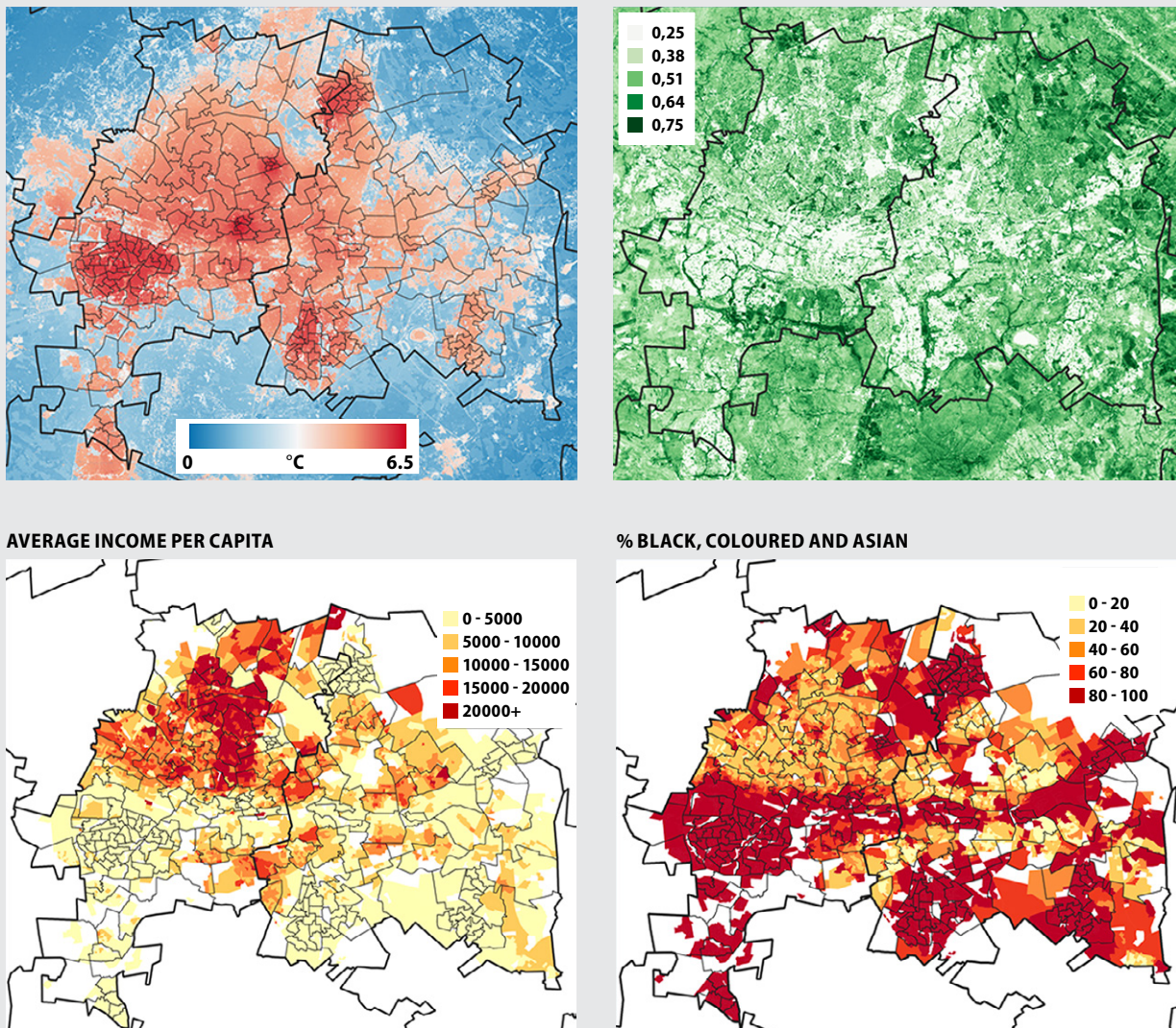
### POOR RESIDENTS ARE DISPROPORTIONATELY EXPOSED TO EXTREME HEAT

The analysis presented in Chapter 2 found strongly contrasting heat stress patterns within the metropolitan areas of Johannesburg and Ekurhuleni, densely built and populated areas – such as Soweto, Alexandra, Tembisa and Katlehong – generally experiencing the highest urban heat island intensities. This is not surprising, as a high built density is associated with the abundant occurrence of

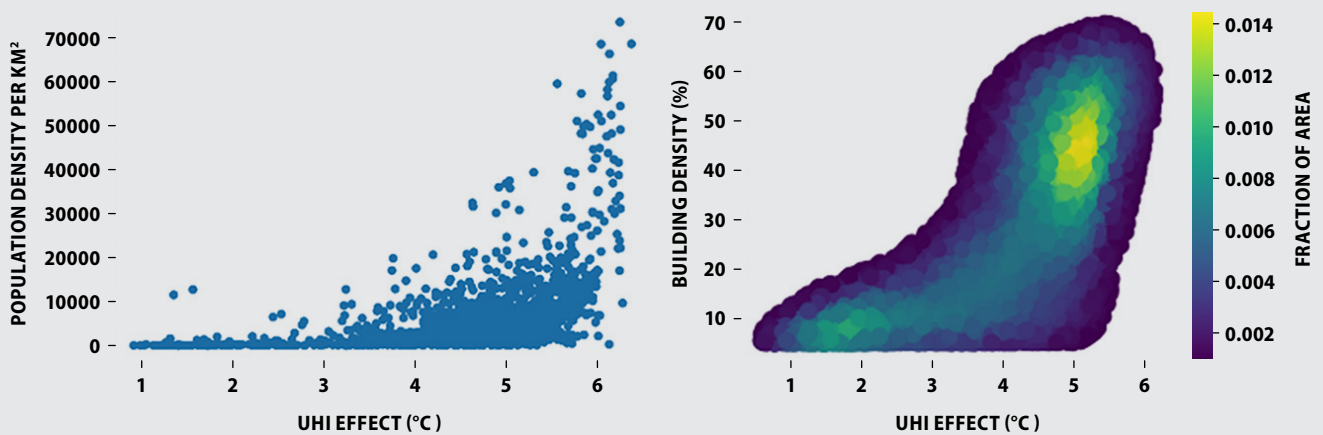
impermeable surfaces and little vegetation (upper right panel of Figure 3.1), both of which constitute precisely the type of conditions that cause the development of strong urban heat islands (Figure 3.2).

**FIGURE 3.1. UPPER LEFT PANEL: URBAN HEAT ISLAND INTENSITY (IN °C), AS IN FIGURE 2.1; UPPER RIGHT PANEL: SATELLITE-BASED VEGETATION ABUNDANCE (FRACTION); LOWER LEFT PANEL: THE AVERAGE INCOME PER CAPITA; LOWER RIGHT PANEL: PERCENTAGE BLACK, COLOURED AND ASIAN.**

Source: the images in the lower panels were produced based on data provided by Venter et al. (2020).



At a finer spatial scale, similar conclusions can be drawn, e.g., reverting to Figure 2.2, it is clear that less densely populated green residential areas exhibit much lower heat stress levels than (adjacent) densely populated neighbourhoods devoid of any vegetation, often by at least one category of heat stress (e.g., ‘strong heat stress’ reducing to ‘moderate heat stress’).

**FIGURE 3.2. URBAN HEAT ISLAND (UHI) INTENSITY VERSUS POPULATION DENSITY (LEFT PANEL) AND BUILDING DENSITY (RIGHT PANEL).**

As argued above, a high built density and population density together with a low vegetation density are key to explaining high urban heat island levels. At the same time, these high-density areas coincide in a marked way with patterns of certain socio-economic characteristics. Indeed, Figure 3.1 identifies such densely built areas largely as neighbourhoods that are home to majority black residents, having a low per capita income and lacking green vegetation. A further analysis (not shown here) also indicates that these neighbourhoods exhibit a low ranking in the Quality of Life (QoL) census and in exams performance. These neighbourhoods generally also feature less hospitals, despite the higher population densities.

In addition, high urban densities and associated heat exposure levels generally coincide with poor housing conditions, buildings often being constructed with unsuitable materials such as corrugated metal sheeting, which adds to people's vulnerability to excessive heat. This was also apparent from the indoor monitoring results presented before (Figure 2 5), which found that indoor air temperatures in low-cost dwellings may exceeded outdoor air temperatures by several °C, exceeding 10°C in one case.

From the above, a picture emerges that poor residents of densely built and barren neighbourhoods are disproportionately exposed to the effects of excessive heat. These communities also happen to be more vulnerable, among other because of poor housing conditions. Moreover, they exhibit a low adaptive capacity, e.g., generally being unable to invest in thermal insulation, better building materials or active cooling. While these patterns have their roots in apartheid-era spatial planning, they give rise to 'green apartheid' still today (Figure 3.3); therefore, it is of paramount importance to catch up, to accelerate the greening of under-provisioned neighbourhoods and to implement cooling measures for low-cost dwellings.

Finally, it is important to reflect on the fact that the vulnerable inhabitants of those dense and exposed settlements, who are taking the brunt of climate change impacts, contribute much less to greenhouse gas emissions than those living in well-off neighbourhoods, who enjoy a lower exposure to excessive heat and have the means to adapt.

**FIGURE 3.3. GREEN APARTHEID: CONTRASTING GREEN SPACE ABUNDANCE AND HOUSING QUALITY BETWEEN NEIGHBOURING CITY QUARTERS (KYA SAND AND BLOUBOSRAND).**

Source: Google Earth.



## ● 3.2.

# INTENSIFYING URBAN HEAT PRESENTS **NEGATIVE HEALTH IMPACTS**

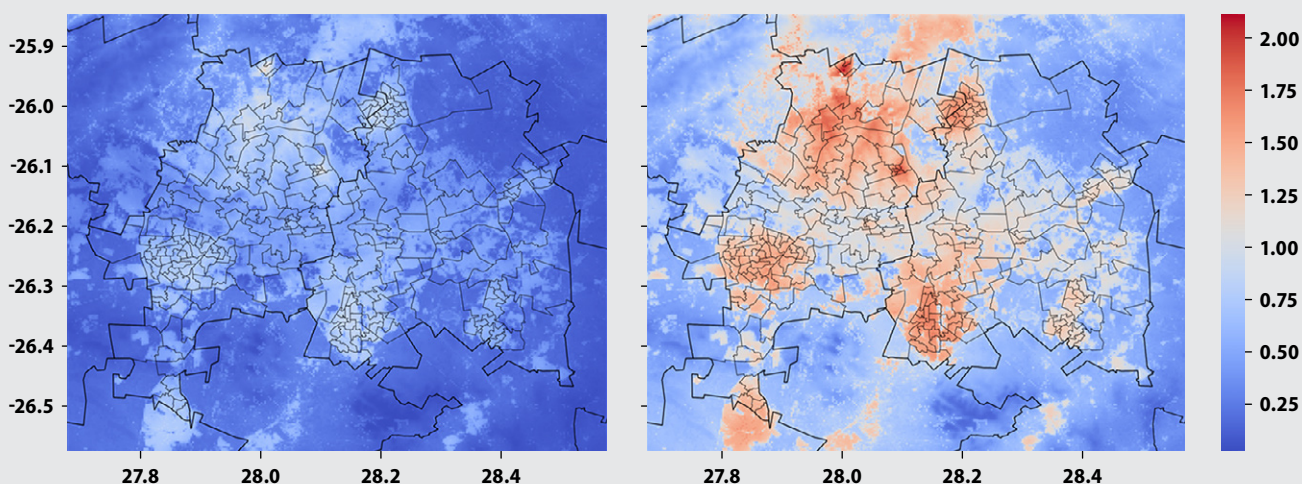
In temperate climate zones (the Johannesburg-Ekurhuleni area currently being one, see Figure 1.2), heatwaves claim more victims than any other weather-related disaster, such as flooding (Borden and Cutter, 2008). This point is illustrated most strikingly by comparing the death toll attributed to Hurricane Katrina in 2005 (amounting to less than 2,000) to that of the European heat wave occurring in 2003 (70,000 reported heat-related deaths).

Heatwaves give rise to an increased morbidity and mortality, especially in vulnerable population groups such as the elderly, young children, and persons suffering from underlying disease. Heat adversely affects pregnancy, including pre-term birth, and leads to aggression and suicide. In South Africa, the health sector is probably the sector most affected by extreme heat. Unfortunately, little is known about the impact of extreme heat in Africa, even though recent studies (Harrington and Otto, 2020) ascertain that, on the continent, heat represents an under-recognised issue. Moreover, climate-health experts have expressed concerns regarding the fact that few health adaptation measures have been implemented in South Africa.

Some of the most prevalent diseases and causes of death in South Africa carry a particularly adverse relation to extreme heat, namely, tuberculosis, HIV/AIDS and non-natural death caused by violence and accidents. Persons suffering from HIV/AIDS and/or tuberculosis have a weakened physiological response (e.g., reduced lung function), making them more vulnerable to extreme heat. Violence and accidents are known to be aggravated by extreme heat. These diseases and causes of death exhibit clear links to the adverse socio-economic conditions faced by many South Africans, including poverty, poor housing, malnutrition, and limited access to medical facilities.

Figure 3.4 presents heat-related excess mortality occurring in Johannesburg and Ekurhuleni for present and future conditions, expressed as a percentage, based on the urban climate simulations conducted in the study and using the finding by Wichmann (2017) that heat induces an excess mortality of 0.9% per degree Celsius increase in daily mean apparent temperature (which combines temperature and humidity) above a threshold of 18.7°C.

**FIGURE 3.4. PERCENTAGE OF HEAT-RELATED EXCESS MORTALITY FOR PRESENT (2001-2020, LEFT) AND MID-CENTURY (2041-2060, RIGHT) CONDITIONS.**



The spatial pattern found in Figure 3.4 reflects that found in previous maps (e.g., Figure 2.3), again identifying Soweto, Alexandra, Tembisa and Katlehong as being particularly exposed, with present excess mortality rates of the order of 1%, against 0.5% for the less dense urban areas. In addition, some residential areas near Bloubostrand-Maroeledal-Jukskeipark (North Johannesburg) also feature a high excess mortality. A possible explanation for the latter is that, among the urban areas occurring in the domain, this area is lying lower by several hundred metres, potentially yielding higher temperatures by 1-2 °C.

Figure 3.4 also shows that in the urban portions of the domain, heat-related excess mortality roughly doubles by 2050, relative to today, from an average value of 0.75% to around 1.5%. Considering the annual overall mortality rate in South Africa – which is about 1% – and taking order-of-magnitude figures of 6 million and 3 million inhabitants residing in Johannesburg and Ekurhuleni, this means that, today, these metros suffer approximately 450 and 225 heat-related deaths per year, respectively. A doubling towards 2050 implies 900 resp. 450 heat-related deaths, ignoring population growth. Extrapolating, somewhat speculatively, to the end of the century, a high climate scenario (leading to a temperature increase of almost 6°C relative to today) might induce an excess mortality of 3.75%, i.e., 2250 heat death in Johannesburg and 1125 in Ekurhuleni, on average, every year.

Apart from the direct health effects of extreme heat, rising temperatures also induce an increased transmission of vector-borne diseases, which are likely to become more common, spreading into new areas. Malaria, which is transmitted to humans through the bites of infected female *Anopheles* mosquitos, is the most common infectious disease in South Africa after HIV/AIDS and tuberculosis. Even though the high elevation of the Johannesburg-Ekurhuleni area currently precludes the establishment of *Anopheles*, the spread of the vectors and the disease will likely increase with rising temperatures. It is expected that this will be particularly the case in urban areas, owing to their elevated night-time temperature values, which strongly determines the habitat suitability for these mosquitos. An issue of particular concern may be the recent discovery of a new malaria transmitting mosquito, *Anopheles stephensi*, a species known to thrive in urban environments.

Another, indirect, health effect stems from the impact of heat on mental health and aggressive behaviour. This is highly relevant in South Africa, where one in six has a mental health disorder and where the prevalence of partner violence ranks among the highest in the world. It has been estimated that homicides may increase by 4-5% per degree Celsius temperature rise, meaning that – using the current figure of approximately 20,000 homicides per year as a basis – a 1°C temperature increase may induce up to 1,000 additional homicide cases per year.

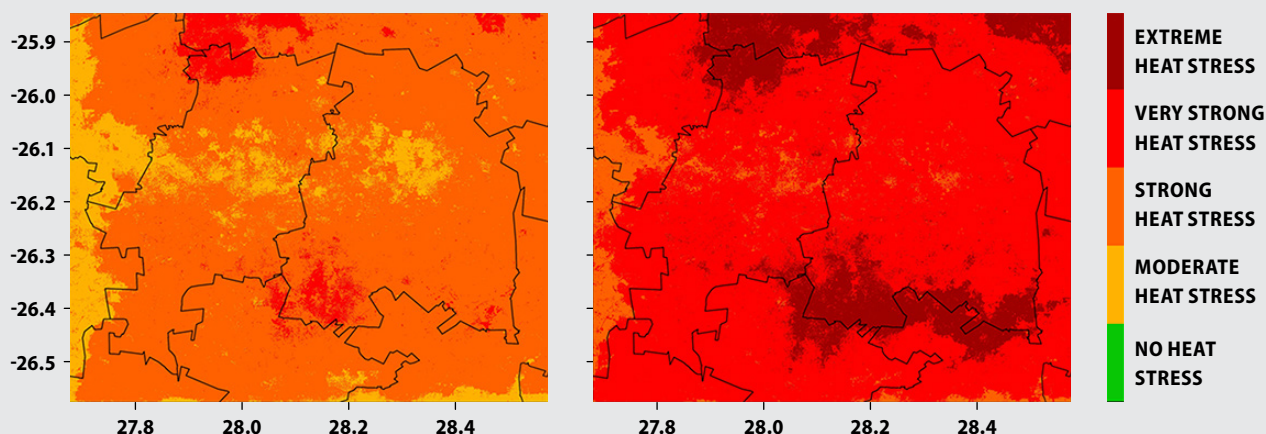
● 3.3.

# REDUCED LABOUR PRODUCTIVITY WILL AFFECT THE ECONOMY

Climate change, and enhanced extreme heat in particular, impacts labour productivity, thus affecting the overall economy (as expressed, e.g., through the country’s GDP). Rising temperatures will mainly affect workers already exposed to extreme temperatures, such as outdoor workers, and those that are employed in workshops that are not adequately protected from overheating.

**FIGURE 3.5. HEAT STRESS LEVELS EXPERIENCED DURING THE HEATWAVE DAY OF 6 JANUARY 2016 AT 15:00 LOCAL TIME, CONSIDERING PRESENT (LEFT) AND FUTURE (2050, RIGHT) CLIMATE CONDITIONS.**

The topographical effect (higher altitudes in the central parts of Johannesburg and Ekurhuleni) explain the lower heat stress found there.

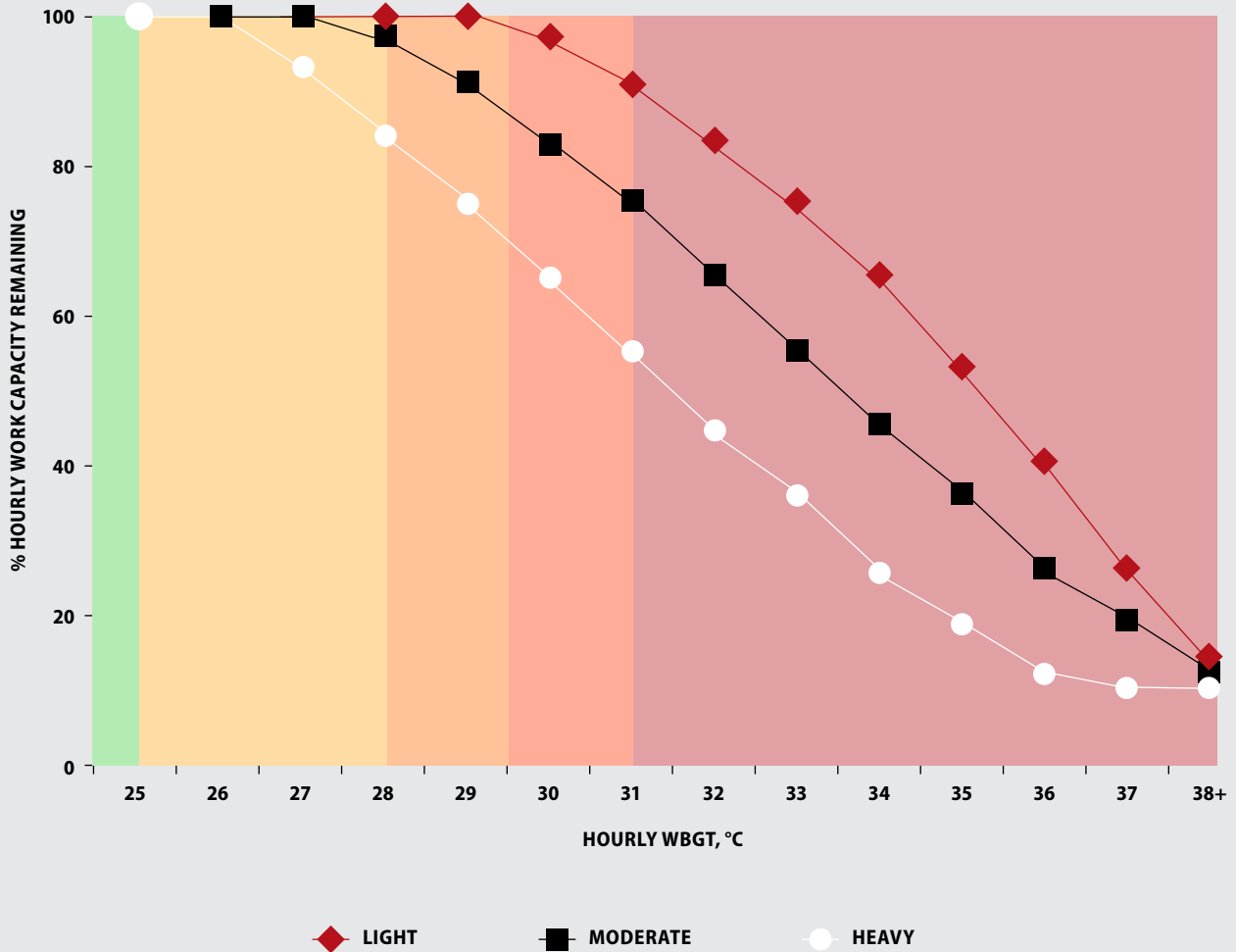


In South Africa, the International Labour Organisation (ILO, 2019) estimates that excessive heat has caused a labour productivity loss amounting to 5,000 full-time jobs in 1995, with a further expected rise to 13,000 lost jobs by 2030. Studies have linked labour productivity to the wet bulb globe temperature (WBGT, see Table 2.1) concluding that beyond a WBGT value of 25°C, labour productivity drops steeply, on average falling to 50% at values of approximately 33°C. Considering that climate projections show an increase of the WBGT by at least one heat stress category (Figure 3.5), during heatwave episodes a productivity drop between approximately 10% and 50% (depending on the intensity of work) is to be expected (Figure 3.6). Apart from problems associated with outdoor heat stress, issues are to be expected also in the numerous workplaces without effective cooling systems. In those factories and workshops that do have effective cooling systems, problems may arise in areas with frequent power cuts.

**FIGURE 3.6. LABOUR PRODUCTIVITY VERSUS WBGT FOR DIFFERENT WORK INTENSITIES.**

The colours correspond to the heat stress categories defined in Table 2.1.

Source: adapted from Kjellstrom et al. (2014).



An important element to consider here is the high level of informal employment in South Africa, amounting to 34% (ILO, 2019) and exhibiting a high degree of variability within the country. This poses a severe challenge, as the informal economy is characterized by high levels of poverty, inequality and the lack of social safety nets and occupational health protection, thus making the informally employed very vulnerable to the negative impacts of heat stress on their livelihoods. Overall, informal employment concerns more women than men, and more the young and old than the middle-aged within the population. As is the case for health, experts indicate that (too) few heat adaptation measures have been implemented in occupational settings, despite existing legislation.

## ● 3.4.

# INCREASED HEAT WILL STRAIN INFRASTRUCTURE (INCLUDING ENERGY DEMAND)

**T**he current impact of heat on transport and infrastructure is generally acknowledged to be less than that of flooding and storms. Still, projections (e.g., for Europe) indicate that heat may become the dominant cause of infrastructural damage towards the end of the century. With respect to railway infrastructure, excessive heat causes rail buckling, the expansion of swing bridges, overheating of sensitive electronic equipment and overhead line sag (drop), leading to considerable delays and costs. With respect to road infrastructure, excessive heat can lead to softening of asphalt and damage to road surfaces – especially under the weight of heavy trucks – and bridges.

Excessive heat also affects critical energy infrastructure, among other by incapacitating transformer hubs, by reducing the electricity grid's transmission capacity and by reducing the yield of photovoltaic (solar) panels. In addition, the energy sector will be affected by an increased cooling energy demand, being required to supply more energy to power fans and, most importantly, air conditioning units. To quantitatively estimate this increase, the annual number of cooling degree hours (CDH) was estimated from urban climate modelling results for the Johannesburg-Ekurhuleni area. The CDH increases from a current (2001-2020) value of 2261 to a value of 3121 in 2050 (high climate scenario), i.e., an increase by 38%. This temperature-only increase of cooling energy demand is to be added to the increase caused by a rising number of cooling units, which has been estimated at 85% between 2020 and 2030 alone (Covary et al., 2015).

The impact of heat on critical infrastructure, and infrastructure networks in particular, may lead to indirect effects by triggering cascading effects, affecting a variety of sectors. As an example, consider extreme heat causing a failure in the electricity distribution network (e.g., caused by transformer overheating), in turn triggering a whole range of secondary effects, including electrical trains that get stuck and without a working cooling system; with compromised safety measures at railway crossings; labourers arriving at their work delayed; or hospitals getting in trouble by a lack of network power and a failing ICT infrastructure.

The problem with cascading failures is that they are difficult to predict, because of the involved complex interdependencies. The costs of the associated indirect impacts (productivity loss, service interruption) may run high. Indeed, transport infrastructure but also, e.g., the electricity network represents a great share of economic activity, contributing to the proper functioning of nearly all sectors. With respect to heat impacts on infrastructure and subsequent service disruption, much can be learned from the analysis of a heatwave that occurred in 2009

in southern Australia, which has been extensively reported on in QUT (2010). Apart from having an impact on excess mortality, this heatwave was observed to particularly affect critical infrastructure, leading to costly service interruptions and response costs, which have been estimated at 800 million AUD (Australian Dollars, 2010 value), in a region that has a population size comparable to that of the combined Johannesburg-Ekurhuleni area.

**FIGURE 3.7. CRITICAL INFRASTRUCTURE FACES A CHANGING CLIMATE: OLIVER TAMBO AIRPORT (JOHANNESBURG)**

Source: PretoriaTravel / Wikimedia Commons



CHAPTER

# 4. HEAT IN CITY CLIMATE STRATEGIES



Even though adaptation programmes and strategies have been developed at provincial (Gauteng) and municipal level (Johannesburg and Ekurhuleni), it appears fair to say that adaptation planning with respect to (urban) heat impacts has received comparatively less attention than, e.g., drought and flooding.

In regard to **local heat mitigation measures and policy**, the *Gauteng city region climate change response strategy and action plan* (van Weele et al., 2020) states that measures should aim to “integrate mitigation and adaptation outcomes to maximise the opportunities for co-benefit outcomes. The implementation of urban green infrastructure (trees) constitutes a measure that eminently benefits both adaptation and mitigation. Apart from this, any (local) cooling measure, be it through enhanced

greening or through other means (e.g., cool roofs), will reduce cooling energy demand, thus also serving mitigation goals; the use of solar panels to power building cooling installations contributes to both aspects.

The *City of Johannesburg climate action plan* (CoJ, 2021) refers to the vulnerability of the communities living in the poorer parts of the city, which additionally have a limited adaptive capacity, hence the importance to prioritise actions targeting these communities. The City of Johannesburg acknowledges the role of urban green infrastructure in alleviating temperature extremes, with a particular role for community urban gardens. The development of mechanisms to cool health facilities is put forward as important, including through the use of renewable energy to meet energy demands for cooling. Apart from health care facilities, cool shelters to protect community health and care for vulnerable groups are seen as important. Finally, as a soft (i.e., immaterial) measure, awareness-raising campaigns to educate citizens on how to remain cool during a heat wave are relevant, as are early warning systems and information dissemination mechanisms to alert people to potential heatwaves.

The *Ekurhuleni climate change response strategy* (EMM, 2015) equally promotes urban green infrastructure as a basis for efficient adaptation measures. Among other, the strategy mentions urban agro-forestry, increasing shading and natural cooling by means of the planting of indigenous trees to protect crops, and using crops with a higher heat tolerance. Ekurhuleni also expresses concerns regarding the effect of increased temperatures on the transport system, including 'softening of paved roads, melting of tyres, increase in driver discomfort and exhaustion, leading in turn to a greater risk of accidents, ...'. The strategy expresses the importance of upgrading homes of those who are vulnerable to extreme heat, acknowledging that air conditioning may not be an appropriate solution (too expensive, counteracting mitigation efforts, unreliable power). Ekurhuleni also promotes heat early warning systems, the increased wearing of sun-shielding clothing and pro-active heat wave response plans.

**International studies**, in particular the report *Impacts, Adaptation, and Vulnerability*, as part of the IPCC's Sixth Assessment Report (IPCC, 2022), ascertain that the protection of social infrastructure (schools, hospitals) against extreme heat is important. Air conditioning is an efficient means to protect from excessive heat, though its use should remain limited, given the negative side effects (enhanced greenhouse gas emissions, enhancement of the urban heat island intensity).

Establishing public cooling centres for use during heat waves may be an option, and the use of solar energy is seen as a partial solution. Passive cooling constitutes a valuable measure, e.g., the use of cool roofs, featuring highly reflecting materials. Adaptation through green infrastructure (nature-based solutions) is considered to present a very high potential for reducing heat risk, constituting a sustainable option to improve health and livelihoods in cities, particularly for

poor, marginalized groups, and offering multiple co-benefits, including combating flood risk and improving mental health. However, to maximize the adaptation benefits of nature-based solutions in regulating urban heat, it is important to target the implementation of urban trees and other green infrastructure in dedicated areas where heat vulnerability and risk are the highest, especially considering communities that lack urban tree canopy or accessibility to parks to cool off during hot days or heat waves. Urban agriculture and urban agro-forestry are promoted as relevant components of a nature-based solutions approach to heat adaptation, coming with multiple co-benefits, such as improving the food security situation among poorer communities.

Interventions benefiting public health are considered as highly important. This includes raising awareness of the symptoms and importance of heat stress, early warning systems, heat-health action plans, and the provision – by health workers – of cooling interventions, such as supplying cool water or fans, during heat waves. Heatwave warning systems emerge as one of the most cost-efficient ways of addressing the risk of heat to human lives.

With respect to grey (infrastructural) measures, roof whitening and improving ventilation during extreme heat are important, as is the use of insulation materials or altering building construction materials to improve their ability to moderate indoor temperatures. Shutters and solar blinds are found to be very efficient ways to lower indoor temperatures, for residences and office buildings alike. Natural ventilation during the night is an efficient way to shed excessive heat from buildings. With respect to building cooling measures, it is particularly important to ensure that facilities serving vulnerable groups (schools, hospitals, elderly homes) are well adapted to high temperatures. Likewise, workplaces are important targets for adaptation: apart from physical modification (e.g., cool roofs) they may require new occupational safety and health procedures to address climate change-related heat stress.

CHAPTER

**5.**

# RECOMMENDED ACTIONS



**A SET OF CONCRETE ADAPTATION MEASURES IS PROPOSED FOR JOHANNESBURG AND EKURHULENI, BASED ON THE INSIGHTS EMERGING FROM THE PREVIOUS CHAPTERS. EACH OF THE MEASURES IS DESCRIBED IN DETAIL BELOW, TOGETHER WITH RECOMMENDED ACTIONS.**

## ● 5.1.

# STRATEGIC URBAN GREENING IN UNDER-PROVISIONED AREAS

A simple visual inspection of aerial photography (e.g., Figure 3.3.) shows that large differences remain in the abundance of green vegetation between (often adjacent) neighbourhoods. Satellite imagery (upper right image in Figure 3.1.) reveals that neighbourhoods including Soweto, Alexandra, Tembisa and Katlehong feature a vegetation abundance of 0-30%, and often even less than 15%. Conversely, well-off urban quarters generally feature a vegetation abundance in the range of 30-60%. Consequently, heat stress levels are higher in the townships, night-time urban heat island values exceeding that of greener city quarters by 2°C and more (Figure 2.1.) and – during heatwave episodes – daytime heat stress in the greener residential areas generally being at least one category less than in densely built townships (Figure 2.2).

At the same time, heat vulnerability and exposure rank high in areas with little vegetation, considering, for instance, that residents generally have less access to space cooling in their homes. Also, the light materials their homes are constructed with make them prone to overheating, as was clear from the monitoring data presented in Section 2.3.

In addition, residents of those areas are generally deprived of the multiple co-benefits that urban green infrastructure has to offer, including beneficial effects on mental health or the collection of food products from urban homestead trees. Therefore, it is important to focus future greening efforts on those neighbourhoods that are currently lacking significant green infrastructure. The impacts are considerable, the monitoring data shown in Figure 2.9. having demonstrated that, locally, urban trees can reduce the heat stress level by 3-4°C in terms of wet-bulb temperature, which corresponds to a reduction by one or two categories of heat stress (e.g., from very strong to moderate).

An important caveat is in order regarding the critical dependency of urban green infrastructure on water availability. Indeed, considering the projected future drought in South Africa (Figure 1.2.), it will be necessary to foresee infrastructure to buffer water in seasons with excess rain (which at the same time will help reduce flooding risk). Care should be given to designing appropriate local water storage systems, avoiding adverse effects such as open water bodies that might suit disease-spreading mosquitos. Simple rainwater harvesting systems based on barrels attached to buildings' roof drainage pipes could be very efficient. Still, when designing the storage, care should be taken to dimension it properly, considering the amounts of available rain versus the amounts of water required to irrigate the urban green infrastructure; and choosing appropriate greenery that is indigenous and has less water requirements while still providing the same benefit.



## RECOMMENDATIONS

- **SET A TARGET FOR THE NUMBER OF TREES TO BE PLANTED IN AREAS CURRENTLY DEVOID OF GREEN INFRASTRUCTURE, BY A CERTAIN FUTURE TIME HORIZON (E.G., 2030).**

The vegetation abundance maps shown previously can be used as a starting point to identify areas lacking in green vegetation. At the occasion of the World Cup Football in 2010, Johannesburg planted 200,000 trees; currently, the tree planting target should be more ambitious, so as to be compelling to the public and decision makers alike. Useful guidance is provided by the “3-30-300 rule” (UNECE, 2021), which states that individuals should be able to see at least three trees from their home, that there should be a 30% tree canopy cover in each neighbourhood and 300 metres should be the maximum distance to the nearest high-quality public green space.

- **INCORPORATE URBAN GREENING IN EXISTING PUBLIC WORKS SCHEMES IMPLEMENTED IN UNDER-PROVISIONED AREAS, IN THE PROCESS CREATING GREEN JOBS FOR (OFTEN LOW- OR UNSKILLED) PEOPLE LIVING IN THE NEIGHBOURHOODS THAT WILL MOST BENEFIT FROM IT.**

- **LEARN FROM GOOD PRACTICE EXAMPLES ELSEWHERE.**

A good starting point is to engage with ICLEI, which has a recognized expertise in the domain of nature-based solutions for African cities. Both Johannesburg and Ekurhuleni are members of ICLEI, which should facilitate this activity. Apart from learning on the technical aspects of tree planting, it is important to get insight into suitable financing schemes.

- **OBTAIN MAYORAL SUPPORT AND COMMITMENT (A ‘PLEDGE’) FOR THE TREE PLANTING SCHEME.**

In addition, the Mayor could be a key figure in an annual festival to celebrate tree planting and to highlight progress in terms of the number of trees planted.

- **PRIOR TO THIS, THE METROS SHOULD CONSIDER CONDUCTING A PLANNING EXERCISE IN TERMS OF SITES, SPECIES, COSTING, FEASIBILITY, AND THE DEGREE OF RISK, AND DECIDE WHERE THEY WANT TO IMPLEMENT GREEN FEATURES SUCH AS ROADSIDE TREES OR POCKET PARKS.**

Moreover, an appraisal of suitable rainwater harvesting systems needs to be conducted, accounting for the expected future rainfall amounts.

## ● 5.2.

# HEAT-HEALTH WARNING AND AWARENESS

**H**eat-health early warning and management systems exhibit very clear benefits. For instance, in France, it was concluded that the heatwave management plans implemented following the 2003 heatwave reduced mortality during the 2006 heatwave considerably (Fouillet et al., 2008). Also, the World Health Organisation (WHO, 2021) ascertains that heat early warning plans present an advantageous benefit-to-cost ratio, achieving a large health impact in return for a relatively modest investment.

It would be potentially very impactful to partner with public health authorities and the South African Weather Service (SAWS) to establish a **heat-health early warning system** and associated measures (e.g., community workers visiting isolated elderly people, communicating recommendations regarding shelter and hydration), based on the guidance provided by the World Meteorological Organisation (WMO, 2015) and on national and regional weather forecasts provided by SAWS.

Important, though, is that such a scheme should account for the urban heat island phenomenon – in particular the elevated night-time temperatures – since studies show that the latter cause a lack of nightly rest, thus hampering the recuperation from excessive daytime heat and leading to an increased mortality rate. Together with the competent parties (in particular the South African Weather Service and/or experts managing the South Africa Air Quality Information System), the feasibility of incorporating urban characteristics in the weather forecast should be assessed, either through deterministic modelling or by means of a statistical approach.

Residents of the townships Soweto, Alexandra, Tembisa and Katlehong constitute a specific target audience for a heat-health early warning system, considering their elevated exposure (Figure 2.1., Figure 2.3.) and enhanced mortality risk (Figure 3.4.). Moreover, it is important for a heat-health warning system to reach people suffering from pre-existing disease, the elderly and (those in the care of) the very young, as these segments of the population are especially vulnerable to excessive heat. Finally, communication of early warning guidance must ensure social justice, avoiding the exclusion of those with fewer resources, especially as these typically constitute the most exposed and vulnerable population groups (Figure 3.1.). For instance, text message alerts may reach a much larger audience than a sophisticated smartphone app, given that in South Africa feature phones are considerably more widespread than smartphones.

Despite the strong impact of heat on health, public awareness is largely lacking. For instance, during the citizen monitoring campaigns conducted in the present study, it emerged that most community participants were barely or not aware of the projected impacts of climate change with respect to excessive heat. Since awareness

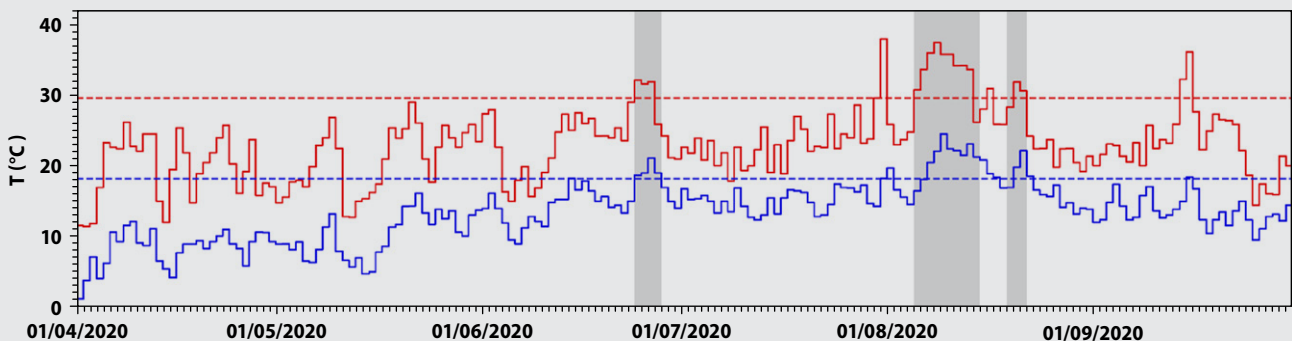
is a prerequisite to building communal support for adaptation measures, it is of paramount importance to launch a **climate and heat awareness programme**.

Awareness campaigns should include accessible but strong key messages, such as the expected doubling of heat-related mortality towards 2050 (Figure 3.4.). As in the previous measure, it would be very relevant to involve the highest political instances in the communication and actions. For instance, the Mayor could announce an initiative targeting sports federations, having them sign a charter to avoid excessive heat during sports games (e.g., by shifting football games to the cooler hours of the day). The involvement of schools is very important. To facilitate this, students could be involved in a research trajectory, contributing to the mapping and monitoring of heat stress. Not only would they learn valuable skills, their involvement would lead to an enhanced awareness of climate change impacts.

**FIGURE 5.1. EXAMPLE OF THE TEMPERATURE TIME SERIES THAT SERVE AS THE BASIS FOR A 'HEATWAVE DEGREE DAY' CALCULATION, FOR THE CITY OF ANTWERP (BELGIUM), FOR THE (NORTHERN HEMISPHERE) SUMMER OF 2020.**

The red line corresponds to daily maximum temperature, the blue line to daily minimum temperature. The dashed lines correspond to the respective threshold values, and the grey zones identify heatwave episodes.

*Source:* Flanders Environment Agency and VITO, <https://www.vmm.be/klimaat/hitte-eilanden-in-steden> (in Dutch).



Moreover, monitoring heat stress and communicating the results to the public constitute valuable components in any awareness programme. The South African Weather Service and the South Africa Air Quality Information System operate several stations measuring air temperature, based on which suitable monitoring reports can be developed. As mentioned before, accounting for night-time temperatures is important, as they carry the signature of urbanised areas most strongly. One way of incorporating elevated night-time temperatures in a comprehensive heatwave assessment would consist of using the 'heatwave degree days' indicator (Figure 5.1.), which sums day- and night-time temperature exceedances above given thresholds

(typically the 95<sup>th</sup> percentile of the daily values occurring during the summer season), thus accounting for both the length and intensity of heatwaves. The annually recurring production and communication of graphs, such as the one shown in Figure 5.1., is not very costly, generally taking a few days of expert work.



## RECOMMENDATIONS

- **ESTABLISH A DIALOGUE WITH RELEVANT PARTIES (NATIONAL TREASURY, SOUTH AFRICAN WEATHER SERVICE, PUBLIC HEALTH AUTHORITIES) WITH A VIEW TO ESTABLISHING A HEAT-HEALTH EARLY WARNING SYSTEM.**

Care must be taken to design protocols and actions that reach the most vulnerable, among other through the use of appropriate communication channels (e.g., a simple text message-based alert system). In order for such a system to be relevant to urban communities, it is of paramount importance to incorporate night-time minimum temperatures in the heatwave definition.

- **MONITOR AND COMMUNICATE HEAT STRESS ON A REGULAR (ANNUAL) BASIS,**

releasing the information shortly after the end of the summer season, using – for example – the ‘heatwave degree days’ indicator shown in Figure 51, constructed with data from the South African Weather Service and/or the South Africa Air Quality Information System.

- **LAUNCH A CLIMATE CHANGE AND HEAT AWARENESS PROGRAMME, DEMONSTRATING THE PROJECTED EFFECTS OF CLIMATE CHANGE ON FUTURE LEVELS OF HEAT STRESS IN AN ACCESSIBLE WAY AND ACCOUNTING FOR THE URBAN CHARACTER OF NEIGHBOURHOODS IN JOHANNESBURG AND EKURHULENI.**

The evidence contained in the present report, such as the heat stress maps and monitoring results, constitute relevant material to underpin such a programme. Make sure to engage higher political instances as well as relevant organisations (e.g., sports federations).

- **ESTABLISH A HEAT-HEALTH OBSERVATORY TO MONITOR AND QUANTIFY EXCESS MORTALITY DURING HEAT WAVES IN A SPATIALLY EXPLICIT WAY (E.G., PER WARD OR PER NEIGHBOURHOOD), SUCH INFORMATION BEING OF PARAMOUNT IMPORTANCE FOR HEAT-RELATED PUBLIC HEALTH PLANNING.**

To achieve this, a dialogue should be initiated with South Africa’s public health authorities, university departments and research centres that have a recognised expertise in the matter.

## ● 5.3.

# COOLING STRATEGIES FOR LOW-COST DWELLINGS

Several investigations conclude that low-cost dwellings exhibit excessive temperatures, owing to poor insulation and ventilation, and owing to the use of light materials such as corrugated metal sheets. Some of the monitoring results presented in Section 2.3. found indoor temperatures exceeding outdoor values by several °C, in one case even exceeding 10°C.

Considering the large share of people living in low-cost dwellings in Johannesburg and Ekurhuleni, and acknowledging their enhanced exposure and vulnerability to excessive heat, tackling high temperatures in informal and low-income settlements is of paramount importance; a successful implementation potentially yielding a large beneficial impact. The proposed adaptation strategies consider the existing housing stock of low-cost dwellings, aiming to reduce heat for the occupants.

One way to achieve cooling of low-cost dwellings is through the implementation of cool roofs, i.e., roofs with a high shortwave (solar) radiation reflectivity and a high infrared emissivity. The former (high reflectivity) limits the amount of solar radiation that is absorbed by the roof; the latter (high emissivity) maximises the amount of heat that can be radiated away by a hot roof. Simply painting a roof white (Figure 52) addresses both requirements. Indeed, white (or any other) paint not only enhances the reflectivity of a roof, it will generally also yield a high emissivity, certainly much higher than the extremely low values found in some corrugated metal sheets. Initiatives are being taken already in South Africa to mitigate high indoor temperatures through cool roof applications: in particular, the South African National Energy Development Institute (SANEDI) is engaged in developing cool roof projects (<https://www.sanedi.org.za/Cool%20Surface.html>).

Apart from cool roofs, a specific type of urban green infrastructure may help cool low-cost dwellings: given that (mainly single-story) low-cost dwellings are generally rather low, **the installation of pergolas** (Figure 5.3.) to provide shade may be an option. Pergolas are lightweight constructions with beams or wires to support climbing plants. Several investigations have demonstrated the cooling capacity of such structures. However, while pergolas can be constructed rather easily, the fact that they require regular maintenance should be taken into account. Also, care should be taken to select deciduous plant species, i.e., plants that lose their leaves in the cold season, when exposure to the sun's rays constitutes a heating advantage. Finally, in the case of low-quality housing in informal settlements, care must be taken to avoid that the implementation of pergola structures leads to the perpetuation of sub-par quality dwellings, the building of formal homes always constituting the priority. Still, a large stock of suitable low-cost dwellings might benefit from pergolas.



## RECOMMENDATIONS

- LAUNCH A COOL ROOFS PROGRAMME, INTEGRATING IT INTO EXISTING HOUSING PROGRAMMES, FROM THE START ENGAGING WITH THE SOUTH AFRICAN NATIONAL ENERGY DEVELOPMENT INSTITUTE (SANEDI) TO TAP INTO THEIR EXPERTISE REGARDING THE DEVELOPMENT OF COOL ROOF PROJECTS.**

Start by setting up a pilot project in one city quarter, ideally also involving a research partner to conduct measurements of heat stress in dwellings with and without cool roofs. Assess the number of low-cost dwellings in Johannesburg and Ekurhuleni and the associated roof surface, and the cost to paint these. Integrate cool roof requirements into design and procurement standards for existing programmes.

- CONSIDER A PROGRAMME TO EQUIP LOW-COST DWELLINGS WITH PERGOLA-LIKE STRUCTURES, FEATURING DECIDUOUS PLANT SPECIES, TO SHIELD BUILDINGS FROM AN EXCESSIVE RADIATION LOAD.**

Since this is not (yet) a widely established adaptation measure, it would deserve setting up and assessing prototypes first, considering the effectiveness, sustainability (maintenance) and cost of these structures. Also, care must be taken that a pergola programme never becomes a substitute for a regular house improvement scheme.

**FIGURE 5.2. PAINTING ROOFS WHITE TO MAKE THEM COOLER.**

Source: <https://www.coolroofschallenge.org/>



**FIGURE 5.3. EXAMPLES OF PERGOLA-LIKE STRUCTURES PROVIDING SHADE.**

Source: Ochoa et al. (2022).



## ● 5.4.

# COMMUNITY COOL SPACES (SHELTERS)

**S**tudies ascertain that cooling centres may play a significant role in reducing the risks of adverse health impacts of extreme heat exposure, especially for vulnerable people such as the homeless. Studies have demonstrated that spending only a few hours in an air-conditioned environment reduces heat-related illnesses and death.

Of course, the use of air-conditioning is not without issues: not only does it contribute to enhanced heat shedding to outdoor air (thus enhancing the urban heat island), it also contributes to increased greenhouse gas emissions, especially in a country like South Africa where a large share of the electrical power is generated in coal-firing plants. Still, when combined with photovoltaic (solar) panels, air conditioning in community buildings may be a valuable adaptation option, especially considering that, during heatwaves, solar energy is generally abundantly available. Moreover, it is expected that the availability of solar radiation in South Africa will increase with climate change. Solar panels also provide an additional physical shielding of roof surfaces, blocking the solar rays, hence reducing building overheating and lowering cooling demand. Finally, investing in solar panels is generally considered wise, with a positive return on investment, especially considering rising energy prices and continued challenges of load-shedding and rolling black-outs.

This measure holds a lot of potential, since the municipalities of Johannesburg and Ekurhuleni have a fair number of community buildings under their care (kindergarten, elderly homes) where they could implement active cooling and open up to vulnerable people from the neighbourhood. However, care should be taken to ensure the accessibility to vulnerable populations, i.e., either the centres should be within walking distance, or else a proper (and free) access by means of public transportation should be ensured.



## RECOMMENDATIONS

- **INVENTORY SUITABLE BUILDINGS THAT ARE UNDER THE CARE OF THE MUNICIPALITY AND ASSESS THE POSSIBILITY TO INSTALL SOLAR PANELS ON THE ROOF (VERIFY THE EXPOSURE TO SOLAR RADIATION, ACCOUNT FOR INCIDENTAL SHADING CAUSED BY NEARBY BUILDINGS, ASSESS THE SUITABILITY OF THE ROOF CONSTRUCTION TO ACCOMMODATE SOLAR PANELS).**
- **ONCE A LARGE ENOUGH NUMBER OF COMMUNITY COOL SPACES ARE IN PLACE, ESTABLISH A COMMUNICATION PROGRAMME, PREFERABLY WITHIN THE HEAT-HEALTH WARNING PROGRAMME OUTLINED ABOVE, TO INFORM THE PUBLIC.**  
Make sure to reach the most vulnerable segments of the population, such as elderly isolated people, which, e.g., would benefit more from receiving information from community workers than from an announcement through social media.
- **INVESTIGATE WHICH FINANCING SCHEME (INCLUDING INTERNATIONAL CLIMATE FINANCE) WOULD BEST SUIT THE REQUIRED INVESTMENTS (COOLING INSTALLATION, SOLAR PANELS), INCLUDING CONSIDERATIONS REGARDING THE EXPECTED PAYBACK FROM REDUCED ELECTRICITY COSTS.**

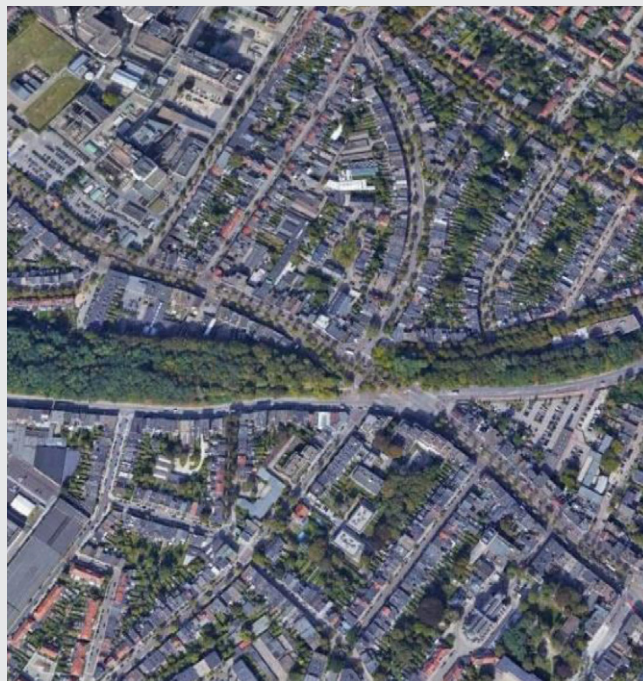
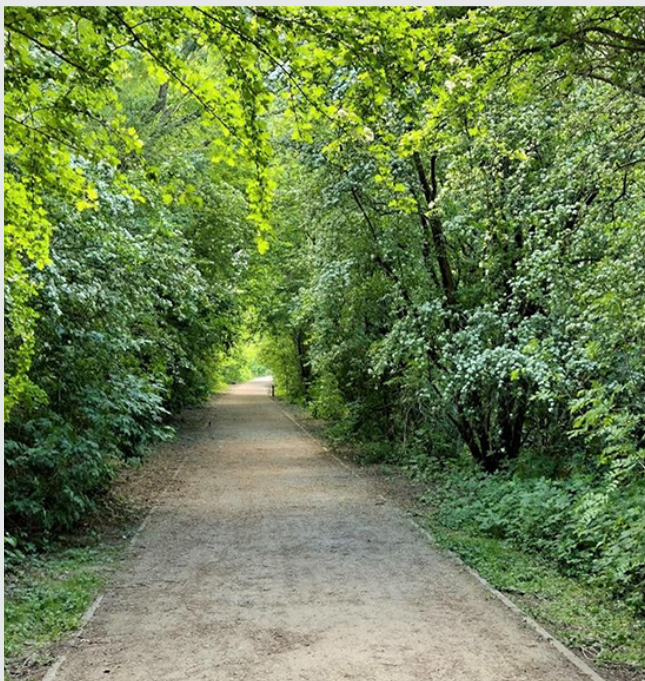
## 5.5.

# PROTECTING INDOOR AND OUTDOOR PUBLIC SPACES FROM EXCESSIVE HEAT

**S**ensitive public **indoor public spaces** such as clinics and schools often suffer from excessive heat, which is problematic given the concentration and vulnerability profile of people in such buildings. Schools and clinics featuring iron corrugated roofs are at a particular risk of overheating, exposing students or patients waiting for treatment to unhealthy levels of discomfort. Among the adaptation measures mentioned before (e.g., those targeting low-cost dwellings or cool community centres), several can be applied to clinics and schools, and to other buildings where vulnerable people gather. As shown above, cool roofs and air conditioning (preferably powered by solar panels) constitute potentially efficient cooling means. Likewise, well-targeted vegetation, thanks to its shadowing properties, can be a very powerful heat mitigation measure.

**FIGURE 5.4. EXAMPLE OF 'BOULEVARD'- OR 'TUNNEL'-LIKE VEGETATION, PROVIDING SHADE ON A LOCAL WALKWAY (UPPER IMAGE), EMBEDDED IN A GREEN BERM THAT WINDS THROUGH THE TOWN OF MORTSEL IN BELGIUM (LOWER IMAGE).**

*Source: left image by Koen De Ridder, right image from Google Earth.*



With respect to mitigating **outdoor heating** of public spaces, targeted vegetation would constitute the main cooling means. The targeted implementation of green infrastructure may help protect waiting areas near the entrance of clinics or at public transportation stops from excessive heat. A few well-positioned trees, casting shade in the right spot (e.g., at the position of a queuing line) or a pergola covering an outside waiting area at a clinic may reduce exposure to heat stress considerably, bringing heat stress down from ‘very strong’ to ‘strong’ or ‘moderate’. Another useful type of targeted vegetation, potentially reducing heat loads for a large number of people, is available in the form of so-called ‘boulevards’ vegetation, i.e., tree lines established on both sides of extensively used walking alleys, streets, bicycle paths and sidewalks (Figure 54). The tops of opposite trees should form a (nearly) closed canopy, or else pergola-like structures could be implemented, providing shadow to crowds of local commuters or school children.



## RECOMMENDATIONS

- **ENGAGE WITH THE HEALTH AND EDUCATIONAL SECTOR TO IDENTIFY SCHOOLS AND CLINICS THAT EXHIBIT HIGH LEVELS OF INDOOR HEAT STRESS. PRIORITIZE THESE PUBLIC SPACES WITH RESPECT TO **CLIMATE-PROOFING INVESTMENTS** (E.G., SOLAR LOUVRES, COOL ROOFS, AIR-CONDITIONING IN COMBINATION WITH SOLAR PANELS).**

- **WITH RESPECT TO OUTDOOR PUBLIC SPACES, IDENTIFY WALKWAYS THAT ARE INTENSIVELY USED BY COMMUTERS (INCLUDING SCHOOL CHILDREN) AND ASSESS THE FEASIBILITY TO IMPLEMENT ‘BOULEVARD’ **VEGETATION CORRIDORS** ALONG THEM.**

The use of mobile phone-based ‘density maps’ (tracks) may provide useful information regarding the intensity of use of walkways. For schools, in particular, inspiration can be found in the OASIS project conducted in Paris, making school yards resilient to excessive temperatures (<https://uia-initiative.eu/en/uia-cities/paris-call3>).

## ● 5.6.

# URBAN VEGETABLE GARDENS (AGRO-FORESTRY)

According to the UN Intergovernmental Panel on Climate Change (IPCC) 'urban agriculture and forestry can improve nutrition and food security, household income and mental health of urban farmers while mitigating against some of the impacts of climate change like flooding and landslides (by stabilising the soil & reducing runoff), heat (by providing shade and through evapotranspiration) and diversifying food sources in case of drought'.

**FIGURE 5.5. MANZI COMMUNITY URBAN GARDENING PROJECT IN CAPE TOWN.**

**Source:** Violence Prevention through Urban Upgrading (VPUU), <http://vpuu.org.za/safe-node-area/community-urban-gardening/>.



Urban vegetable gardens have a capacity to locally reduce urban heat stress, especially when crops (low vegetation) are combined with interspersed trees in an agro-forestry approach, the trees protecting the crops from excessive heat stress and limiting soil moisture losses; in addition, they reduce the heat exposure of workers cultivating the land underneath the trees.

Community urban gardening eminently combines with the implementation of natural (organic) compost, which presents many climate benefits, such as preserving soil moisture and enhancing below-ground carbon sequestration. Compost also presents multiple other advantages, such as an improved soil fertility, urban waste reduction (through the collection of organic waste), and the creation of jobs for the urban poor.

Urban gardening initiatives exist in South Africa, such as the Manzi urban gardening project (Figure 5.5.) at Monwabisi Park in Cape Town, focusing on community urban gardening and food waste management. Johannesburg features the Siyakhana project (<https://siyakhana.org/temp/>), located in the Bezuidenhout Park, which attaches a strong importance to the capacity of urban gardens to reinforce the sense of community. For further examples, and for overall inspiration and support in the development of urban agriculture projects, the City of Johannesburg can rely on its membership of the Milan Urban Food Policy Pact (<https://www.milanurbanfoodpolicypact.org/>); Ekurhuleni may consider joining the Pact.



## RECOMMENDATIONS

- **ENGAGE WITH EXISTING URBAN GARDENING INITIATIVES SUCH AS THE MANZI (CAPE TOWN) OR SIYAKHANA (JOHANNESBURG) PROJECTS AND LEARN FROM THESE EXAMPLES.**
- **ESTABLISH A PROGRAMME TO ACHIEVE A CONSIDERABLE UPSCALING OF URBAN GARDENING INITIATIVES:**
  - (1) identify suitable spots where urban agro-forestry plots could be developed, focusing on derelict areas in the townships;
  - (2) engage with the local communities and community workers that are active at neighbourhood level;
  - (3) provide the community gardening groups with basic equipment (shovel, wheelbarrow) and materials (trees, fencing wood) required to establish the urban gardens;
  - (4) establish an organic waste recycling and processing scheme to produce natural compost for the urban community gardens.
- **ENGAGE WITH THE MILAN URBAN FOOD POLICY PACT TO TAP INTO THEIR EXPERTISE, INCLUDING REGARDING SUITABLE FINANCING SCHEMES.**

## ● 5.7.

# PROTECT WORKERS AND ENSURE LABOUR PRODUCTIVITY

**O**utdoor workers are among the most exposed population groups, especially those in physically demanding jobs such as construction workers, road building and repair labourers, waste pickers and (urban) agricultural workers. It has been stated that the increasing heat exposure of workers constitutes the most important occupational health impact of climate change in South Africa. When exposed to excessive heat, outdoor workers will lose productivity, which directly affects national income metrics such as the GDP. It has been estimated that heat related productivity losses (combined in- and outdoor) can reduce GDP by several percent, which would correspond to annual losses of the order of a billion USD for each Johannesburg and Ekurhuleni.

Yet, few measures are taken by employers to protect health or improve worker comfort. It has even been concluded that the implementation of existing legislation to protect workers against the health effects of heat exposure is lax. Even in settings where it is apparently warranted, basic measures to decrease the health risks of workers in exposure settings, such as the provision of safe water, are not always implemented. Yet, regulations addressing this do exist in South Africa. The Occupational Health and Safety Act stipulates that the time-weighted average wet-bulb globe temperature (WBGT) should not exceed 30°C. In case this cannot be met, the Regulation goes on to require that labourers should first be found fit by a registered medical practitioner to perform hard labour under hot conditions, and subsequently to ensure that employees are acclimatized, get enough fluid intake, know how to avoid heat stroke and provide medical care to deal with it. As a first adaptation measure, a monitoring system ought to be put in place that ensures that heat-related occupational health concerns are effectively taken at heart and made verifiable.

Another adaptation measure relates to monitoring the WBGT in the working environment. The devices that were used to monitor WBGT in the present study would qualify for such a use. At a cost of around 150 USD per device, the provision of WBGT data loggers constitutes an affordable measure. In addition, soft (behavioural) measures may be implemented during heatwaves, such as changing working hours to avoid the hottest parts of the day or regular breaks, which is a low-cost measure with a potentially large beneficial impact, although it requires some level of flexibility from both employers and employees. Finally, simple, and cheap yet efficient measures should be put in place, such as providing protective clothing (sunhat) and ample fluids.

With respect to indoor workers, the concern is largely similar as for outdoor workers, i.e., protecting workers from excessive heat and avoiding labour productivity loss. Yet, adaptation measures for indoor conditions may be rather different because, most of the time, direct exposure to solar radiation is less of an issue. The term 'indoor' is vast, covering modern cooled offices, factory buildings (see Figure 5.6.), and small workshops without cooling systems. The same official regulations as those mentioned in the outdoor work section (Occupational Health and Safety Act, see above) apply to indoor workplaces, hence the provision of drinking water constitutes a simple but necessary measure, as is the continuous monitoring of the WBGT.

**FIGURE 5.6. AERIAL VIEW OF MEADOWDALE, GERMISTON (CITY OF EKURHULENI), SHOWING AN ARRAY OF FACTORY BUILDINGS WITH THEIR CHARACTERISTICALLY WIDE LOW-RISE (NEARLY) FLAT-ROOFED BUILDING SHAPES, FEATURING LARGE BUILDING ENVELOPES.**

*Source: Google Earth.*



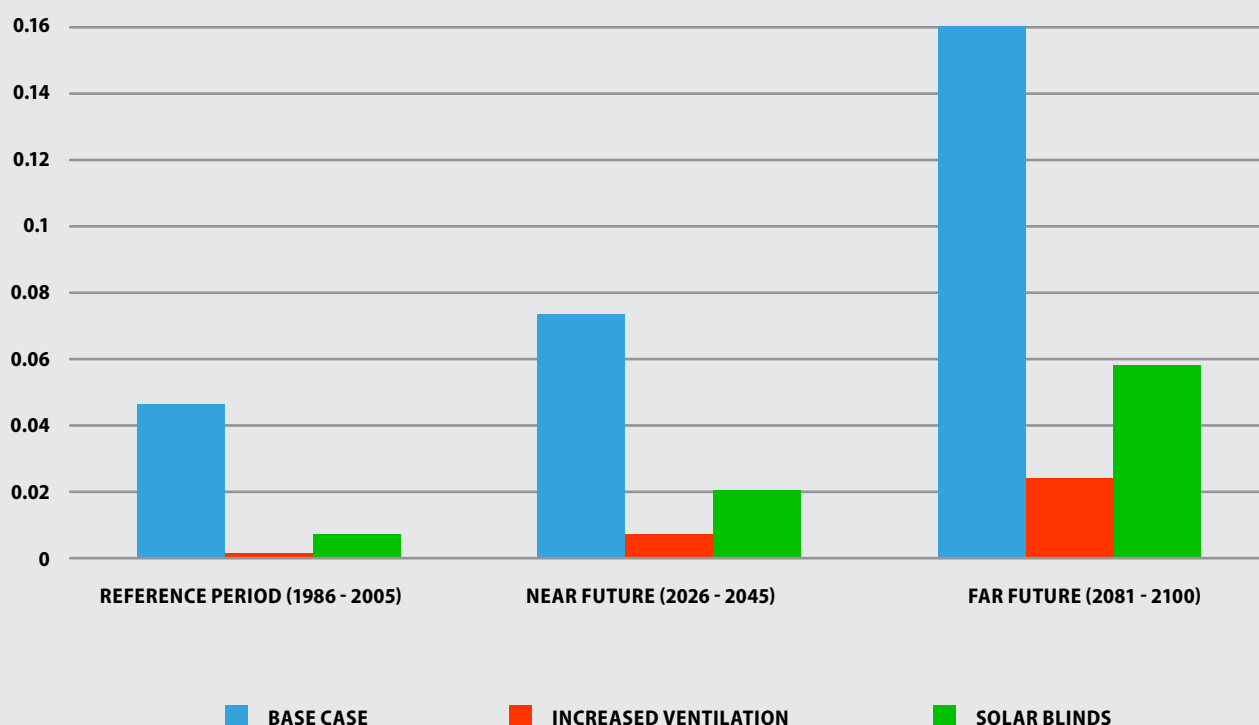
Industrial buildings as those shown in Figure 5.6. merit special attention, given that the City of Ekurhuleni hosts a large number of them, its economy being largely driven by industrial activity. This type of industrial buildings exhibits large heat gains through its envelope, because of the vast surface areas and (often) simple and light construction systems. Moreover, industrial buildings may suffer from internal heat gains stemming from manufacturing process loads. Studies in Mexico (which

features a climate not unlike the projected climate for Johannesburg-Ekurhuleni) have shown that the best approach to protect industrial buildings from overheating is to implement a cool roof (high reflectivity and emissivity, see previous sections) or to simply insulate the roof. Additionally, industrial buildings with metallic roofs benefit the most from the implementation of rooftop solar energy panels.

**FIGURE 5.7. ESTIMATION OF THE FRACTION OF LOST WORKING HOURS IN A BUILDING OFFICE IN ANTWERP (BELGIUM), FOR AN AVERAGE SUMMER, CONSIDERING PRESENT AND FUTURE CLIMATE CONDITIONS.**

Blue bars refer to the situation without measures, red bars show the result of increasing the ventilation (passive cooling, including 'night flush'); green bars represent the effect of solar blinds.

Source: Hooyberghs et al. (2017).



For office buildings, several adaptation measures exist. Physical measures include increased ventilation and the use of solar blinds. Even though these are fairly simple and non-costly measures, the example presented in Figure 5.7. shows that both are effective in reducing the number of lost working hours. Shading by targeted vegetation such as trees appears less relevant, except for very low buildings. The reason is that, during the hottest period of the year, in Johannesburg and Ekurhuleni the sun at noon stands overhead in the sky, making any tree-based shading inefficient unless the vegetation is on the roof. Alternatively, an array of roof top solar panels may constitute an efficient solution, since it provides shade as well as energy to power an active building cooling system, without putting an extra strain on the regular electricity production and transmission system.

As was the case for outdoor work, behavioural indoor adaptation measures consist of changing the work regime, shifting working hours to the cooler times of the day, i.e., early morning and evening, a measure that studies have been found to reduce lost labour productivity by approximately a factor of two. Finally, indoor climates in small workshops without active cooling may be made more comfortable by applying some of the cooling strategies for low-cost dwellings described above, including cool roofs.



## RECOMMENDATIONS

- **ENGAGE WITH UNIONS AND EMPLOYERS' ORGANISATIONS TO ENSURE THAT, AT THE VERY LEAST, THE OCCUPATIONAL HEALTH LEGISLATION ALREADY IN PLACE IS RESPECTED.**

Jointly devise ways to enforce and monitor this, among other by appointing (and training) a person in charge of heat issues within each working team.

- **INSTRUCT EMPLOYERS TO ENSURE THAT OUTDOOR WORKERS RECEIVE APPROPRIATE PROTECTIVE CLOTHING, SUCH AS A SUNHAT, AND ARE OFFERED THE POSSIBILITY OF A REGULAR FLUID INTAKE.**

- **ESTABLISH A GROUP-BUYING SCHEME TO PURCHASE WBGT MONITORS AT A REDUCED COST AND PROVIDE TRAINING IN THE PROPER USE OF THESE INSTRUMENTS TO WORKERS AND SUPERVISORS.**

- **INVENTORY FACTORY AND OFFICE BUILDINGS THAT WOULD BENEFIT FROM PHYSICAL HEAT PROTECTION MEASURES IN THE FORM OF SOLAR BLINDS, ROOF WHITENING (ESPECIALLY FOR METALLIC ROOFS), ENHANCED ROOF INSULATION, AND THE INSTALLATION OF ACTIVE (SOLAR POWERED) BUILDING COOLING.**

Engage with building owners to assist them with achieving cooling objectives.

## 5.8.

# MINIMIZE ENERGY NEEDS FOR COOLING

The combined impact of climate change and the urban heat island is expected to induce enhanced cooling energy requirements. It has been estimated that, for each degree of temperature increase, peak electricity load increases by up to 4.6%. As mentioned in Section 3.4., by 2050, increasing temperatures alone will cause a rise of the cooling energy demand by 38%. Together with the projected increased market penetration of cooling devices (85% increase in the period 2020-2030 alone), this will cause additional strain to an electrical power system that is already having difficulties of a stable energy provision, blackouts occurring frequently.

The previously mentioned cool roofs can contribute to reducing cooling energy demand by lowering indoor temperature, although in many situations this would not apply, e.g., low-cost dwellings will rarely be equipped with an active cooling installation. Solar panels are useful, since the use of locally produced solar energy reduces the load on the metropolitan energy distribution system. Moreover, solar panels reduce the cooling energy requirement of buildings by up to 12%, simply by shielding them from solar radiation. Urban vegetation also has the potential to locally cool the environment hence reduce building cooling requirements, although it is important to be aware of the localized impact of urban trees and other vegetation.

Whereas, in the previous paragraphs, cooling energy demand reduction was described as a climate adaptation measure – among other reducing peak loads hence enhance the resilience of the electrical power systems – these measures obviously also serve mitigation purposes, especially given the large share of electrical energy in South Africa that is produced in coal-firing plants, which emit copious amounts of greenhouse gases.



## RECOMMENDATIONS

- **ENGAGE WITH EMPLOYERS AND BUILDING OWNERS TO BRING ENERGY CONSUMPTION DOWN, CONSIDERING MEASURES SUCH AS CREATING COOL ROOFS ON FACTORIES BY INSULATING AND WHITENING THEM.**
- **IN PARTICULAR, THE INSTALLATION OF SOLAR PANELS AS A POWER SOURCE FOR BUILDING COOLING INSTALLATIONS MAY BE USEFUL, THE MORE SO BECAUSE SOLAR RADIATION IS GENERALLY ABUNDANTLY AVAILABLE DURING HEATWAVES.**  
In addition, this may take some strain off the regular electricity producing and distributing system hence limit blackouts.

## ● 5.9.

# MAINSTREAM HEAT MITIGATION ACROSS CITY STRATEGIES

**U**rban heat presents a multi-faceted challenge that calls for action from many stakeholders: from urban planners to public health officials, employers and labour organisations to meteorologists and leaders of the education system. Heat mitigation touches on many departments of city government; as such responsibilities are often dispersed and fragmented.

Therefore, it is important to make heat mitigation the business of all city departments, by mainstreaming adaptation into their sectoral planning and operations. Indeed, adaptation measures only get implemented concretely through their mainstreaming in other policy domains. Yet, achieving an effective mainstreaming of adaptation in (urban policies) is not straightforward; knowledge on what makes mainstreaming effective is scarce and fragmented. The introduction of a 'climate reflex' when planning in all policy domains is a necessary starting point. For instance, in the domain of urban infrastructure and renewal, public tendering procedures could require that the submitting parties (architects, contractors) account for climate considerations in the proposed designs. Another useful action that can be implemented easily would consist of an assessment of departmental strategic plans with respect to the inclusion of present and future heat-related concerns.

An overarching recommendation is to appoint a City Heat Officer ('heat champion'), to work across city departments, to drive forward heat as a theme, and to ensure that city government integrates heat mitigation action across their policies and operations, including in the domains of health, infrastructure, housing, occupational health and safety, private sector development, and communications. Inspiration can be found in cities having appointed City Heat Officers, including Miami, Santiago de Chile, Athens, and Freetown. Several of the recommendations provided in the previous sections could in fact be assigned to this City Heat Officer, such as engaging with local communities to create support for enhanced greening in under-provisioned neighbourhoods; establishing a dialogue with public health and meteorological authorities to envision a heat-health early warning system; or engaging with employers and building owners to identify and implement building cooling strategies



## RECOMMENDATIONS

- **CONSIDER APPOINTING A CHIEF HEAT OFFICER, WORKING ACROSS CITY DEPARTMENTS, AND DRIVING FORWARD HEAT AS A THEME.**
- **CONDUCT AN ASSESSMENT OF DEPARTMENTAL STRATEGIC PLANS WITH RESPECT TO THE INCLUSION OF HEAT.**
- **INCORPORATE CLIMATE CONCERNS IN PUBLIC TENDERING PROCEDURES OF ALL CITY GOVERNMENT DEPARTMENTS.**

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# URBAN HEAT IN JOHANNESBURG AND EKURHULENI


Impacts and Mitigation Options



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