UNDRR
UN Office for Disaster Risk Reduction

HEATWAVES:
addressing a sweltering risk in Asia-Pacific

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EXECUTIVE SUMMARY

The last decade was the warmest on record, and leading organisations on climate change indicate that warmer temperatures are not a potential threat but a surety. In this report, we take the assumption of the UN's Intergovernmental Panel on Climate Change's climate projections. This report considers ways in which disaster risk reduction (DRR), climate change adaptation (CCA), and related scientific communities can rise to data challenges in order to provide policymakers with the evidence needed to set priorities and make decisions. Given the sizeable threat posed by extreme heat events, we detail the human impacts of heat waves, ranging from individual and community health to the built environment.

The purpose of this report is to 1) explore the drivers of increased risk and socioeconomic impact of extreme heat and 2) identify and propose priority risk management policies for reducing vulnerability and human impact of extreme heat events. This report should inform and help focus strategic directions for local governments, frontline agencies, and policy makers responsible for climate and disaster risk management, urban development, and health and social protection. We hope this report will open doors to debate and new thinking at regional and global levels.

This report focuses on the Asia-Pacific region with further attention given to the urban poor. It reviews the current knowledge about human impact of heat waves. The discussion is enriched by the expertise and practice shared by key informants from a range of fields, including but not limited to public health, meteorology, medicine, and disaster risk management.

The report briefly covers global and regional patterns of heat waves and main challenges for measuring effects of extreme heat at individual and community levels. It discusses some of the significant direct and indirect effects of heat and socio-economic factors which negatively impact population health and wellbeing. The report also addresses the paucity of data related to heat waves and suggests some potential approaches for closing data gaps.

The report concludes with policy recommendations drawing on its content including valuable inputs from key informants and incorporating illustrative exemplary boxes throughout the report. The recommendations are applicable at varying administrative levels and offers practical and scalable options. They focus on improving data quality, reducing impact in populations most at-risk for negative outcomes, encouraging innovative adaptations in urban planning, creating meaningful and enforceable regulatory protections, and developing and utilizing heat action plans.

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CHAPTER 1. HEAT WAVES: PREPARING FOR A GROWING THREAT

Nearly a decade ago climate change was recognised as "the biggest global health threat of the 21st century," placing the "lives and wellbeing of billions of people at increased risk" (1–3) and presenting a "potentially catastrophic risk to human health" (4). According to the World Health Organization (WHO) regions exhibiting the poorest health systems were the least able to adapt, prepare, and respond to the variety of increased health risks likely to occur in a changing climate.

Climate extremes such as cyclones, droughts, floods, have grown in frequency and severity, and global attention has been forced toward mitigation and adaptation of these events. However, a number of these climate events remain under a cloud of uncertainty, posing major methodological and measurement challenges to capture impact and losses accurately. Moreover, the pathways and mechanisms by which they actually impact people, settlements, and social organisation are badly understood, and evidence is poor. In consequence, policies to respond to these events are based often on assumptions and anecdotal understanding of field level impacts. Managing heat waves is particularly prone to these challenges, and this report focuses on this growing threat.

In 2015, WHO and WMO issued joint statements underscoring the urgent need to plan to act against heat waves. As a result of human-induced changes to the climate, global mean surface air temperatures show a rising trend over the last 100 years (5) and globally, increasing frequency, intensity, and duration of extreme heat events is widely acknowledged at all levels.

Heat-related policies, studies, and analyses have generally focused on systems-based approaches and are undertaken from large-scale perspectives. Associated risk reduction objectives are often set for decades, requiring adherence by large populations, and necessitating the development and execution of broad policies to promote prevention of impacts through behaviour change efforts with vulnerable population. While these systems-based policies and programmes are fundamental components to reduce human-heat impacts, there is also not only a place but a necessity for person- and community-centred policies. Changing behaviour or reorienting policies at local levels are not easy undertakings, and more focused attention on the perspectives of individuals, households, and communities can fill the gaps large-scale approaches miss. Public health successes like the eradication of polio or improving maternal nutrition have revealed the importance of well-identified objectives with actionable, targeted activities for bringing about substantive change. Step-by-step goals and using person-centred policies, in addition to broad, systems-based approaches, can lead to transformative, longitudinal change.

The purpose of this report is to 1) explore the drivers of increased risk and socioeconomic impact of extreme heat and 2) identify and propose priority risk management policies for reducing vulnerability and human impact of extreme heat events.

The report focuses on the Asia-Pacific region and examines inequities and the disproportionate impact of extreme heat events on vulnerable communities, particularly the urban poor. We review and discuss the current knowledge about heat waves – from individual, to household, to community perspectives. This discussion is enriched by the expertise and practice shared by key informants from a range of fields, including but not limited to public health, meteorology, medicine, and disaster management.

First, we describe the global and regional patterns of heat waves before setting out some of the main challenges for measuring effects of extreme heat at individual and community levels. We discuss some of the significant direct and indirect effects of heat and socio-economic factors which play a negative role on population health and wellbeing. We round this discussion on the paucity of data related human impacts of heat waves and suggest some potential approaches for closing data gaps.

We conclude with policy recommendations drawing on the report content including valuable inputs from our key informants and incorporating illustrative exemplary boxes throughout the report. Our recommendations are applicable at varying administrative levels and are practical and scalable options. They focus on improving data quality; reducing risk in urban areas and for vulnerable populations; encouraging innovative adaptations in urban planning; creating meaningful and enforceable regulatory protections; and developing and utilizing heat action plans, early warning systems, anticipatory action schema, and impact assessments.

CHAPTER 2. OVERARCHING ISSUES

2.1. HEAT WAVES: CHOOSING PRIORITIES

In the last four decades, extreme weather events have increased substantially, affecting more people as years go by.[1] The numbers of climatological and meteorological disasters increased by 87% in 2010 – 2019 compared to decade 1980 – 1989. Population affected by these disasters has increased by nearly 40% with the impact disproportionately felt by those most at risk such as women and girls, people living with disabilities, elderly and children, migrants and refugees, and people living in poverty. From current available evidence, trends in violent storms, destructive floods, and extreme heat are likely to continue for years, regardless of global, regional, and national policies. The UN's Intergovernmental Panel on Climate Change (IPCC) concludes that increases in the global mean surface temperature of less than 1oC would seriously impact severity of heat wave risk, a temperature threshold reached in 2017 and now exceeded (6).

The IPCC scientists now project that the number of exceptionally hot days and extreme heat waves will increase most rapidly in the tropics, with a high-confidence prediction that extreme heat events will become widespread in these regions at 1.5 oC of global warming (7). They further indicated that "limiting global warming to 1.5°C instead of 2°C could result in around 420 million fewer people being frequently exposed to extreme heat events, and about 65 million fewer people being exposed to exceptional heat waves." Unfortunately, the results of measures for global warming control have not been encouraging. As broader climate change processes continue to worsen despite global efforts, we need to focus on practical adaptation and mitigation as the main strategies for containing the effects of climate change.

1 Data from EM-DAT. Available for download at https://public.emdat.be. Downloaded May 2020.

2.2. GLOBAL AND REGIONAL PATTERNS OF HEAT WAVES

Amongst the major natural hazards with significant human impact, heat waves have increased faster than all other types of climate-related disasters in the last two decades. This report relies on EMDAT data, but there are other useful data sources such as NATCAT (Munich reinsurance), SIGMA (Suisse reinsurance), DesInventar (UNDRR) CATDAT (Karlsruhe University), all of them with advantages and disadvantage like those of EMDAT. They all have different definitions, methodologies and approaches that makes difficult to combine different sources, and we have chosen to use EMDAT to maintain comparability across time and geographic location. Box 0 below describes the thresholds, inclusion criteria, definitions, and considerations relevant to data used in this report.

BOX 0. DATA USED IN THIS REPORT

Data in this report is pulled from EM-DAT due to the database's compatibility across time and location. In order to avoid issues related to comparability across databases – many of which have different methods for collection and utilise different definitions – we have selected to use EM-DAT as the sole source in this report. However, there are a number of high-quality databases that collect and report disaster data, including heat waves, that contribute information and data points to the EM-DAT database. Definitions and reporting terminology are established by the individual countries and often differ between them, so it is difficult to aggregate data across countries and regions.

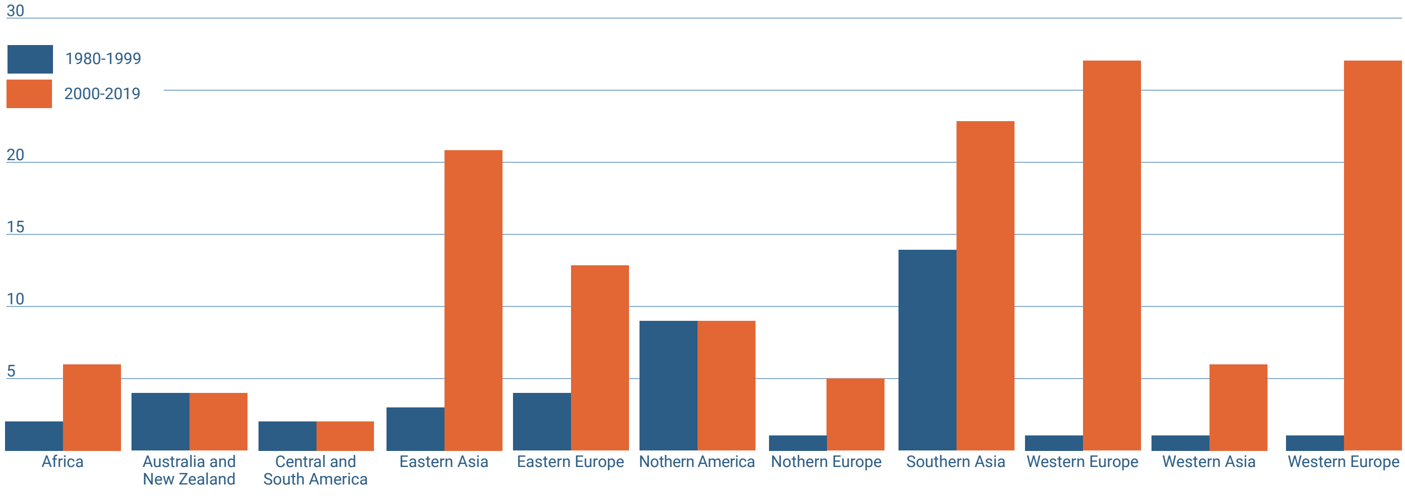
WHAT IS EM-DAT?

CRED's Emergency Events Database (EM-DAT) contains the world's most comprehensive data on the occurrence and effects of more than 24,000 technological and natural hazard-related disasters from 1900 to the present day. Originally created with the support of the WHO and the Belgian government, the main objective of EM-DAT is to inform humanitarian action at the national and international levels in order to improve decision-making in disaster preparedness, provide objective data for assessing communities' vulnerability to disasters and to help policymakers set priorities. It has received funding from USAID since 1999. Since 2014, EM-DAT also georeferences disasters, adding geographical values to numeric data which is essential for deeper analysis. Details on EMDAT's methodology & partner organizations can be found on our website www.emdat.be.

All data entries into EM-DAT must have one of the following criteria: 1) ten or more people reported killed, 2) one hundred or more people reported affected, 3) a declaration of a state of emergency, or 4) a call for international assistance. EM-DAT broadly defines heat waves as "a period of abnormally hot and/or unusually humid weather." Heat wave events in EMDAT typically rely on declarations of heat waves by State authorities, accepting that temperatures experienced during these events will vary over time and place. For historic reasons, emergencies declared by the authorities as wildfires or other emergencies caused by extreme heat are recorded separately. This effectively deflates the total number of heat waves on record in EMDAT.

EMDAT data suggests that compared to storms or floods, heat waves increased over 230% globally between the decades 2000 – 2019 and 1980 – 1999 (EMDAT, 2019). In the former decade, more than 150,000 deaths were attributed to heat waves, a vast underestimate of the true toll of extreme heat on affected populations. These figures can be misleading and better efforts (e.g., modelled estimates or excess death estimates) must be made for more plausible figures. Among the regions most affected, both in terms of occurrences and severity of impact, South and West Europe, followed by East, South, and West Asia (Figure 2) have been hit hardest, although it is important to note challenges with comprehensive data reporting which will be addressed later in this report.

FIGURE 1. HEAT WAVES BY UN REGIONS[2] OVER TWO PERIODS: 1980-1999 & 2000-2019[3].



2 Refers to the region a given country belong. In EM-DAT, a country name is automatically linked to the UN regional division classification as described here: www.unstats.un.org.

3 Since 1980, there have been cheap telecommunications, and non-reporting bias is low for acute disasters. However, heat waves are events that are poorly defined, often resulting in heat waves going unreported. The authors of this report, together with Prof Shakor Hajat of the London School of Hygeine and Tropical Medicine are currently undertaking a study to estimate the non-reporting bias through a case study in India. Please contact the authors for more information.

Regional response and indeed reporting differ widely. Europe, especially Western Europe, has been highly sensitised to the vulnerability of its population following the severe consequences of the 2003 and 2006 heat waves. As a result, preparedness, early warning, and early action mechanisms have improved significantly. More than 70,000 deaths were attributed to the heat wave of 2003 in Europe (15 EU countries and Switzerland), sending shockwaves through the civil society and political structures. Ministers resigned and the state authorities of most of these countries scrambled to recover. Detailed and well-designed preparedness plans were then put in place with reserved resources for emergency services. Temperature thresholds were set, above which all workplaces had to allow their staff to return home, nursing homes and senior residents' homes received special training and resources for high heat days. Since then, most of the European Union countries have put in place specific policy measures to foresee imminent heat spells and mechanisms to avert the human impact of extreme heat in both residential and work settings. Many European countries have also implemented heat action plans as part of the climate change adaptation policies such as the French Heat Health Watch Warning System installed months after the devastating heat wave (2003) (8).

Asia has also witnessed a substantial increase in heat waves. This region presents a diverse profile as the region includes both advanced economies, such as Japan and South Korea and developing and highly populated countries such as India and Indonesia. The influential Report of The Lancet's Countdown on Health and Climate Change, specifically points to elderly populations in India, China, and Japan as particularly vulnerable to heat exposure (9). These and other countries in the region have growing populations in densely crowded, peri-urban settlements where household level resources do not always permit effective protective conditions such as cooled interiors, easy access to potable water and green spaces. Working and living conditions in many cities of this region are particularly hazardous in high heat conditions.

2.3. HEAT WAVE PREPAREDNESS AND RESPONSE

Similar to the European case described above, examples of post heat wave planning from the Asia region also stand out as best practices with worthwhile lessons. Examples from India, Pakistan, and Australia are highlighted in Box 1, Box 2, and Box 3 below.

BOX 1. BRINGING DOWN HEAT IMPACT IN AHMEDABAD.

Ahmedabad's Heat Action Plan (AHAP) is particularly strong given its multi-level approach for reaching individuals by leveraging the power of not only individuals but also community groups and media platforms. Home to roughly 8 million people and growing at a rate of 2.5% annually, Ahmedabad is a rapidly urbanising municipality. However, preparedness for extreme heat events occurs year-round in the form of trainings, capacity building, and publicity campaigns. Another strength of the AHAP is that it includes people "on the ground," who have high exposure to heat like traffic police, midday rush delivery workers, and street vendors. A "stoplight" colour-coded early warning scheme is used for promulgating awareness about heat events and associated risks – with yellow indicating hot days, orange indicating heat alerts, and red indicating extreme heat alerts. Heat alerts trigger the activation of cooling centres, water conservation measures, SMS and WhatsApp notifications, and hospital preparations. After-action reports, urban planning initiatives, and epidemiological profiling and studies are conducted in the post heat-season. The iterative evaluation of the performance of the Ahmedabad's heat action plan has proven to reduce heat-mortality. For example, in 2015, over 2,300 Indians died in a heat wave of historic magnitude with vast geographic spread, but Ahmedabad, where temperatures exceeded 45 C, claimed fewer than 20 of heat-related deaths. The success of the Ahmedabad Heat Action Plan sets the standard for other cities and municipalities to develop effective strategies for heat-related adverse event mitigation.

BOX 2. HEAT MANAGEMENT PLAN: SUCCESS STORY FROM KARACHI.

The intent of the Karachi Heat Management Plan (HMP) is to reduce heat-related morbidity and mortality through three foundational strategies (10). First, Karachi's HMP calls for the targeted dissemination of timely information throughout the course of an extreme heat event. A strength of the HMP is its use of a three-tiered alert system. This system uses a yellow, orange, and red colour scheme to convey easily identifiable and interpretable threat levels to the population. Furthermore, community networks are mobilized to increase awareness of best practices at the community level. Second, following the 2015 heat wave that spanned India and Pakistan and killed more than 1,000 people in Karachi alone, the city recognised limited interagency collaboration as a key shortcoming of the city's response. Therefore, substantive changes were made to define a command structure by integrating the response capacities of disaster, public health, education, meteorology, and social sectors. Finally, Karachi's HMP calls for particular attention to data monitoring amongst the most at risk, including nomads, internally displaced persons, those living below the poverty line, those living in an informal settlement, pregnant women, malnourished children, and the elderly.

BOX 3. BEATING THE HEAT: HOW QUEENSLAND DID IT.

The strength of Queensland's Heatwave Management Sub-Plan lies in its clear structure for risk assessment, response, and public communication (11). Similar to Ahmedabad's HAP, Queensland uses a white, yellow, orange, red, scheme to code heat waves as no heat wave, low intensity, severe, and extreme. Assessments of likelihood of impact consider area size, population, number of vulnerable groups, and forecasted duration. These assessments are used to trigger the response system, which is detailed throughout the plan with risk matrices for determining appropriate actions to be carried out by given actors. Further, the plan clearly delimits the agencies in charge of the complete spectrum of heat wave response. For example, Queensland Health; the Department of Housing and Public Works; the Department of Communities, Disability Services and Seniors; and the Queensland Fire and Emergency Services, amongst others, are cooperatively involved in response functions. Severe and extreme heat waves have the highest attributable mortality of any natural hazard impacting Australia in the last 200 years. Given the grave health implications of these events, Queensland's plan bullets potential health impacts ranging from direct effects such as heat illness to indirect effects, such as deterioration of mental health.

The non-clinical health impacts of heat waves further underlie the importance of heat wave management at a population-level. For example, increased demand for water, damage to crops, and infrastructural stress can have longitudinal impacts on the health and wellbeing of communities. These considerations are addressed throughout the plan, focusing on actionable risk mitigation measures at the government and population levels. In addition to cooperative management from multi-sectorial agencies, the plan uses simple messaging by encouraging the public to 1) have a plan, 2) stay hydrated, 3) stay out of the sun, 4) keep cool, and 5) check on and look after others. By articulating concise, actionable steps for all parties, the Queensland Heatwave Management Sub-Plan empowers governmental organisations, community groups, and individuals to reduce the potential negative health impacts of exposure in heat waves.

Ahmedabad (India), Karachi (Pakistan), and Queensland (Australia) heat action plans offer well-executed examples that can inform other efforts in the region. While these programmes are emblematic of key progress in heat wave preparedness, many countries in Asia and the Pacific are working to develop financially and culturally pragmatic heat preparedness plans, especially in highly populated urban areas where the phenomenon is the most detrimental (12).

Essentially, the severity of the heat events in many countries, the scope of the population that it affects, and the slow recognition of the potential economic downturns and socio-political discontent is drawing attention of both civil society organisation and public authorities.

2.4. CHALLENGES WITH MEASURING POPULATION-LEVEL IMPACTS

Indicators of heat wave severity and cost are often more syndromic in nature, making the timely linkage between detection and attribution challenging to the three main components of disaster risk reduction (DRR) - prevention, risk mitigation, preparedness, and response. Two important barriers upstream to DRR is data collection and operational research. One particular challenge is the **need for an operational definition at national or sub-national levels, of what constitutes a 'heat wave'** (Box 4). While a precise definition does not need global consensus, definitions need precision at national and local levels that trigger response or early prevention. For example, without a clear start and end date of a heat wave event, it is hard to define the "emergency" period of a heat wave "event" during which death tolls or other impacts can be measured. Without agreed, fixed, locale-specific temperature baselines, it is difficult to calculate losses, illnesses, or attribute deaths to a given heat wave. Lack of definition of a heat wave event is also problematic for administrative action that would trigger relief or other mitigating actions.

Some promising and innovative work has been undertaken to address these issues. For example, the START Network in Pakistan uses hazard prediction modelling during heat wave season to give lead-time warnings of events in key population centres a minimum of 10 days in advance. An alert triggered the system in May 2020, allowing for the deployment of funds, resources, and targeted messaging, covering over 4.5 million people in Karachi for the duration of the high heat risk interval. Similarly, the Vietnam Red Cross has implemented a forecast-based funding scheme for heat wave anticipatory response in Hanoi, where past heat waves were responsible for a 20% jump in all-cause hospitalisation and an over 45% jump in respiratory-related hospitalisations (13–16). The forecasting program allows for early action when heat indices over a 2-day period are higher than the 99th percentile-based value (derived form daily heat indices of summer months from 2007 – 2018) trigger the release of funds and resources (17). Such programs help mitigate the health impact of extreme heat events by targeting high-vulnerability populations such as the elderly and outdoor workers.

BOX 4. WHAT IS A HEAT WAVE?

There is no universally accepted definition of a heatw ave amongst scientists. Rather, different regions measure heat events based on an appropriate historical baseline. The IPCC defines a heat wave as, "a period of abnormally hot weather" (18). EM-DAT defines a heat wave broadly in order to cover global reports: "a period of abnormally hot and/or unusually humid weather." Further, a heat wave lasts for two or more days, and the exact temperature criteria for what constitutes a heat wave varies by location. The Red Cross offers a similar definition: "a prolonged period of excessive heat, often combined with excessive humidity." The definition is further contextualized, saying: "generally temperatures are 10 degrees or more above the average high temperature for the region during summer months, last for a long period of time and occur with high humidity as well."

In the face of climate change, many scientists argue that it is more important to take action to mitigate the risks of hea twaves than to try to establish what local temperatures determine whether a number of very hot days amounts to a heat wave. They also point out that factors other than heat are critical to impacts on human health, including humidity, the sun's strength, the duration of an individual's exposure to extreme heat, and the absence of a significant cooling period overnight. Forecasting of heat events has begun to move from focusing solely on maximum temperatures to incorporating impact on health by using heat index to better encompass heat exposure for impacted populations. However, thresholds for heat events in areas that frequently experience extreme heat do not fully capture the dimensions impacted by such exposure (19). Scientific studies on heat waves often define the event for their specific purposes. For example, a study on pregnancy outcomes and extreme heat in the USA defined "extreme heat" as temperatures above the 95th percentile of each county-specific temperature distribution.

MEASURING POPULATION-LEVEL IMPACT IN TERMS OF MORBIDITY AND MORTALITY

Effective plans require estimation of the numbers of people who may be affected, but estimating populations affected by disasters is an exercise open to uncertainties. In most other acute events such as floods or storms, affected populations are estimated by the numbers of people who are injured, homeless or need humanitarian aid. In heat waves, **the characterisation of affected populations is significantly more problematic and hence more often than not, it is simply not done.** Well thought out and evidence-based heat action plans, forecasting models, and anticipatory action schemes can serve as critical tools for characterising affected populations and sectors, including but not limited to manufacturing and construction workers, street vendors, and delivery services and gig economy workers.

Estimating deaths due to heat stress has been an almost insurmountable barrier – mostly due to a lack of field-tested methods. **The causal link between deaths on hot days and heat exposure can be difficult to establish,** and deaths attributable to heat-related causes may therefore be underestimated. Heat exposure can exacerbate a range of other medical conditions other than heat-stroke and hyperthermia – conditions typically associated to extreme heat by the medical profession. Thus deaths from many other causes, including but not limited to cerebrovascular, cardiovascular, and respiratory diseases, certain infectious diseases are major contributory factors for deaths due to heat waves but do not get captured during hot weather as they do for other disasters such as storms or floods (20).

Notwithstanding the fact that **vital registration and death certificates** are not uniformly maintained in many developing countries, counting death tolls from heat waves is particularly challenging. In addition to institutional gaps in systematic registration of death tolls, there is an added obstacle of **diagnostic clarity** on what would constitute a heat related death. Development of operational definitions by the appropriate mechanisms of the national medical profession of conditions that constitute a heat related death would be very helpful for young practitioners and incorporated in the medical curricula.

These two weaknesses reduce the comparability of analyses across countries or even across time in the same country (2). EM-DAT, for example, records that Europe accounted for 88% of heat wave deaths worldwide over the past 20 years (2000 – 2019) (Figure 1) whereas they are implausibly low in countries where the heat waves are the severest and most intense. The statistics from Europe reflects the concerted efforts by well-established public health authorities in these countries to quantify the tolls in 2003 and 2006 heat waves using the methodological approach of "excess deaths estimation". This method is used to estimate how many individuals may have died due to a particular event or process (in this case heat waves) compared to how many would have died without it. (Box 5). In other words, it is the consideration of the counterfactual which is an estimation of the consequence if the event did not occur. The method of excess death calculation is gaining in popularity in public health and epidemiology and has been shown to be most useful for wide impact events such as deaths from severe insecurity or armed unrest.

BOX 5. EXCESS DEATHS

Excess deaths refer to the number of deaths above the baseline, or benchmark, number of deaths from a comparator year.

Many studies use excess mortality to characterise the population-level heat impacts of heat exposure (21). While excess mortality is not the most encompassing measure of the full population impact of heat exposure, this measure is useful for pattern analysis and can be indicative of underlying mechanisms that garner attention.

CHALLENGES WITH MEASURING AND ENUMERATING POPULATION EXPOSURE

The numbers available for those affected by heat waves are extremely small for low and middle-income countries (LMICs) and understanding of the pathways to extreme heat exposure very poor. In addition to simply undercounting the victims of heat waves, sound scientific studies from poor, vulnerable settings that explore evidence from field studies are quite rare, making for a **weak evidence base for policy change.** (22). Reviewing epidemiological evidence of the impact of heat in LMICs, Green and colleagues found that that poor sub-groups, are not only at increased risk of heat related morbidity and mortality but have a lower capacity to protect themselves or adapt to high temperatures. They noted in conclusion that development of effective policy and countermeasures are hobbled by lack of studies and data on heat and its impact on people.

Lowering risks for the highly exposed poorer communities will need a deeper understanding of local risk factors and hence inform evidence-led policymaking. In the following sections, the report details how these risk factors operate in high-stress heat environments and propose policies for risk mitigation. Furthermore, cascading effects of certain disasters such as heat waves and heightened pollution are matters of significant concern. They need focused attention to develop methodological techniques that measure the full human impact of a disaster in order to ring stronger evidence to drive policy at local levels.

On an encouraging note, despite these challenges, there is undoubtedly, an emergence of research on heat waves in Asia and Australia, often focusing on climatological and meteorological questions (2). The knowledge gap on the influence of persistent high heat on human health and socio-economic factors, as well as risks at the community level for households or individuals, is still wide.

CHAPTER 3. INDIVIDUAL AND COMMUNITY LEVEL IMPACTS: DRILLING DOWN

The intersection of health and heat exposure is wide ranging. This section describes the nature of three of these relationships: 1) heat and vulnerable populations, 2) heat, urbanisation, and built environment, and 3) heat and infectious disease risks.

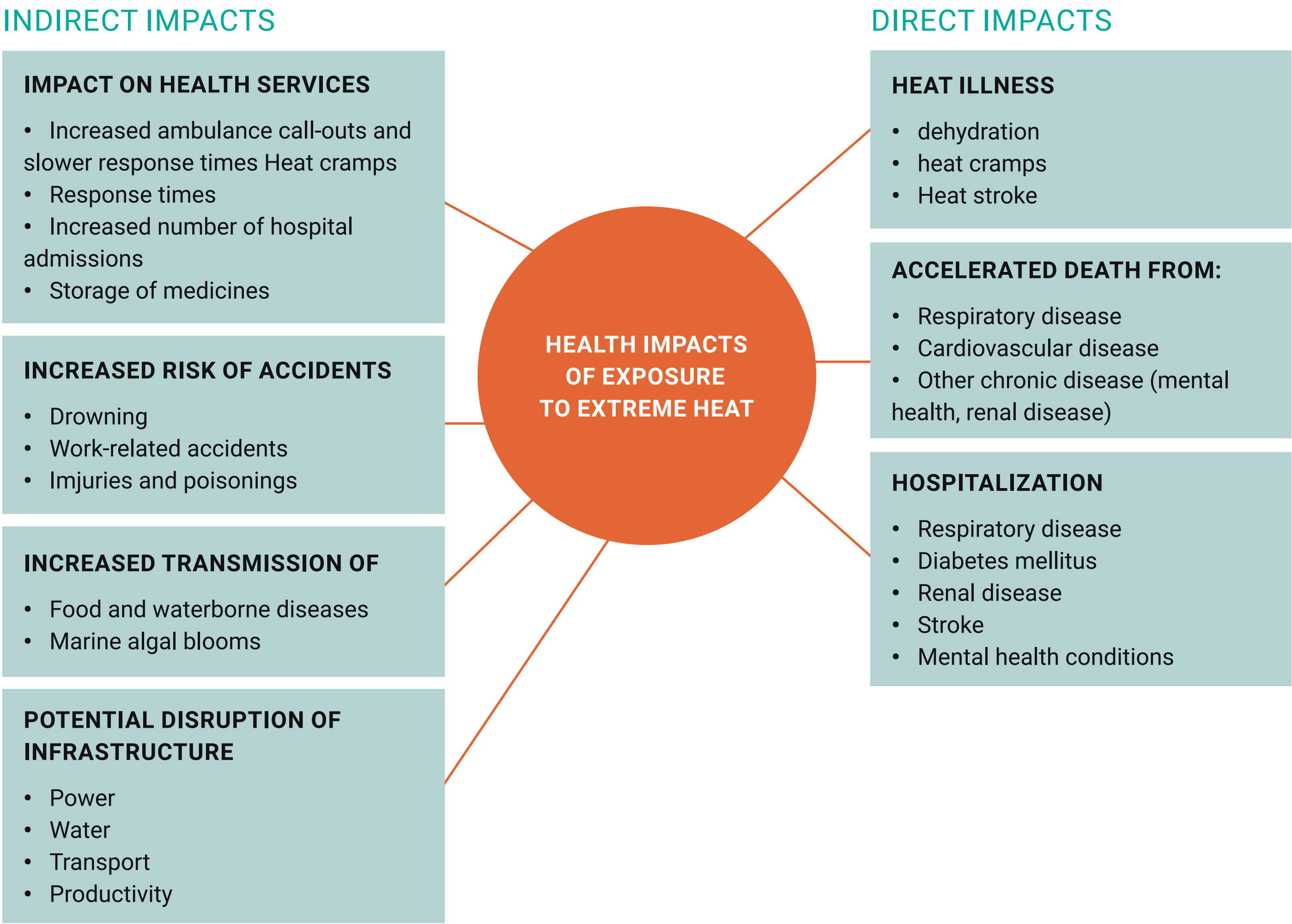
The primary interface between an individual and extreme heat is physiological and describes ways in which this phenomenon affects the human body and its response. The biological response of the body to excessive heat is wide-ranging and often presents as non-specific symptoms such as chronic fatigue, pain, or fever without a known cause. Direct impacts of heat can result in physiological changes, leading to heat illness, hospitalisation for exacerbating pre-existing health conditions and accelerated death. The primary physical manifestations of heat exposure are summarised in Table 1. Beyond these direct impacts, indirect impacts of heat can generate major ripple effects in the social and economic systems that underpin families and livelihoods, as illustrated in Figure 2.

TABLE 1. HEAT-RELATED ILLNESSES AND ASSOCIATED PHYSICAL PRESENTATIONS. *

HEAT STROKE	High body temperature (39oC/103oF) Hot, red, dry, or damp skin Fast, strong pulse Headache	Dizziness Nausea Confusion Losing consciousness, fainting, or passing out
HEAT EXHAUSTION	Heavy sweating Cold, pale, and clammy skin Fast, weak pulse Nausea and vomiting Muscle cramps	Tiredness or weakness Dizziness Headache Losing consciousness, fainting, or passing out
HEAT CRAMPS	Heavy sweating during intense exercise Muscle plain or spasms	
SUNBURN	Painful, red, and warm skin Blisters on the skin	
HEAT RASH	Red clusters of small blisters, usually on the neck chest, groin, and elbow creases	

*Adapted from the US Centres for Disease Control and Prevention (23).

FIGURE 2 HUMAN HEALTH IMPACTS OF EXTREME HEAT. *



*From the World Health Organization, 2018 (24).

The physiology of heat stress is related to heat gain in the body caused by a combination of external heat from the environment and internal body heat generated from metabolic processes. Rapid rises in heat gain weakens the body's ability to regulate temperature and can result in various conditions such as heat cramps, heat exhaustion, heatstroke, and hyperthermia. Heat-related mortality begins with the arrival of hot temperatures and dissipates within a 3-4 day period (25). Small children, the elderly, and pregnant and lactating women are populations of particular concern for negative health outcomes related to heat exposure.

Effective preparedness and response, especially at individual and community levels, involves a basic understanding of the factors that exacerbate the vulnerability of a person to extreme heat. Many cardiovascular, metabolic and respiratory conditions are intensified by decreased air quality during heat waves as well as by the additional metabolic stress of heat exposure (4). As these conditions (e.g., diabetes, obesity, smoking) become increasingly prevalent in low- and middle-income countries, deaths precipitated by heat waves can be expected to increase significantly. In India, for example, the increasingly frequent and intense heat waves of the last decade have occurred concurrently with increased prevalence of hypertension and diabetes increasing the size of the population segments that are susceptible to negative outcomes (26,27). This trend is particularly strong amongst urban populations, resulting in an increased risk among growing populations and vastly expanding socially and physically vulnerable groups.

Extreme heat in an geographic region is non-discriminatory for those exposed to it, however due to economic inequality determining people's access to resources, the poor are less able to mitigate the impacts of extreme heat. Systemic socioeconomic and resource-related mitigation measures pose barriers to effective mitigation of impact and peoples ability to adapt to these events. The inequity is such, that policies that target the most vulnerable amongst the low-income communities warrant urgent and specific attention. Economic, cultural, social, political, and organizational structures play central roles in how individuals, families and communities are exposed to extreme heat and what they can do about it. Indoor cool spaces, air conditioning, or very simply, easy access to clean and cool water are some of the factors that are beyond the reach of millions in hot developing countries. A simple example is the temperatures that water stored in metal tanks can reach, exceeding acceptable limits for drinking and bathing during high heat conditions. Heated water stored for several hours in metal or galvanised drums also encourage proliferation of bacteria and propagate disease when used for drinking and washing (28).

Wider considerations such as **societal gender roles, workers' rights, housing rights and regulations also have an essential role in determining exposure to extreme heat among vulnerable subgroups** and are discussed also in Chapter 4 of this report.

3.1. HIGH RISK GROUPS: NO SURPRISES

The people most at risk of adverse impact of extreme heat are the elderly, pregnant and breastfeeding women, and infants. Community engagement and participation, targeted information, and support for accessing services and implementing protective policies can ensure an individual's agency, reduce undue heat exposure, and mitigate risks.

THE ELDERLY: A GROWING HIGH RISK DEMOGRAPHIC GROUP

Older individuals especially those with pre-disposing health conditions, are highly susceptible to heat. Most of this is due to the ageing process itself, which reduces the physiological signals of dehydration, reducing the sensation of thirst and accelerates dehydration. Maintaining an human-rights approach top elderly care (e.g. 50 years of age and older and needs should be central to programming and operations here especially since the elderly are particularly vulnerable to its effects. Social networks of the elderly especially if they are alone or otherwise isolated, home monitoring by health agents and possibly legal protections are some measures that fall within an human rights approach for heat wave preparedness and prevention. Public authorities must uphold these rights not only for the elderly but also for persons with disabilities.

Sensitivity of thermoregulation (instant adjustment to excessive heat) of the skin reduces with age, thus delaying the necessary lowering of body temperature. Moreover, elderly persons are more likely to have chronic medical conditions and are more liable to take prescription medications that affect the body's ability to control its temperature or sweat. Over the past two decades, heat related mortality in those 65 and older have increased globally by more than 53% (9).

European countries are facing ageing demographic profiles, with around 20% of the population being over the age of 65. The Asia-Pacific region is now home to a third of the world's elderly population and is facing increased frequency and duration of heat waves (7). Many Asian countries now have an rapidly ageing population with substantial shares over 65, such as Japan (28%), S Korea (15.6%), China (12.0%), and Thailand (10.6%) (29). The future in most of these countries is trending towards a swift increase in elderly as life expectancies rise and socio-economic conditions improve. Vietnam, for example, is likely to have more than 30% of its population over 65 and approximately 6% of its population over the age of 80 by 2050 (30). The capital city of Hanoi has experienced over 175 days with temperatures over 35oC in the last decade, and, with "medium" greenhouse gas concentration (4.5 ppmv), temperatures in Hanoi are expected to increase 23 oC until 2050 (14,31,32). Concurrently, morbidity data from Vietnam has shown a 20% increase in all causes hospital admissions and an increase of more than 45% in prevalent cases of respiratory diseases (33). Together, ageing populations and higher prevalence of underlying conditions, especially as individuals age, create a perfect storm for heat-related morbidity and mortality, leaving the elderly particularly at-risk for negative outcomes.

PREGNANT AND LACTATING WOMEN AND INFANTS AT EXCEPTIONAL RISK

The second group at high risk of negative outcomes related to heat exposure are **pregnant and lactating women and infants.** The effect of heat in urban poor settings on pre-term births and low birth weights are of significant and of immediate importance. Neither of these are easily recuperable, and the consequences of these adverse birth experiences will impair child growth and development with consequences for their lifespan.

Because air pollutant concentration worsens with increasing temperature, both maternal and foetal stress are further amplified in extreme heat events (34). As temperatures increase, pregnant women deliver babies at a younger gestational age, with studies showing preterm delivery increasing from 1 – 6% for every 2oC increase above basal thresholds (35). Researchers from Brown University have estimated a 2.5% increase in preterm births in the four days following a single day with extreme heat using data from the US Statistical Service for 30 million births. These results are indicative of what could be the reality in urban poor settings, which often lack adequate facilities to care for preterm births. The review also cites rare evidence from 19 African countries where birthweights were lowest with each additional hot day during the second trimester of pregnancy (36).

While heat exposure in early pregnancy results in a higher risk of stillbirth than exposure in the later stages, the association between heat exposure and preterm birth holds regardless of timing of exposure (37). Additionally, dehydration due to heat exposure can have cascading adverse effects in pregnant and breastfeeding women, and their infants, including but not limited to still births, premature birth, low birthweight, and lactation suppression in mothers. Building heat stress mitigation programmes on existing local maternal care systems, such as India's Janani Shishu Suraksha Karyakaram (JSSK), a social protection programme for women and infants operating throughout the country, are proven cost-effective options for the efficient use of support systems already in place to support women and child health services.

Another key consideration for heightened heat risk among women is the way in which gender norms, roles, and responsibilities can impact women's access to open air. On an individual level, women are often responsible for household domestic tasks, including cooking, often over open fires in small rooms with inadequate ventilation. In households that lack piped water, women are also usually responsible for fetching water on extremely hot days. Common tube well sources are often the only available source of water, and women are tasked with traveling to these wells, often accompanied by their infants, further exposing both women and children to heat, air pollution, and direct sunlight for extended periods of time. Indoor stoves and open flame cooking add organic matter into indoor air and heat to the interior of dwellings, increasing exposure particularly among women.

The diurnal cycle of minimum and maximum temperatures is an important factor influencing heat-related morbidity and mortality. Physical recuperation of metabolic and cardiovascular stability following protracted heat exposure during the day require sufficiently cooler night time temperatures (38,39). **When body temperatures fail to drop at night, the sustained heat can place the elderly, pregnant and lactating women, and their infants at high risk for negative outcomes related to heat exposure.** This is especially pronounced when modest drops in temperature outside are not felt indoors since women tend to spend more time inside and are less likely to sleep outside due to social norms and safety concerns, reducing the opportunity for them to benefit from any cooling or fresh air.

3.2. MANAGING HEAT THROUGH BUILT ENVIRONMENT AND URBAN DESIGN

There is increasing interest in exploring ways in which poorer communities, especially in urban settings, are affected by heat and ways in which risk reduction can be undertaken by local government, urban stakeholders, and communities. Results of studies clearly indicate that heat impacts on population subgroups are not uniform and risks vary significantly based on the interaction of individual, household, and community factors with biological, environmental, health, social, and geographic variables (2,10). Managing urbanisation and the community level problems linked extreme heat is rapidly rising to the top of the sustainable development agenda especially in Asia.

In 2018, 55% of the world's population lived in urban areas. This number is projected to increase to 68% by 2050, with nearly 90% of the increase concentrated in Asia and Africa (43). The urban poor in Asia are concentrated in informal settlements and, in many cities, represent communities often several million strong. The informal settlement area in Tondo accounted for 38% of the total population in Manila and nearly a third of the Kolkata metropolitan population are estimated to live in squatter colonies or "bastis" (44).

One of the more threatening phenomena in less planned urban growth is the growth in **urban heat islands.** These are well defined urban areas that experience more heat stress than the surrounding suburban or rural areas due to concentrated anthropogenic heat (44,45). As populations continue to urbanise, the phenomena of the urban heat island effect pose ever greater risks to population health.

A study in Adelaide, Australia conclusively found that populations with pre-existing health conditions (e.g. obesity, cardio-vascular, diabetes) have measurable risks for physiological stress during heat waves. (47). They also found that indoor air conditioning was protective against negative health outcomes related to heat exposure but having air conditioning resulted in more limited utilisation of other heat adaptations in the built environment such as the use of heat-resistant building materials and utilising shade and green spaces. Admittedly, solutions or findings in high resource settings such as those in Australia may not be extended to poorer communities in urban informal settlements. Other, low-cost solutions that make use of natural processes are more realistic options. The physical aspects of the heat island effect such as building coverage and water percolating surface coverage have been demonstrated to drive the elevated heat experience in Bangkok, Thailand (48). Other such studies suggest that improving urban design expanding urban green spaces and building more efficient transportation and energy infrastructure are clearly likely to minimise the effects of urban heat islands.

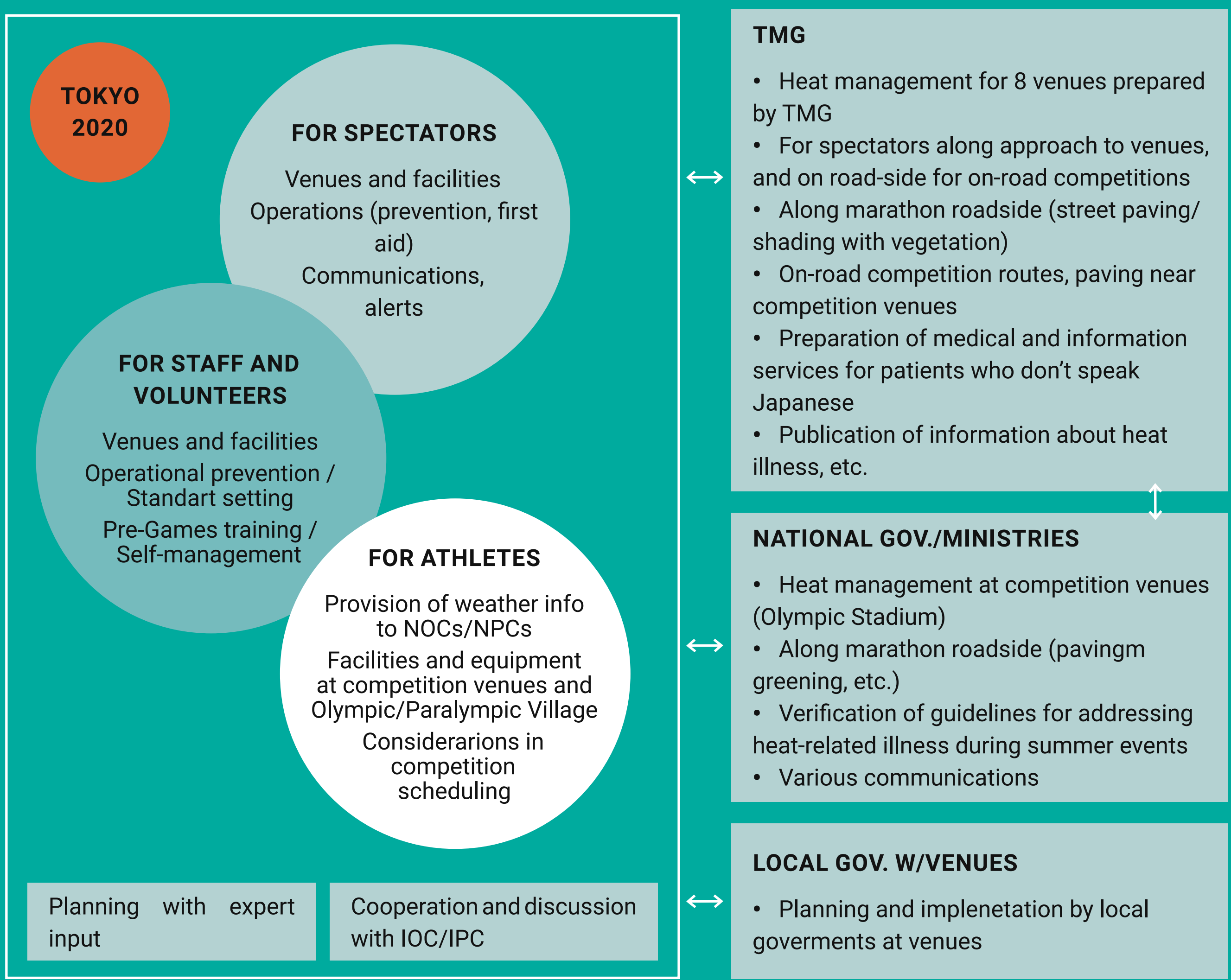
While not a panacea, green spaces offer positive environmental benefits and reduce the heat island effect. Green spaces include urban forests, such as parks, agroforestry like orchards and coffee farms, and grassy areas, including golf courses and sports fields (49). The development of urban green spaces falls under the purview of local governments and urban stakeholders. For example, in Ho Chi Minh City, Vietnam, a study found that every 1-square kilometre increase in green space per 1000 people could prevent more than 7 heat-related deaths (50). In a review of published research, Aram and colleagues found that green spaces of 10 or more hectares contributed to 1 – 2o C reduction in temperatures up to 350 metres beyond the greenspace boundaries (51). Singapore established an objective of being an urban, green city in 1967, and its laws and policies have been reflective of this goal since then. In 2020, nearly 47% of the land in Singapore was covered in green space.

Green spaces also have an appreciable capacity for carbon storage as shown in a land use and land crossover analysis in Myanmar (49). Research in Beijing, China has, however, shown the carbon benefit is diminished by high levels of urban development elsewhere, highlighting the need for intentional design and planning to maximise the effectiveness of green spaces (52). Japan's Green Curtain Project and similar undertakings in Greece illustrate the positive effects of "green walls" on buildings for reducing indoor temperature and heat-strain on buildings (53,54). Japan has further extended its work on developing urban green spaces to planning for the 2020/2021 Tokyo Olympics (Box 6). Multi-benefit policy changes can bolster both heat resilience and sustainable development in urban centres.

BOX 6. GREEN SPACES, HEAT MITIGATION, AND THE 2020/2021 SUMMER TOKYO OLYMPICS

Tokyo 2020 Games (Games of the XXXII Olympiad and the Tokyo 2020 Paralympic Games) are scheduled to take place from 23 July to 5 September 2021. To reduce heat-related risks, a collaborative effort was established by multi stakeholders including the Tokyo Organising Committee of the Olympic and Paralympic Games, the Tokyo Metropolitan Government (TMG), other local governments, and the national government (Figure 1).

FIGURE 1. STRUCTURE OF COLLABORATION FOR MEASURES AGAINST HEAT TOWARDS THE TOKYO 2020 GAMES. *



*The Tokyo Organising committee of the Olympic and Paralympic Games, 2020 (55).

Preventive measures include enhancement of green spaces (strategic planting and less pruning of trees to provide more shade), transferring several competitions to cooler locations, moving starting times earlier for some road-based competitions, support towards entities providing "cool spots" such as shade and mist, installation of heat-resistant pavement, distribution of personal cooling equipment such as paper hand fans to spectators, providing weather information and early warning information in the official mobile app and website, coordination and training of medical team and volunteers.

Regarding heat-resistant pavement, TMG and the Ministry of Land, Infrastructure and Transport have installed a total length of 133.8 km as of 2019. This pavement was designed so that those on the roads are exposed to less heat and was installed in locations including the Paralympics marathon course. To verify the impact of countermeasures, they were tested and evaluated at trials held in 2019 (56).

During the planning stage of the various venues, heat reduction measures were integrated into comprehensive landscape management. Umi no Mori, or Sea Forest, of which the cross-country course will be a venue for equestrian events and the waterway a venue for canoe and rowing, turned land which was originally a landfill into a green space (Figure 2).

FIGURE 2. BIRDS-EYE IMAGE OF UMI NO MORI (SEA FOREST)

©Tokyo Metropolitan Government

Soft measures include guidelines for heat countermeasures established by the Ministry of the Environment (2020) and Tokyo Metropolitan Government (2020), which will remain in place after the Tokyo 2020 Games (57,58).

Contributed by Tomoko Takeda, The Institute for Global Environmental Strategies (IGES), Japan

Sustainable development and heat-aware urban design are essential to build more heat-resilient cities and new low cost solutions will have to found to face the burgeoning effects of increasingly frequent heat waves (59). Thoughtful urban planning and design options can integrate fiscally reasonable and high-impact solutions to reduce the negative health effects of heat exposure.

The second important factor for **heat management in urban areas is the built environment.** Peri-urban settlements commonly display characteristics that heighten heat exposure for urban poor families attributable to both individual housing design and neighbourhood planning. The urban informal settlements lack professional architectural design and engineered solutions which relates to land-use (e.g., irregular, and unplanned street layout, absence of streets, pathways, corridors and public spaces, plots occupation, etc.), safety, construction costs and land tenure insecurity. These characteristics are often the consequence of the unrecognised legal status of these often vast communities and where basic conditions for community health protection whether from heat or other extreme climate threats are sub-optimal.

Construction materials, such as cement walls, clay tile or corrugated tin roofs, are known to raise the indoor heat stress index to dangerous levels even at relatively low outdoor temperatures. They account for higher indoor temperatures compared to similar spaces in rural areas where houses are often constructed of mud and thatched roofs (60). Box 7 gives examples and considerations for housing construction in rural settings and highlights the importance of considering all-hazards approaches to housing design.

Ventilation and **housing design play an important role in air exchange and night-time cooling,** but windows are often not frequently seen in poor urban housing design, a consideration for which there is no clear evidence-base. Roofs, in particular, are known to be key design factors to reduce heat retention in small and cramped dwellings. As hot air rises, the roof cavity or the roof material will tend to be warmer and capture hot air, trapping heat indoors. Design elements that are cheap and easy to implement such as air vents below the roof can draw cool air and direct temperature exchange to help circulate air. Roofs are exposed to large amounts of solar energy as well, thus adding the effects of outside heat. This is a particular issue for roofing materials such as concrete with high thermal mass, galvanised iron, or corrugated tin. These materials trap heat and release heat slowly as opposed to thatched roofing that aerates and maintains coolness. Thatching is commonly relegated to rural establishments as it can pose a fire hazard in crowded urban settings. In its stead, treated polyvinyl chloride could be an appropriate material for use in urban settings given that it absorbs much less heat than concrete, iron, and tin roofing materials but does not pose the same fire hazard as thatched roofing (61).

The potential for architectural and urban design innovations to improve indoor air quality, increase ventilation rates, and decrease heat retention is widely recognised to be high. Cutting edge technologies for exterior coatings such as heat-reflective, ultra-white paints and coatings have been shown to efficiently reduce indoor temperatures (62,63). Other developments such as Thermocol insulation and Modroof technologies, can also be effectively used in informal settlement housing to reduce indoor temperatures (64). In addition to these advances, simple changes like heat-sensitive placement of doors, windows, and other openings, and the use of earth-to-air heat exchangers, are also effective methods to reduce heat retention.

New technologies are rapidly developing, and these innovations are marketable in the short run and often cheap and easy to implement.

BOX 7. ASPIRATIONS ARE MAKING OUR WORLD HOTTER – LESSONS FROM THE FRONTLINES OF A POST DISASTER RECONSTRUCTION

Gujarat, on the West Coast of India, saw a devastating earthquake in January 2001. Behind the scenes of death, devastation and subsequent reconstruction was a story of how various hazards overlap to make disaster management a complex science. The earthquake struck while the region was reeling under a drought, and the spectacle of destruction was set in a landscape of parched land. As reconstruction started, many homeowners wanted to build with concrete, and to have flat concrete roofs, the kind they see in cities and aspire for. Many aid agencies obliged, with a belief that providing such stronger houses will reduce the risk from future earthquakes. The folly of this engineering centric view was soon evident as families found such concrete homes unbearable to live in during the hot summers when temperatures reach around 50C. The journey of learning lessons on heat started there, as we went about reconstructing homes with traditional designs and materials, including tile roofs that `breathe' and keep the indoors cool.

Reconstruction programmes in the Andaman Islands after the Indian Ocean Tsunami of 2004, and flash floods in the desert region of Barmer in 2006 strengthened these views. After switching from timber and thatch houses to those with tin roofs, the residents of the Andamans were found devising ways to cool their homes with nets of stringed dry leaves as shading devices. Those in Barmer who opted for concrete homes were found moving back to traditional mud houses with thatch roofs as they were significantly cooler in the desert heat.

The term `Build Back Better', which came into being after the Indian Ocean Tsunami and has now become part of the disaster management lexicon, is often read as an approach for better structures that would avoid damage to buildings in similar future disasters. With this restricted view, issues of thermal comfort, and environmental sustainability, often get ignored. This is not true just for the deserts and the hot plains, cold regions are also reeling with heat. In the aftermath of the 2010 flash floods in Leh, in the cold desert region of the Himalayas, when prefabricated shelters were deployed a similar story of unbearable indoor heat during the summer days emerged. Heat that affects human comfort and health is defined as a deviation from the normal, and hence a significant shift even in the cold regions can be quite harmful.

Urban heat islands are invisible to the eye, but heat maps glow even in the dark

What we learnt working largely in a rural landscape is of course more pronounced and better researched and documented in urban settings. Research on disaster risk and local innovations in urban low income settlements, found that families living in slums in cities like Delhi, Dhaka and Nagpur rank heat as a higher order risk than other hazards such as flooding, even though they live in frequently inundated locations. The impact is felt harder, since daytime occupants of these houses are already the most socially vulnerable groups, including infants, their mothers, the elderly and persons with disabilities. Their conditions can be severe, as we found that indoor temperatures during a summer day, when the outdoors record 37C, could hover around 47C. They also have little room to escape, as most such slums have crowded lanes and no shaded open spaces.

City or village, indoor heat is part of the new normal everywhere. What concrete backed urban heat islands do in cities is achieved by increasing shifts towards modern construction in the villages – hotter nights and no respite. The reduced gap between day-time and night-time temperatures has telling impacts on health. While earlier the concern during heat waves used to be fatalities from outdoor exposure, the emerging threat is of morbidity and stress, and the resultant loss of productivity due to indoor heat.

Indigenous knowledge and local innovations offer solutions, if you have the eye for them

Gujarat showed us how traditional houses called Bhungas, built with stone in mud mortar and earthen tiled roofs, performed better than modern structures in the earthquake as well as the heat. Barmer repeated the lesson with its version of similar homes, the Dhanis, with mud walls and thatch roofs. Urban slums across the heat belt demonstrate an amazing array of solutions where frugal innovation overlaps with tradition, to give answers like green walls and roofs where families grow food on their tiny shacks and also cool their homes down anywhere from 6 to 10 degrees C. Other local innovations that we have found and tried to help communities improve include indoor roof insulations using discarded cardboard, ventilators made from buckets, and cool walls made of stacked water drums. While local groups are attempting to systematise, scale and mainstream such solutions, the real answer will lie in a much larger scale recognition of local practices in policies and plans to counter the threat of heat. (2 photos)

Contributed by SEEDS – India

3.3. HEAT AND INFECTIOUS DISEASE

Our last priority issue is the association between heat and infectious diseases.

Climate change and global warming can have complex effects on infectious diseases, causing some to increase, others to decrease, and many to shift their distributions. Seasonal transmission patterns, driven by rural-urban migration and agricultural practices, can be greatly influenced by climate(65). Prolonged heat events or even peaks have been known to change dynamics of disease transmission and promote or exacerbate outbreaks in humans and wildlife (66). Temperature and precipitation are the two main environmental drivers of infectious disease, including water-borne diseases like cholera or vector-transmitted infections like malaria, parasitic helminths.

In poorer or densely populations settings, water quality and quantity, are weak links in times of extreme heat. While constraints during heat waves in developed economies are mostly limited to non-essential use of water (e.g., watering lawns or washing cars), the stakes are significantly more serious in poorer countries. Communities served by common tube wells face scarcity of water as ground water levels fall. Reserves in stored communal water tanks decrease and the chances of contamination increase as household water storage or roadside puddle water reduce in size, concentrating waterborne pathogens and attracting disease carrying vectors. Rapid deterioration of solid waste management systems creates optimal conditions for the growth and spread of water-borne illnesses such as typhus and other forms of diarrhoeal disease.

Reduced water levels during heat waves also result in higher concentrations of certain pathogens such as cholera bacilli (vibrio cholerae), resulting in more frequent cholera outbreaks. The growth of this bacilli increases as sea surface temperatures rise and create warm, nutrient-rich waters (67). A recent study found statistically significant increases in cholera cases two days after extreme heat in the Matlab research site in Bangladesh (68). The authors concluded that tree cover as a measure of green space in some areas may help reduce the risk of cholera during heat waves by mitigating the ill-effects of heat exposure.

While heat has important impacts on transmission patterns of vector-borne diseases, it is also important to note the cascading impacts of heat in the context of the COVID-19 pandemic. Decreased air quality during heat waves and additional metabolic impacts of heat stress can exacerbate the clinical effects of COVID-19 (69,70). Those living in informal urban settlements, workers in congregate settings, pregnant and lactating women, the elderly, and the medically vulnerable are all populations at high-risk for both heat-related illness and COVID-19. Although the longitudinal effects of COVID-19 are not thoroughly understood, individuals recovering from COVID-19 are likely more susceptible to negative health impacts from heat exposure (71). The need for personal protective equipment for healthcare workers

– especially in field hospitals and non-traditional clinical settings – as well as workers in congregate settings, can amplify the effects of heat, necessitating deliberately planned, socially distant breaks for hydration and cooling. Common measures for reducing heat exposure during heat waves – utilising cooling/hydration centres, closing shutters during the day, staying indoors or covered spaces – are not naturally conducive to social distancing or maximising airflow (72).

The impact of extreme heat on individual health is challenging to capture in a systematic manner, especially among poor communities. Sustained heat exposure without the opportunity to cool off, especially at night, aggravates morbidity and mortality, among women, children, and the elderly. Operational research using robust scientific designs, such as randomized control trials, should be developed to characterise the direct impacts faced by each vulnerable group. Results from such targeted research can convincingly inform both interventions and policy and help with advocacy.

Furthermore, both vector-borne and water-borne diseases are specifically linked to heat waves and are highly fatal in contexts where co-morbidities such as acute malnutrition and dehydration are pre-existing risks for both children and adults. Critical analysis of changing risks for infectious diseases will be critical for effectively reducing morbidity and mortality as changing transmission patterns affect heat-exposed populations.

Continued attention and updated guidance are needed to maximise public protection against health impacts of extreme heat exposure in the context of the COVID-19 pandemic. Local governments and organisations should continue to promote heat-protective behaviours while working with communities to ensure that compound risks from heat and COVID-19 are minimised. Such measures could include but are not limited to ensuring adequate ventilation and social distancing in hydration and cooling centres, checking on elderly and isolated neighbours, implementing staggered working hours to decrease crowding when feasible, and providing safe break spaces for workers.

CHAPTER 4. HEAT WAVES: SPECIAL FOCUS ON SOCIAL AND LABOUR PROTECTIONS

One of the main targets of the Sustainable Development Goals is the reduction of social and economic disparities across the world but especially in developing countries, where the consequences of such imbalances are severe.

Climate change exacerbates these inequalities and extreme heat does so in less measurable ways than many other more acute disasters such as storms or floods. Although studies on heat related social and economic disparities (e.g., ability to afford air conditioning units or fans, access to workplace protections in white-collar occupations, availability of piped water or proximity to water access points) are rare, work in Vietnam and India have shown that poverty related conditions such as illiteracy, access to potable water, clean toilets, and occupational heat exposure were all predictors of heat-related hospitalisations and associated negative health outcomes (33,73).

Conceptually, there are three main paths by which climate change and its extremes drive social inequalities: **1) increases in the exposure of disadvantaged groups to the adverse effects of climate change, 2) increases in their susceptibility to damage caused by climate change, and 3) decreases in their ability to cope and recover from the damage suffered (74).** While the dimensions of the relationship between socioeconomics and heat-health risks are vast and wide ranging. Here we focus on labour conditions. These are arguably two important contributors to population impact of extreme heat and are likely to respond well and rapidly to policy interventions.

Heat waves do not have the high-profile impact on industry and the economy in the same way as catastrophic floods or storms. Nonetheless, 1.4 per cent of total working hours were lost worldwide in 1995 as a result of high heat levels – the equivalent of around 35 million full-time jobs (75). By 2030, this share will rise to 2.2 per cent – a productivity loss equivalent to 80 million full-time jobs. The loss in monetary terms is then expected to total US$2,400 billion (PPP). Lower-middle- and low-income countries would be the worst affected, losing 4 and 1.5 per cent of their GDP in 2030, respectively. In South Asia, resulting productivity loss may even reach 5 per cent, and Table 2 illustrates the number of working hours expected to be lost to heat stress across different economic sectors across different countries.

TABLE 2. HEAT-RELATED WORK HOURS LOST, COMPARING 2000 AND 2019*

	BILLIONS OF WORK HOURS LOST IN 2000	BILLIONS OF WORK HOURS LOST IN 2019	WORK HOURS LOST PER PERSON IN 2019
Global	199.0	302.4	52.7
India	75.0	118.3	111.2
China	33.4	28.3	24.5
Bangladesh	13.3	18.2	148.0
Pakistan	9.5	17.0	116.2
Indonesia	10.7	15.0	71.8

Vietnam	7.7	12.5	160.3
Thailand	6.3	9.7	164.4
Nigeria	4.3	9.4	66.7
Philippines	3.5	5.8	71.4
Brazil	2.8	4.0	23.3
Cambodia	1.7	2.2	202.2
USA	1.2	2.0	7.1
Mexico	0.9	1.7	17.4
Rest of the world	28.7	58.3	27.5

* Source: The Lancet Countdown Report (2020) (9)

By 2030, heat-related stress in the workplace is projected to result in US $4.2 trillion in productivity losses (76). More recently, Four Twenty Seven's 2020 report *Measuring What Matters: A New Approach to Assessing Sovereign Climate Risk* calculated 41 trillion USD in gross domestic product is at risk due to heat stress globally (77). In term of impact to the economy, large productivity losses are already being experienced due to heat stress. In South-East Asia alone as much as 15% to 20% of annual work hours may already be lost in heat-exposed jobs and this figure may double by 2030 (76). These economic measures are reinforced by the Lancet Countdown 2020's assessment of 302.4 billion work hours – 52.7 hours per person – being lost as a result of heat events in 2019 as shown in Table 3 (9). India alone contributed the loss of 118.3 billion work hours due to heat in 2019. Further, the International Labour Organization, meanwhile, estimates that a global rise in temperature of 1.3 C will result in 2.2% of total working hours being lost worldwide by 2030, equivalent to 80 million full-time workers losing their jobs (76).

TABLE 3. PERCENTAGE OF WORKING HOURS LOST TO HEAT STRESS BY SECTOR, 1995 & 2030*

	1995						2030					
Country	Agriculture in shade (%)	Industry (%)	Construction (in shade) (%)	Services (%)	Total (%)	Total (thousand full-time jobs)	Agriculture in shade (%)	Industry (%)	Construction (in shade) (%)	Services (%)	Total (%)	Total (thousand full-time jobs)
Brunei Darussalam	1.64	0.27	1.64	0.01	0.27	0	4.27	0.88	4.27	0.03	0.45	1
Cambodia	9.05	3.99	9.05	0.67	7.53	394	14.52	7.8	14.52	1.7	7.83	769
Indonesia	4	1.03	4	0.03	2.14	1885	7.68	2.8	7.68	0.17	2.97	4018
Lao People's Dem. Rep.	3.18	1.28	3.18	0.21	2.8	52	5.71	2.66	5.71	0.49	4.51	158
Malaysia	3.09	0.71	3.09	0.04	1.05	83	6.18	1.91	6.18	0.12	1.51	246

Myanmar	5.21	2.09	5.21	0.3	3.21	720	8.71	4.12	8.71	0.67	2.65	855
Philippines	3.2	0.89	3.2	0.06	1.62	426	6.5	2.35	6.5	0.23	2.33	1217
Singapore	4.33	0.89	4.33	0.01	0.5	8	9.3	2.52	9.3	0.07	0.84	33
Thailand	8.1	0.89	8.1	0.71	5.34	1695	13.03	7.08	13.03	1.63	6.39	2637
Timor-Leste	0.16	0.89	0.16	0	0.08	0	0.7	0.09	0.7	0	0.36	2
Viet Nam	5.71	0.89	5.71	0.35	4.4	1650	9.71	4.96	9.71	1.03	5.14	3062
South East Asia	5.2	0.89	5.2	0.19	3.1	6913	8.87	3.89	8.87	0.54	3.66	12999

*Adapted from ILOSTAT database, HadGEM2 and GFDL-ESM2M climate models (75)

Extreme heat and the increase in heat wave events coincide with zones where work conditions and local infrastructure (e.g., electrical and power grids, public transit systems, water delivery systems) are inadequate. In many of these settings, social protection laws may exist but the level and inclusivity of protections (e.g., excluding migrant workers, etc.), as well as the enforcement of these protections, may be weak. Moreover, high rates of informal jobs or subsistence employment make application of labour regulations challenging. By 2040, 82 million Indians are projected to face extreme heat exposure with 75% of the country's population facing particular risk from outdoor occupation, including but not limited to jobs such as construction, farming, and fishing (77). Insights from regions other than Asia confirm this impact. In agriculture, manufacturing, and mining-driven economies across South American countries (Colombia, Venezuela, Bolivia, Peru, and Guyana) 80 – 100% of the population are projected to be exposed to extreme heat stress by 2040. The United Arab Emirates, where there is an appreciable amount of informal labour and little social protection for these workers, is set to experience one of the highest hazards related to heat exposure by 2040. The projection for exposure is unlikely to be much different for the countries in the Asia region.

Outdoor work carries clear risks from exposure to direct sunlight and ultraviolet light exposure. Important efforts to address these shortcomings in worker protection have been made in India, where district administrations are empowered to regulate labour conditions as needed, often shifting working times for outdoor labourers, and initiating social protection measures through the duration of the heat event. These considerations show that the stratification of risk by population groups and occupation groups can be indicative of the inequality between groups even within the same country.

For women working outside of the home, manufacturing sector jobs such as in garment factories are common sources of employment, especially in Asian countries. These factories employ hundreds of women in scanty spaces with insufficient ventilation and few breaks for water or fresh air. **Indoor workplaces** without adequate cooling systems also pose specific risks for morbidity, with both income and productivity losses exacerbated by factory and site closures during extreme heat events. Men are equally, although quite differently, at risk due to the gender division of labour. They are often engaged in manual work in factories, road repairs, or the building industry and are exposed to the hottest hours of the day. Health risks for young, active workers employed on building sites and in manufacturing plants are significant in heat events, despite this population not being in the usual groupings of those with high health risk. One study on heat stress amongst Nepalese migrant workers in Qatar between 2009 and 2017, for example, found that up to 35% of cardiovascular deaths were preventable by measures that were neither costly nor difficult to implement in the workplace (78). Construction workers, including men and women, are often daily wage labourers and are exposed to high heat at the risk of losing their meager daily earnings. The exposure of both women and men should not be underestimated in terms of its impacts on their personal health, survival, and the equally important survival of their families.

Other high-risk occupations such as refuse collection, laundries, bakeries, or other cooking activities, also expose workers to additional heat on top of the ambient temperatures due to their occupational context. Worker attrition can also affect productivity when transport systems fail in regions without heat-resilient or heat-adapted public transit infrastructure, and limit population mobility (79).

Simple and pragmatic changes in social protection and labour policies in heat conditions can benefit large swaths of the population. A good example of a programmatic solution is the Administrative Measures on Heatstroke Prevention (AMHP2012) programme implemented on 1 March 2012 by the Chinese government in in Guangzhou, China, in response to occupational health impacts of extreme heat (80). The study quantified the intervention effects of the AMHP2012 on extreme heat related occupational injuries and subsequent insurance payouts. Following the implementation of the AMHP2012 program, insurance claims for heat-related illnesses decreased significantly. This study brings valuable evidence on the efficacy of a national policy on protecting occupational illnesses during extreme heat.

In conclusion, although heat waves are less high-profile than other types of natural hazards, their impact on industry and economy are far reaching, posing significant threats to workers without social protections or labour rights– both men and women – and societal and economic systems.

CHAPTER 5. IMPACT DATA: MIND THE GAP

Surveillance, early warning, and system strengthening and capacity building are central themes of the IRFC's framework for heat action (BOX 8). However, data needed for these undertakings are clearly a major obstacle for better management of heat waves. Surveillance or registry data even for high resource countries are outdated or inexistent. The best option would be to strengthen the routine data systems through institutional strengthening. This is a major undertaking in most countries, which needs substantial resources and takes years to be achieved. However, in its absence, there are two options which may be worth immediate consideration to provide persuasive evidence for policy makers: satellite technology and sentinel systems.

The natural home for remote sensed data is in meteorological forecasts, exposure analysis, hazard modelling and damage assessment, but recently, it has shown promise for obtaining reliable data on heat waves and disease spread. Remote sensed data can inform policy at a more granular level, holding enormous promise for forecasting heat waves and associated human impacts. Further, satellite data has great potential as a low-cost, systematic surveillance method to monitor water and vector borne disease and temperature extremes. Researchers in Bangladesh used remote sensed data to establish that the risk of cholera increased up to four fold during the six weeks following a 5-degree spike in sea surface temperature (81). Geographic information systems have also been successfully used to model malaria risk patterns in endemic areas such as sub-Saharan Africa, India, Brazil, and Thailand, and many of these studies highlighted key linkages to heat. These methods are successfully used to monitor West Nile virus in Europe and North America (82,83).

Today, many agencies not only collect satellite sourced data for disasters but provide them at nominal or low costs to the humanitarian community. A good example is the International Disaster Charter founded by the European Space Agency (ESA) and National Centre of Spatial Studies (Centre National d'Etudes Spatiales, i.e., the French Space Agency (CNES)), bringing together a non-binding membership on national space agencies. The Charter supplies valuable satellite data for humanitarian crises management including monitoring of populations at imminent risk or victims of natural or technological hazards. There are other sources of remote sensed data that are available for free or nearly free. One promising source is the Copernicus twin satellites (operated by the European Space Agency) with high revisit frequencies and high-resolution images. The mission of this initiative is very relevant to heat wave monitoring, early warning, response, and recovery in that the main mission objectives include land monitoring, emergency management, security, and climate change. Analysed with ground-truthed information, this data source can yield very rich results for heat wave management. Google Earth also has excellent potential especially when dealing with informal settlement populations from where official data is scant, totally absent, or outdated. The Google Foundation is open to research collaborations and provides a promising point of entry for such scientific endeavours. Bringing in other novel initiatives such as World Pop, a source that provides valuable and up to date population denominators, and Humanitarian OpenStreetMap (HOT), a crowdsourced database using mapping to increase access to disaster-affected populations, with modelled satellite data can be invaluable for estimating impact across different comparable zones such as the mega-cities of Asia.

Tightening coordination and co-operative links between meteorological forecasting agencies and community institutions responsible for public health risks reduction is central to an effective response to heat waves. The promise of such approaches is reflected in the success of Vietnam Red Cross' forecast-based-funding scheme, Pakistan's START Network heat wave anticipatory action and disaster risk financing program, and National Disaster Management Authority (India)'s steps to strengthen impact-based forecasting (described previously). Forging linkages between forecasting and public health sectors offers the opportunity for significant and immediate population benefit.

Early warning for imminent heat events generally depends on alerts issued by meteorological agencies. It is undoubtedly the most reliable and in the recent decades, models and quality of data have progressed by leaps and bounds. However, there is still much work to be done for these systems to maximise population-level protection. Today forecasts are generally on target or sometimes slightly out of range, but they can be used as a good indication of what is to come in terms of meteorological conditions. As a complement to this key service from meteorological organisations, monitoring health conditions at community level can also make the early warning-early action process much more effective. Typically, such monitoring of health conditions is done through classical surveillance systems used all over the world for public health disease control and monitoring. An example of the collaboration between meteorological and public health entities for early warning systems and surveillance is given in Box 9. But a variation on this technique can present a promising approach for early identification of a heat wave using human impact indicators and arguably a realistic option in resource poor settings.

BOX 8: IFRC OPERATIONAL FRAMEWORK FOR HEAT ACTION

With climate change at the center of the IFRC's 2030 strategy, extreme heat stands out as a growing area of expertise and action. The IFRC is developing a framework that outlines an operational path for the IFRC is taking to reduce the impacts of extreme heat on vulnerable people. Recognizing that heat is one of the most ignored and yet clearest impacts of climate change, the international movement IFRC has developed 3 key targets:

1. 250 million people better protected from heat by 2025, in at least 150 cities and towns.

2. 50 Red Cross Red Crescent Societies actively implementing heat wave risk reduction, preparedness or response efforts.

3. 50 national disaster policies or laws recognize extreme heat as a form of disaster.

In order to achieve these targets, the framework includes a number of priority areas for action including urban planning, health system strengthening, early warning and early action, capacity strengthening, awareness raising, research, and policy. The framework will be launched in Fall of 2022 and will inform the IFRC's work on heat action towards its Strategy 2030.

BOX 9. POPULATION-SPECIFIC EARLY WARNING SYSTEM

Early warning systems are widely recognized as key adaptation measures for response to more frequent and intense heat events. Thresholds and meteorological indices employed in early warning systems of heat waves are essential. Considering the different responses of population groups, early warning thresholds are suggested to be localized and specified to reflect population tolerance to heat. Meanwhile, as an increase in the frequency of high-temperature days might lead to changes in physical adaptation, the performance of early warning systems needs to be evaluated and revised periodically based on local heat-related mortality and morbidity data.

A case study evaluating the performance of Shanghai heat-health warning system based on heat-related illness data shows that, with the temperature threshold of 35°C, 50% of heat-related illnesses and 58.2% of heat-related deaths occurred on dates that had no heat warnings from 2014 to 2015. Moreover, different from existing studies, while infants and seniors are deemed as vulnerable population groups to heat, young and middle-aged males were found to suffer more heat-related illnesses in hot weather. This is probably due to the extra longtime outdoor activities of these specific population groups in hot days.

The heat-related mortality and morbidity data used in this research is collected from the national heat-related illness surveillance system developed by the Chinese Center for Disease Control and Prevention, which collects data from local medical institutions. Data collection was guided by a national plan, the Hygiene Emergency Plan for High Temperature, released by the Ministry of Health and the China Meteorological Administration in July 2007.

A lower threshold could make the public more aware of health-threatening conditions but could also increase socioeconomic costs. For example, while a decrease in the warning threshold would increase the warning frequency and socioeconomic costs, it might also cause warning fatigue. The trade-off between these two aspects is essential for decision-makers and other stakeholders in early warning systems' design and improvement (84).

Classical surveillance systems are often costly to upkeep and require substantial human resources for data compilation. Sentinel surveillance systems, in contrast, use information from selected “indicator” sites only and are often practical and less expensive alternative. Sentinel surveillance systems are widely used in emerging infectious diseases to capture early signs of an impending increase of a health condition. The approach essentially monitors a limited number of health facility sites (e.g., a few hospitals or primary care centres) in the monitoring area as sentinel sites which makes it cheaper and easier to set up - two important advantages if resources are limited. On the other hand, reporting sites are often based on pragmatic considerations, resulting in reporting sites and individuals with disease not having equal probability of being included in surveillance data. While this bias limits the statistically representativeness of the disease estimates, the system usually generates a fairly reliable estimate at a low cost. In the context of heat-related sickness and death, high-volume, high-access facilities could serve as sentinel locations to alert other care facilities should be prepared for treatment of heat related conditions.

Sentinel surveillance allows evidence-based community interventions to be launched early in the process and eventually modified. There are many options for early indicators for surveillance for health impacts. Monitoring outdoor consultations in primary health care clinics for a broad spectrum of heat related conditions, for example, can serve as early alerts to increasing impacts. Integrated forecasting and sentinel surveillance systems present affordable, high-impact options but need to be field tested to establish predictive power and operational feasibility.

CHAPTER 6. POLICY AND RESEARCH RECOMMENDATIONS: LOW HANGING FRUITS FOR URGENT NEEDS

To achieve concrete, measurable, and positive results, both policy and research need well defined foci. Involvement of front-line organisations is a key factor in policy development and research, and they should be clearly incorporated in any calls to action or initiatives as joint partners.

Choosing priorities has an undeniable disadvantage as it invariably means that some areas may be temporarily excluded. However, **focusing on low-hanging fruits or initiatives that are most likely to have success will be more convincing.** They will allow for greater expansion to include more complex and delicate issues and prime communities for a wider roll out of programmes in the future.

We propose six research and policy directions with global evidence of success and measurable results. These recommendations consider the information discussed throughout this document and the seven measures and associated key actions recommended in the Bangkok Principles for the Implementation of the Health Aspects of the Sendai Framework for Disaster Risk Reduction, 2015 – 2030.

The Bangkok Principles highlight seven main areas for addressing the health aspects of the Sendai Framework for Disaster Risk Reduction. These measures and the associated key actions apply across the spectrum of the health-disaster nexus and provide actionable objectives for all jurisdictional levels. The seven measures are as follows:

1. Promote systematic integration of health into national and subnational disaster risk reduction policies and plans and the inclusion of emergency and disaster risk management programmes in national and sub-national health strategies.

2. Enhance cooperation between health authorities and other relevant stakeholders to strengthen capacity for disaster risk management for health, the implementation of the International Health Regulations (2005) and building of resilient health systems.

3. Stimulate people-centred public and private investment in emergency and disaster risk reduction, including in health facilities and infrastructure.

4. Integrate disaster risk reduction into health education and training and strengthen capacity building of health workers in disaster risk reduction.

5. Incorporate disaster-related mortality, morbidity, and disability data into multi-hazard early warning system, health core indicators and national risk assessments.

6. Advocate for, and support cross sectoral, transboundary collaboration including information sharing, and science and technology for all hazards, including biological hazards.

7. Promote coherence and further development of local and national policies and strategies, legal frameworks, regulations, and institutional arrangements.

We also highlight specific areas for policy focus that can be undertaken in partnership with frontline actors to yield evidence-based policy and programming.

1. Practical options for improved quality and quantity of data to enable early action, bolster prevention and preparedness, and inform adaptive response in the short and medium term should be specifically promoted by relevant research and data authorities at regional or national levels, and supported by DRR and civil society organizations.

A) INNOVATIVE USE OF REMOTE SENSED DATA FOR PREDICTING AND MEASURING HUMAN IMPACT OF EXTREME HEAT

Identified as a key action for people-centred approaches to emergency and disaster risk reduction in the Bangkok Principles, enhancing innovation and utilising modern technologies to better prevent and modulate disaster risks offers great opportunity for mitigating negative health outcomes in heat events. Innovative uses of technology are needed to build early warning systems that can contribute to preventing negative health outcomes through early action.

Such innovations are also needed to enhance the rapidity of response and relevance of field collected data, especially for disasters where data is particularly weak or inaccurate. In addition, sound, and scientifically credible research on the pathways by which extreme heat affects communities and individuals is urgently needed.

Remote-sensing data collection methods and rapid field analyses of surveys can provide cost-effective ways to generate evidence for both predictions of and early response to heat waves and heat-related disease outbreaks at many jurisdictional levels. With the ubiquity of mobile phone usage globally, broadcast messages to mobile phones in at risk areas can operationalised for both timely warning and real-time surveillance. Expansion of existing and development of novel methods and tools should be promoted and supported actively by scientific research policy setting bodies such as international and national scientific agencies, research funding programmes, and hydrological and meteorological agencies as well as DRR and civil society organizations . Examples of such entities include as the European Civil Protection and Humanitarian Organization, UKAID, Global Facility for Disaster Reduction and Recovery (GFDRR), Global Heat Health International Network (GHHIN), banks directly involved in disaster recovery, prepardness and response – such as World Bank or Asian Development Bank – IFRC Climate Center, Red Cross/Red Crescent national societies, Start Fund, etc..

B) EFFECTIVENESS OF SENTINEL SYSTEMS TO CAPTURE RISES IN HEAT RELATED MORBIDITY AND MORTALITY IN SETTINGS WITH LIMITED DATA SYSTEMS:

Since data on human effects of heat waves is poor, alternative methods of surveillance need to be developed and tested in situ. Research on practical configurations of sentinel systems that provide effective predictive information at low costs should be encouraged by national and international research programmes on climate extremes, early warning, and human health. The policy must include will field tested options appropriate for the local settings and adapted to the national system for implementation. Monitoring indicators to follow performance and generation of rapid turn-around results during the heat wave period must also be part of the programme.

2. National and municipal level policies should target gender related exposure among women and infants for heat wave preparedness and response. Civil society organizations, DRR, and frontline actors should be encouraged to focus on groups most at risk including the elderly, pregnant and breastfeeding women, and infants.

Given the evidence, we consider that messaging about the dangers of extreme heat for pregnant and breast-feeding women and children are inadequate on its own to change behaviour. Targeted interventions and health systems preparedness for heat-related illnesses are essential across all levels, and gender-responsive policies are needed. Examples of targeted, easily promotable interventions with measurable benefits are described.

• Specially designated community-based cooling and hydration centres should be made available and accessible for women and children. Household delivery of potable water should be available to prevent dehydration in pregnant and nursing women and children.

• Working women who are pregnant, or lactating should be provided paid leave to limit additional heat exposure.

• Extreme temperature preparedness can be integrated into school curricula and other multi-hazard awareness raising campaigns and risk communication instruments. For example, in countries that utilise modular learning curricula, teaching behavioural modifications and best practices for primary and secondary school children could positively impact the children and, by extension, others in their households.

• Free provision of effective and cheap emergency treatment of heat-induced illnesses like oral rehydration salt packets has been observed to be effective in India, among other contexts. Education and training for identifying heat-related illness and heat stroke, including among primary health and community workers, and volunteers can also help reduce heat-related morbidity and mortality.

• Streamlining interventions with health programmes and policies that are already in place is a cost-effective channel for maximising scarce resources and overworked programme staff. Heat related education and supplementary resources, referrals for particularly vulnerable groups such as infants and the elderly at early stages of heat exhaustion are some interventions that can be seasonally tacked on to established community programmes.

• Emergency response infrastructure, such as evacuation centers, field hospitals and health facilities, and shelter should be established, built or retrofit using heat resilient standards.

3. Urban planners, public and private sector front line organisations, including civil society and DRR actors involved in urban sustainable development, post disaster housing reconstruction and recovery must urgently prepare, reduce risks, and adapt for heat waves.

In many locations, climate-smart designs are increasingly in the public consciousness, but these are not translated into practice enough. Young designers and urban planners, construction workers and civil society/DRR organizations engaged in social housing , neighbordhood upgrading and post disaster reconstruction should be engaged in the process to increase uptake of climate-smart design and urban management.

Good practices and practical examples of beneficial urban design and planning should be shared widely, and advocated by international DRR and CCA organisations, national and local governments, DRR and civil society organizations, private sector/construction sector business associations, academia and regional and local authorities.

Special attention should be given to the development of green spaces which have proved to be effective to bring down temperatures and provide relief for heat exposed residents. The Sendai Framework Targets C and D, in alignment with Sustainable Development Goals 1 and 11, call for development and protection of urban green spaces as a means of reducing economic losses and degradation of vital infrastructure due to disasters (85). Baseline inventories, frequent monitoring, and post-disaster impact assessments for green infrastructure are necessary steps to meet the criteria set forth in global targets. Regulations for development, rehabilitation and post disaster recovery should require green design elements such as green walls and also require businesses to repopulate foliage removed in the building process. Local governments and developers should mandate the preservation of existing green spaces, require green landscaping and tree planting in building development, and incentivise the creative expansion of green spaces in densely built environments.

Finally, options need to be found that allow those living in informal settlement households while sustainably modifying risks posed by the built environment. Good practices of urban regeneration and informal settlement upgrading exist. Reform and modifications to existing settlements can introduce new approaches and low-cost technologies that promote climate-smart/heat resistant/improved ventilation. These could include, among other innovative options, the use of bio-climatic architectural design, thermal resistant construction materials, street layout re-design.

4, Technical institutions and research centres should develop and test in partnership with civil society, DRR, private sector, and government actors financially feasible structural options for reducing heat retention in low-income housing

Inadequate ventilation and high indoor temperatures increase vulnerability during extreme heat events. Innovative design can improve indoor air quality, increase airflow, and result in better heat dissipation. Civil society organisations in many countries have taken up this challenge. Successful experiences should be evaluated for scaling up by housing authorities, private sector and local governments . Organisations having demonstrated benefits of heat resistant solutions should be provided relevant support for wide promotion specially in affordable housing programs.

More specifically, local housing design policies should actively encourage the provision and use of simple yet effective tools for heat control while minimising the use of heat retaining materials. Such tools include but are not limited to white-washing tiles and roofing material. Public outreach and community-based programs, including in the post disaster and recovery stages should be leveraged to educate households on infrastructural and object placements to increase airflow.

Policy measures should promote and subsidise alternative options for housing materials that are less heat retentive and can be realistically implemented. Such policies would have a notable impact on rural and urban low-income communities where roofing is commonly made of highly heat retentive materials such as galvanised iron or corrugated tin. Architectural options such as better positioning of windows, orienting buildings to reduce solar radiation exposure of exterior walls, shaping buildings to increase natural airflows, and increasing ventilation with protection against rain or pests such as mosquitoes should also be identified, explored, and promoted. Further, new and potentially low-cost technologies such as green roofs and walls that can lower indoor temperatures should be further field tested for effectiveness, and, if feasible, subsidised.

While redesigning impoverished and informal urban settlement is a major challenge, it needs to start somewhere. Many obstacles stand in the way of change in these types of urban settlements where extreme heat is increasingly an issue and can in itself, become the genesis of social unrest. Political complexities, vested financial interests, and reluctance of local planners to open what could be a Pandora's box of unpleasant issues, are all examples that can apply to most urban and peri-urban settlements in Asia and elsewhere. Availability of technical solutions and stepwise interventions and programming can act as a catalyst for long term progress towards improving dwelling conditions of the urban poor.

5. Authorities responsible for social and labour protection through legislative action and enforcement should review regulations for protection against heat for both male and female workers in high exposure occupations.

Main actors for heat protection policy, regulation and monitoring are employers, labour unions, ministries of labour and worker protection, workplace safety, associations of workers. There is a wide range of penalty- or incentive-based regulatory mechanisms available to national, city and other local authorities to mitigate work-related heat stress for at-risk workers. Beyond these frameworks that govern labour conditions during heat waves, social protection legislation that consider heat as an occupational risk is central to mitigation of heat wave impacts. Specific programmes such as shock responsive protection schemes, social assistance programmes for inability to work and lost wages due to heat and expanded workplace protections – are some practical solutions. Civil society organizations can support advocacy and knowledge generation on needs, cost, benefits, and effectiveness for labour protective and shock responsive measures. Examples of effective regulatory conditions, following a declaration of heat wave are:

- Mandatory work breaks at the hottest times of day or shifting operational hours to early mornings and nights when the heat-humidity matrices are lower

- Provision of free drinking water during a declared heat wave

- Regular organisation of training of workers to identify the signs and symptoms of heat exhaustion and stress and designating shaded or cooler areas on site

- Mandated or incentivised cascade shift patterns at at-risk manufacturing, construction, and other work sites, designed to minimise the time that individual workers spend in high heat or high humidity

- Information and messaging programmes to encourage male and female workers to wear loose-fitting, light weight, and light-coloured clothing to allow for the evaporation of sweat, and natural cooling of the body

6. Local and regional authorities should develop, implement, and iteratively evaluate heat action plans. Civil society, DRR actors and the private sector should engage in the development, implementation, monitoring and evaluation of such plans to foster learning and adaptive risk governance systems.

- As described for Ahmedabad, Karachi, and Queensland, heat action plans are a comprehensive approach to mitigating the negative health impacts of extreme heat events. HAPs are a particularly potent tool for risk mitigation because they allow for local designation of threat levels, calibrated to the unique environmental, social, and cultural considerations of the locality. As living documents, they should include regular evaluation of triggering mechanisms, monitoring of response time and quality by implementing agencies and overall success of the policy.

- Utilise a multi-sector approach to both triggering and responding to extreme heat events

- Specifically integrate health components of HAPs with national and subnational disaster risk reduction policies, as described by the Bangkok Principles for the Implementation of the Health Aspects of the Sendai Framework for Disaster Risk Reduction, 2015 – 2030.

- Create clear warning system and anticipatory action schema that is easily communicated to at risk and affected populations, using methods such as colour-coding or numbering threat levels or any others inclusive of persons with disabilities, special needs groups (migrants, elder, minority groups, illiterate, etc.) and responsive to preferred communicaiton channels in different context.

- Engage community members – especially those in high risk, vulnerable groups – community actors such as local NGOs, voluntary organizations, and humanitarian partners to develop an action plan that will confer protection to not only the general population but also those disproportionately affected by heat exposure

- Data and information sharing between local, regional, and national authorities, DRR, private sector, and civil society organizations and across sectors to ensure that cumulative response actions are commensurate with identified threat levels

In conclusion, impact of extreme heat **is related to disenfranchisement and socio-economic vulnerabilities of the most affected communities.** The effect of extreme heat is mainly constrained to the poor and hence has little political traction. It is the global community, DRR and development partners, and local civil society who can push for change and should put their shoulders to the wheel to bring about progress.

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