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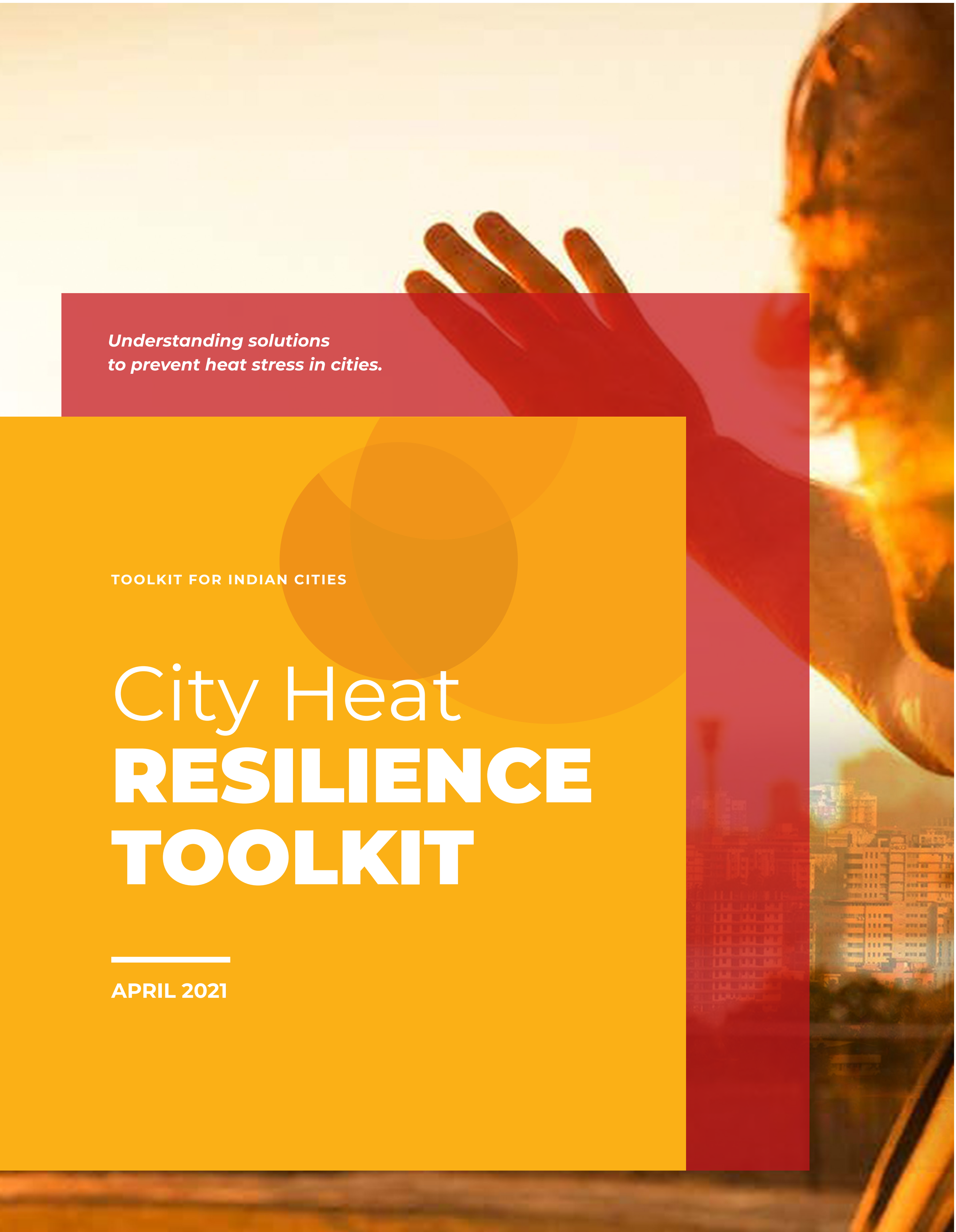

Understanding solutions to prevent heat stress in cities.

TOOLKIT FOR INDIAN CITIES

City Heat RESILIENCE TOOLKIT

APRIL 2021

The report is developed with the support of Climate and Development Knowledge Network through the Knowledge Brokering Program. The report is developed through the understanding, literature review and analysis by the technical team and inputs from the contributors as well as experts.

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ABBREVIATIONS

CBO	–	Community Based Organizations
DP	–	Development Plan
GHG	–	Green House Gases
HI	–	Heat Index
LG	–	Local Government
IPCC	–	Intergovernmental Panel on Climate Change
MNRE	–	Ministry of New and Renewable Energy
NIDM	–	National Institute of Disaster Management
NRDC	–	National Research Development Corporation
PCE	–	Passenger Car Equivalent
PCU	–	Passenger Car Unit
SDGs	–	Sustainable Development Goals
SHG	–	Self Help Groups
SMC	–	Surat Municipal Corporation
SUDA	–	Surat Urban Development Authority
UBL	–	Urban Boundary Layer
UCL	–	Urban Canopy Layer
UHI	–	Urban Heat Island
UHCRCE	–	Urban Health and Climate Resilience Center of Excellence
ULB	–	Urban Local Body
UN	–	United Nations
UNDP	–	United Nations Development Program
UNFCCC	–	United Nations Framework Convention for Climate Change

PREFACE

The phenomenon of heat stress refers to the excessive heat that the body can tolerate without physiological impairment. For millions of workers, and therefore the economy, it is a sign of distress. Heat stress affects outdoor workers (especially those engaged in agriculture and at construction sites), labourers, schoolchildren and senior citizens. It has been acknowledged that extreme heat waves will become more common worldwide because of the rising average global temperature. The changes in weather patterns, coupled with the El – Nino effect, are increasing the average temperature in Asia, especially in India, where high relative humidity compounds the effect. All these factors adversely impact public health, environment and infrastructural services.

Research evidence shows that the rise in temperature is leading to urban floods, flash floods, heat waves, storms and unpredictable weather patterns, impacting farm yields. There is also evidence that climate change is causing an inadvertent increase in extreme weather events and in the severity of natural disasters. This eventually impacts public health, more severely of the vulnerable sections, and causes infrastructural damage, leading to economic losses.

It is projected that by 2030, around 2% of the total working hours worldwide would be lost annually (Office, 2019) because of either inhabitable conditions or low productivity due to heat. Unfortunately, heat stress is generally accompanied by challenges at the city and individual levels. In India, cities as well as decision makers face various challenges such as lack of social protection, high mortality rates due to heat stroke, spread of diseases and adverse living conditions in informal settlements, besides evaporation/ drying of water bodies, degradation of green spaces, melting of tar roads and more importantly, limited empirical evidence to understand the lack of standardised health data.

Every city is different and requires local contextualised solutions. Therefore, the initiatives by the local governments are of prime importance. Along with building a system for monitoring the climate impacts on health- which is more appealing to the community, policy makers and administrators - the local governments need to include climate change and heat waves in their development agenda. They need to monitor the situation and manage the early signs of increasing heat by changing their landscape and physical structures through measures such as providing increased shading to the exterior of tall building surfaces and openings by creating vertical gardens and green roofs. While the emergency preventive measures are extremely important, this toolkit considers the built as well as the social environment strategies that can:

1) Reduce the urban heat island effect
2) Protect the health of residents
3) Lower the energy consumption, which in turn reduces gas emissions
4)Potentially provide environmental co-benefits such as stormwater management and improved air quality.

Widespread surface changes can reduce the urban heat island effect. However, to mitigate it, the local governments would face many challenges, including the complexity of the choices available, limited resources and authority, the need to coordinate among many local agencies and to consider measures to counter the climate change impact. Further, any action of the local governments would be incomplete without community participation, where the households and individuals also have to undertake many measures and actions. This toolkit provides a decision-making platform for local governments to help overcome these barriers. It analyses the issues based on their direct/ indirect effects and the intensity of their impact. Additionally, the toolkit provides a framework for prioritising these issues and provides recommendations with which the local governments can implement the methods, including:
1) technological/ infrastructural solutions;
2)policy recommendations, (i.e., building codes) 3) incentives/ financing solutions, (i.e., fee rebates or grant programmes) and 4) community participation approaches.

While each tool can help to reduce the high temperatures that individuals would otherwise face, a city-wide adoption can drastically reduce the urban heat island effect itself, which provides many benefits. For example, by drawing on the learnings from secondary literature and the primary study of the coastal city of Surat, the toolkit helps local governments to understand the issues and recommendations and to determine what would work best for them.

People covering themselves to protect from scorching heat - Source - time

01 INTRODUCTION

Climate change refers to any major changes observed in the climate for a period of more than 10 years (UNFCCC, 2011). It poses significant challenges to the cities that are experiencing rapid urbanisation and in-migration. In fact, one of the major threats to public health for cities around the world is the escalated heat stress. Hence, there is an urgent need for people to respond to climate change and its consequences.

1.1 Purpose of the toolkit

The toolkit is a comprehensive document for understanding the root causes, prioritising them as well as recommending relevant solutions to the cities in India. The document, therefore, takes into consideration secondary literature and primary learnings from the coastal city of Surat for the purpose of:

- Facilitating the identification of the causes of extreme heat in Indian cities,
- Understanding the ways to prioritise the causes, and
- Providing relevant solutions for preventing heat stress in cities.

1.2 Background and context

Climate change is contributing to the degradation of social, economic and environmental determinants of health. These determinants require attention due to the frequent and severe heat stress events occurring in summer, caused by thermal reflectance from buildings and reduction in green cover due to overcrowding, which leads to poor housing conditions, vehicular emissions and increased use of air conditioners.

These heat waves and heat stress mostly affect people working as construction labourers, vegetable sellers, traffic police officers, salespeople and delivery people, due to increased exposure to environmental degradation and climate change in urban environments. The decreasing air quality and its contribution towards increasing the urban heat island effect are affecting the health of the vulnerable population. Therefore, children, senior citizens, and people with co-morbidities such as hypertension, diabetes, kidney disease, and cancer, besides obesity and severe undernutrition are also vulnerable to climate concerns because of their anatomic, cognitive, immunological and psychological differences, as compared to healthy middle-aged people. Also, this section of the population lacks the capacity to resist the adverse situations of extreme heat stress or heat waves. In this context, while studying the conditions regarding the management of heat stress, air pollution and intersectoral activities, it was observed that Indian cities face the following challenges:

1. Lack of awareness among the stakeholders on the root causes.
2. Lack of data availability and analysis to identify the relevant challenges and develop suitable solutions.
3. Limited institutional capacity for data analysis and interpretation for implementing the solutions.
4. Limited understanding of the intersectoral/ cross-cutting issues.
5. Limited efforts for community participation.

What is an Urban Heat Island Effect?

An Urban Heat Island (UHI) is a common environmental phenomenon characterised by high temperatures in urban areas, especially during the summer months. While globally, the average temperatures have been rising, the UHI effect compounds the situation, at times causing alarming conditions in different pockets/ junctions/ intersections of a city. While there would be many factors leading to the heat island effect, it is believed to be generally caused by:

1. Loss of green area due to urbanisation;
2. Buildings blocking the ventilation corridors and accumulating heat;
3. Construction materials with low specific heat capacities absorbing solar radiation or reflecting it in densely built-up areas;
4. Increase of vehicles and growing electricity consumption producing more anthropogenic heat[3]; and
5. High density of human activities in urban areas, which is a result of the differences in the energy balance of urban and rural environments.

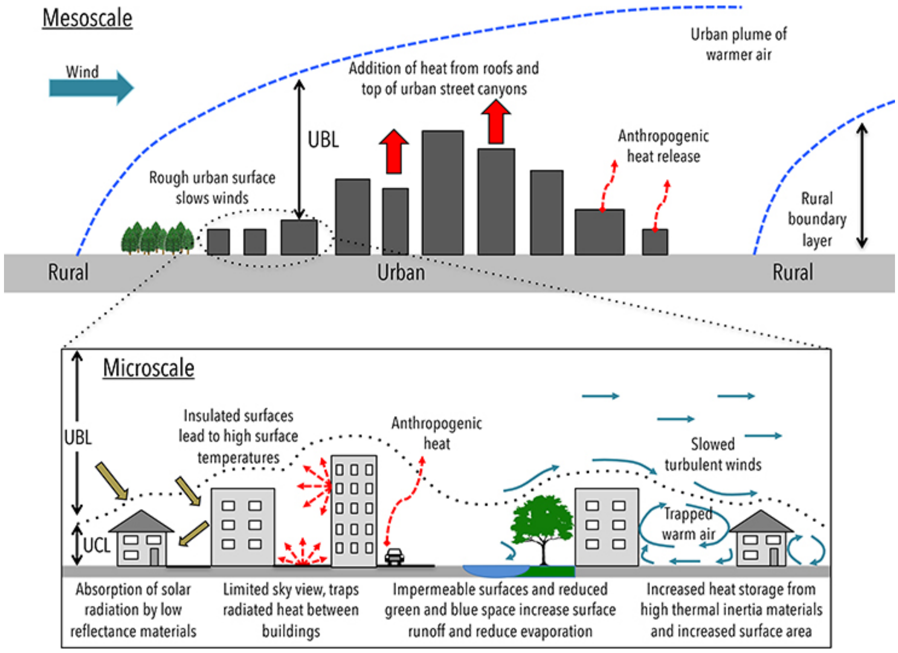

Figure 1: Illustration for the Urban Heat Island Effect

Many studies suggest that atmospheric temperature could be reduced by a degree or two if there is improvement in one of the variables. However, none of the studies could confirm that another variable would not affect the outcome. Thus, UHI is a combined effect of all the variables. A city can choose to act on all variables, especially the least-cost/ no-cost solutions, such as enhancing vegetation cover and implementing building codes that promote the use of materials that provide thermal comfort and are eco-friendly. The above-mentioned variables can be broadly categorised into:

1. **Variables that influence/ trigger retrofit actions,** such as enhancing green space, providing roof-top solutions (such as white roofs, green roofs and solar panels), controlling traffic in congested places and altering mobility services within the existing landscape of the city.

2. **Variables that influence/ trigger future planning and implementation,** for instance, buildings that block natural ventilation and areas with considerable presence of impervious surfaces, such as pavements, roads, sidealks, parking lots, driveways. Addressing such variables is not only a costly affair but may also include the process of rehabilitation and replacement.

1.3 Need for the toolkit

The toolkit focuses on understanding the factors that lead to an increase in the extreme heat conditions as well as tentative measures that can be undertaken to combat the same. Most of the toolkits related to heat stress, such as the Heat wave Guide for Cities (Singh, R. et al., 2019) Climate Change, Extreme Heat and Health Toolkit by NEPHTN (Network, 2013) and the Heat and Health Action Plan, Surat (2014) provide guidance about the management of extreme heat at a personal level and promote green building technology. However, the City Resilience Toolkit (NRDC, 2015) guides the preparation of Heat Action Plans. The literature review revealed that there was a lack of guidance on mitigation measures as well as the management of a heat wave at the city level. Because cities are drivers of development, the preventive measures incorporated at this level will eventually help in the management of heat stress at the national and household levels.

1.4 Impacts of heat stress

Heat stress impacts different aspects of a city such as public health, services, economic activities and the environment. These impacts are deadly and are on the rise globally. In recent years, heatwaves have crossed record highs, causing a large number of deaths. The 2003 heatwave in Europe killed approximately 70,000 people (Singh, R. et al., 2019) and the 2010 heatwave in India killed around 2600 people (Kumar S. 1998); (Surat heatwave action plan 2018, 2018; AMC, 2010). India was ranked fifth among the countries worst hit by heatwaves. Most of the deaths were observed in the states of Andhra Pradesh, Telangana, Punjab, Orissa and Bihar (Guleria, S., 2016).

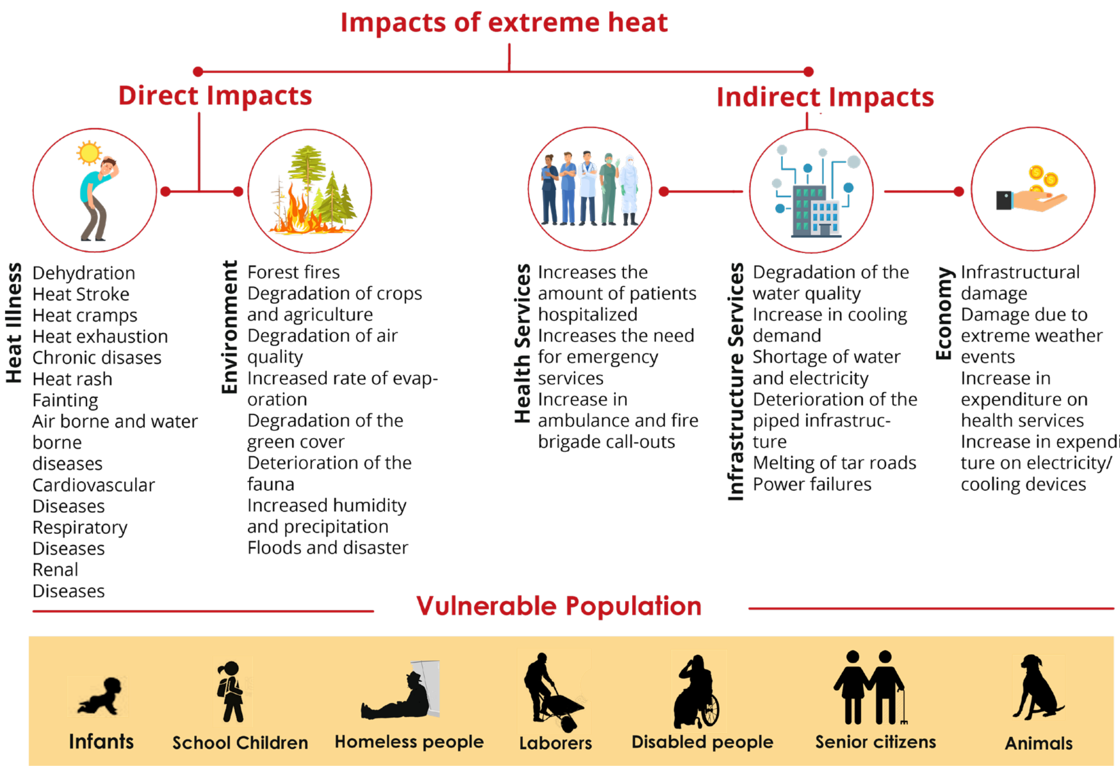

Figure 2: Impacts of heat stress and the vulnerable population

This toolkit considers the study of heat impact on health, environment, infrastructure and the economy of a city. These impacts are classified as direct and indirect.

- Direct Impacts refer to all the instances where the impact on health and environment can be easily observed, such as heat-related illnesses, diseases, forest fires and extreme weather events
- Indirect Impacts refer to the effect on emergency services, infrastructural services and the economy, such as increased ambulance/ fire brigade callouts, stress on water and electricity supply, deterioration of infrastructural services and expenditure on health services. Indirect Impacts also affect the productivity by labourers, leading to the reduction in production.

During extreme heat events, failures or weaknesses in the city systems brings forth challenges for vulnerable groups. Generally, infants, school children, people who are involved in outdoor work, including labourers, traffic police, vendors and sanitation workers, and people with medical conditions, besides senior citizens, street animals and people living in informal settlements (ANNEXURE 1: VULNERABLE POPULATION) are at higher risk of developing serious health problems or mortality during a heatwave. Also, the impact on labour productivity is likely to be the most serious economic loss, and is likely to impact at various levels such as the labourers themselves, their families, businesses and entire communities. The economic, social and health effects of heat stress would make it difficult to reduce poverty, promote urban development and attain the Sustainable Development Goals (SDGs) efficiently. The impacts of heat stress and their relation to the SDGs are also important and need to be considered (refer ANNEXURE 2: CORRELATION OF HEAT STRESS AND SDGS).

Heat waves impacting the construction workers especially women - Source - Alamy

02 DETAILED METHODOLOGY

In many instances, heat is a direct threat to health. Efforts to combat the same consider creating resilience to the extreme heat and therefore facilitating adaptation/ climate change mitigation. Exposure to the extreme heat events has been on increase as the heat instances continue to worsen with the climate change. South Asian countries, especially India, have experienced warming, consistent with the globally observed trends (Kumar S. J., 2012). As an attempt for overall resilience building, a heat action plan was established by the city of Ahmedabad in India. Along with Ahmedabad, Surat has also undertaken certain steps to build resilience toward the heat and humidity through UHCRC project under ACCCRN. However, these steps can be enhanced further to streamline heat resilience in other cities of India with the help of this toolkit.

2.1 Approach

In the above context, the approach for developing this toolkit is based on forming a close loop for building the heat resilience in the Indian cities. This considers a detailed study of the root causes of extreme heat, providing relevant solutions and prioritizing the same. The aim is to provide an end-to-end framework to prevent the heat stress, not only at the personal health level but also at the city level. If the necessary measures are implemented at the macro scale, automatically the positive effects will trickle down in improving conditions during the heat stress at the individual health level.

2.2 Methodology

The toolkit considers a three-step method for achieving the heat resilience in cities. These steps along with the relevant readings, references and case studies provide a package to manage the heat stress. The steps are as follows:

Step 1: Understanding the root causes of heat stress
It refers to understanding the ways to identifying these causes by using the various tools according to the climatic conditions of the city and understanding the broad causes through secondary research (which are observed in the entire country). The three major causes of the heat stress identified include: (i) increase in the impervious surfaces, (ii) increase in the waste heat and (iii) lack of green cover and water bodies. There are various sub-causes under these broad categories according to the context of the city. Therefore, the demonstration of Surat city is provided to facilitate the understanding of this process.

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Step 2: Identifying the solution

This step provides the aspects to be considered for identifying the list of potential solutions for a city. These aspects refer to the area, type and scale of these interventions, which make it a 3-axis matrix. As stated in the Figure 3, the areas of interventions should consider the existing, new and peripheral development. Intervention training in the form of technological solutions, institutional reforms and awareness building programs should be conducted for developing the skills for the climate resilience activities. At the neighborhood, city and regional levels, the scale of intervention should be considered.

Step 3: Prioritisation of issues

As the issues are identified in the step 1, it is important to develop a criterion for prioritizing their implementation. These criteria should include the impact of the intervention on the public health and environment, time _span of implementation, cost of implementation and the reforms in the existing projects/ programs. This methodology gives a four-step screening (refer section 5.1) of an intervention to prioritize it effectively.

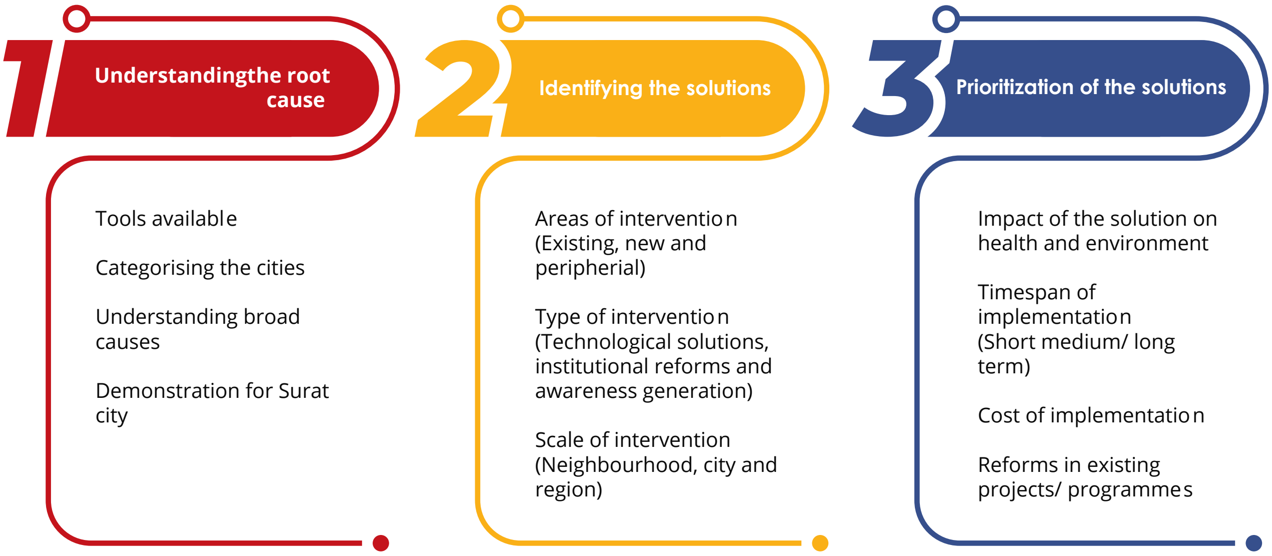


Figure 3: Tools and methods for identifying the contextual challenges

2.3 How to read the document?

This toolkit is designed to help local governments (decision makers) and citizens understand and reduce the risk of heatwaves in cities. For the technical staff of the city government, the guide provides information and recommendations with respect to:

- Working with partners to understand city-specific
- heatwave risks.
- Operational approaches to prepare for an imminent heatwave, and response strategies to reduce negative impacts on human beings during a heatwave.
- Ways to reduce the risks of heatwaves/ heat stress.

For this purpose, the toolkit is divided into three chapters – understanding the root causes, identifying solutions and prioritising those solutions. Each chapter uses the example of the city of Surat to guide the application of the toolkit at the city level, and provides a background and methodology for analysis followed by the demonstration.

Case studies from cities around the world and India are included in Chapter 5 to highlight effective urban heat adaptation strategies, including early warning systems, climate-sensitive designs and public information campaigns. There are recommended actions and online resources for a more detailed guidance on heatwave risks mentioned in each chapter. The analysis and case study sections provide specific links to the reference documents.

Reducing heat stress through cool roofing system - Source -The Rockefeller Foundation

03 UNDERSTAND THE ROOT CAUSE

The evidence of human impact on the environment has grown in the last three decades. It is extremely likely that rising greenhouse gas (GHG) emissions and other anthropogenic factors caused the increase in the global surface temperatures from 1951 to 2010. The increase in GHG emissions, in turn, has been caused by a growing population, vehicular emissions, industrial emissions and an increase in the use of chlorofluorocarbon (CFC) gases (IPCC, 2014). These emissions along with other anthropogenic drivers, detected through climate models/ simulations, have been a major cause of global warming in the last three decades.

3.1 How to identify the causes of heat stress?

In order to tackle heat stress effectively, it is important to identify its major causes in the context of each city. Research findings, as specified in the IPCC Fifth Assessment Report, reveal that activities leading to GHG emissions and other anthropogenic emissions are the broad causes of heat stress globally. However, there are context-based causes for the increase in heat stress in various geographical zones of India, and tackling these can facilitate the provision of an overall solution.

1. **Available Tools**
   To understand and identify the most relevant cause of heat stress in a city, the initial step is to select an effective tool. The selection of this tool is the crux of this entire exercise. If the outcomes of the tool are not relevant for a city, then the city would not be able to identify the causes and undertake efficient actions. As per the research, the following tools can be used:

   - **Secondary data analysis:** This tool can be used when the causes are to be identified for a first-cut analysis as well as for the case building. As the title suggests, it includes thorough review and understanding of the available data related to heat stress in a city from municipal corporations/ local governments, reports from the eminent institutions and organisations, and data analysed by research institutes.

   - **Media analysis:** This tool considers the causes collated from online aggregation sites, news articles, investigative features, social media updates, opinion columns, television broadcasts, among other sources, for understanding as well as verifying the collected data. These sources also have periodic information and actions undertaken towards heat-related issues.

   - **Community interviews:** It considers interviews/ reviews/ feedbackThis tool considers interviews, reviews, feedbacks and workshops conducted at the community level to understand the local issues, factors and community needs and concerns. Focused Group Discussions (FGDs) and Intercept Surveys are the commonly used methods for community interviews.

   - **Key stakeholder workshop/ interviews:** This tool specifically targets key stakeholders and organisations such as municipal corporations, service providers, researchers, community-based organisations and NGOs in the city, relevant to the survey. It is important to conduct thorough secondary research beforehand to identify these key stakeholders and to formulate the questionnaires. Key Informant Interviews (KIIs) are commonly carried out to identify the issues.

   - **Vulnerability assessment:** This tool considers mapping and assessment of the vulnerable areas/ zones in the city with respect to heat islands, increasing temperature and spread of diseases due to heat. Information and Communication Technologies (ICT), remote-sensing methods and people's mapping are the means used to assess heat vulnerability.

2. **Demonstration for using the "Key Stakeholder Engagement" tool**
   This section seeks to identify, explore and elaborate on the essential elements of meaningful stakeholder engagement for adaptation planning to the heatwave mitigation. This provides a step-wise guide for decision makers, city planners, municipal

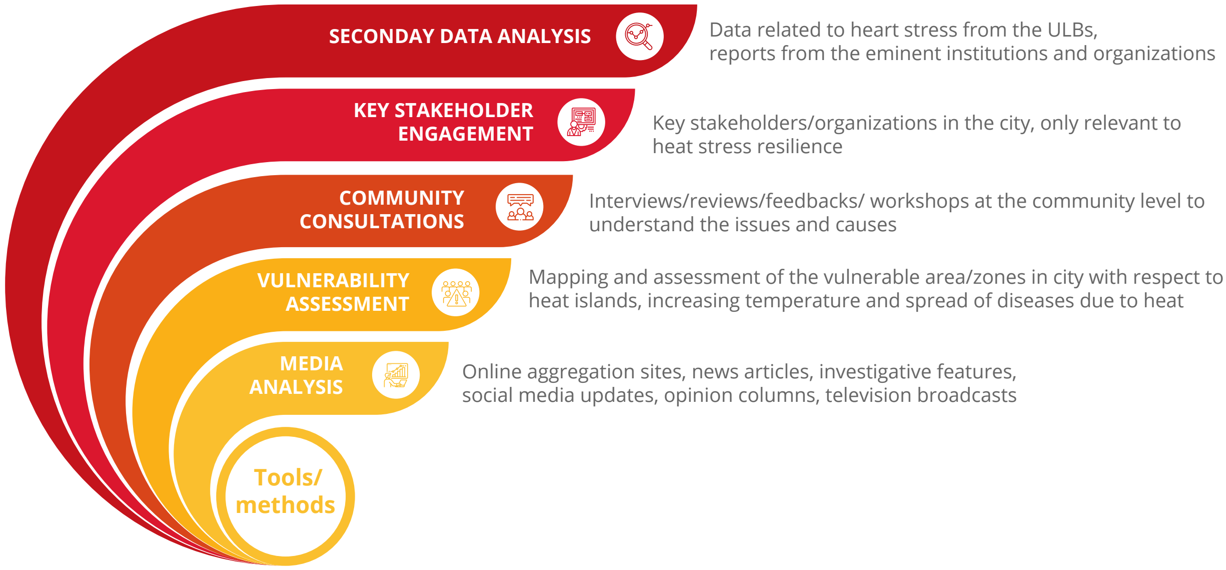


Figure 4: Tools and methods for identifying the contextual challenges

officers, local and regional governments and practitioners looking for additional tools and techniques to engage the stakeholders in the decision-making process for the heat-wave mitigation.

Stakeholders bring different perspectives, values and expectations that can help build a better understanding of the nature and scope of heat wave risks and resilience opportunities, as well as how best to approach them. This planning has a much better chance of being broadly accepted, and consistently maintained if they originate in a process that involves the various levels of stakeholder engagement rather than a "top-down" approach. For instance, a city like Surat with a metropolitan coastal community (where increase in sea levels and storm surges will have implications for building codes, infrastructure planning and emergency management) would require an adaptation approach to heatwaves different from the one required for Delhi. No single approach or tool can work in different contexts; the requirement varies markedly between different groups of stakeholders depending on their ability to adapt to changes as well as cultural practices. Thus, stakeholder engagement is an essential and critical component. The key elements of an effective stakeholder engagement process are:

- Identification of relevant stakeholders and managing their expectations.
- Articulating and communicating the risk and opportunities clearly.
- Structuring and moderating the stakeholder discussions in an effective manner.
- Intra-domestic comfort component.

- **Stakeholder identification and managing their expectations:**

Identification of stakeholders, categorising them into groups, and selecting the relevant representatives of the identified groups are the first steps of the engagement process. Stakeholders vulnerable to heatwaves can be stratified based on:

- *Age:* children and the elderly are more vulnerable.
- *Gender:* women and girls, especially pregnant or lactating women are affected by heatwaves at a higher level.
- *Exposure*: street vendors, traffic police, transport service providers, construction workers and other labourers, people living in slums and densely populated places are likely to get more exposed to heatwaves.
- *Adaptive capacity*: poor people are likely to have less capacity to adapt to the changes in climate.
- *Ability to influence and implement adaptation/ mitigation measures*: decision makers, governments, medical practitioners, planners and climate practitioners are likely to have either the ability to provide pragmatic solutions or the capacity to bring change.

Thus, anyone attempting to structure the stakeholder engagement for a community exposed to the heatwaves should stratify its targeted audience according to the above classification and then identify the appropriate representatives of such groups. For example, relevant NGOs, schoolteachers, medical practitioners or caregivers (such as home makers who take care of their families in India) could be suitable representatives of vulnerable groups such as children and the elderly.

Managing expectation: While it is important to engage, it is also necessary to balance the engagement and keep track of strong influencers and bias. Thus, it would be good to set clear objectives of the engagement, where there is a potential for participants such as political leaders and various forums to influence outcomes.

- **Articulating and communicating clearly**
  Climate science, as it is written and expressed, can often not make sense to a non-climate practitioner. At times, conclusions could be confusing and seem irrelevant. Thus, for communicating the risk and opportunities, the information, data and messages should be articulated in a language that is understood easily by the masses. Infographics, whiteboard animation, audio- visuals and smart art are some of the formats that can be used for communicating the findings. It has also been observed that storytelling about life experiences by the same set of stakeholder groups that the target audience represents would establish more connections and have relevance than any other formats. Thus, the following factors should be considered in the communication planning:

  - A common, preferably, local language to be used.
  - Objectives, desired outcomes, need for engagement, and how it will be used in the decision making should be clearly laid out (managing the expectations) at the beginning itself.
  - Different formats and forums should be used to engage with different groups of stakeholders.
  - The engagement should be carried out at the various intervals during the entire process. It should essentially explain how the feedback is received and applied in decision making.

- **Structuring and moderating the stakeholder discussions**

Different formats of engagement require different kinds of skill sets. For instance, in a group discussion, ideally all parties to the engagement process should trust and respect one another's viewpoints and inputs, and should gain a sense of personal responsibility towards the issue. These features help to motivate participants, promote changes in behaviour and increase external recognition and impact. Having experienced facilitators from a trusted agency to conduct the engagement is extremely useful to help promote these features, rather than governments doing it by themselves. Similarly, city leaders may need to engage with local thought leaders who can influence wider behavioural change and encourage participation. The following approaches should be applied while moderating any discussions:

- *Address gaps in knowledge*: Recognise that lack of understanding and misconceptions about climate change and its correlation with heatwaves, and thereby with human activities, will result in the fact that some engagements will simply involve conveying of information.
- *Acknowledge uncertainty:* Be honest about the uncertainty involved in climate projections, but try to simplify this by identifying the facts, such as increase in temperature and frequent occurrence of heatwaves.
- *Address scepticism*: Engage intensively with influential members of the community to combat scepticism regarding the change needed. It is important to provide messages that directly address the claims and arguments of sceptical individuals and communities. For instance, the builder lobby may not wish to adopt new building codes that may increase the cost of construction. The city leadership may need to identify a progressive company that has the willingness and ability to take the first step and be recognised as a leader in the sector. Peer recognition will then pull others towards progressive approaches.
- *Address emotional reactions*: It has been often noticed that while discussing climate change issues, especially in promoting notions of personal vulnerability, individuals may feel helpless and/ or fearful, and most of the time digress from the point. These feelings can be overcome by identifying

positive and tangible actions and by encouraging stakeholders to focus on being part of a collective response.

3.2 How to understand the heat stress in a city?

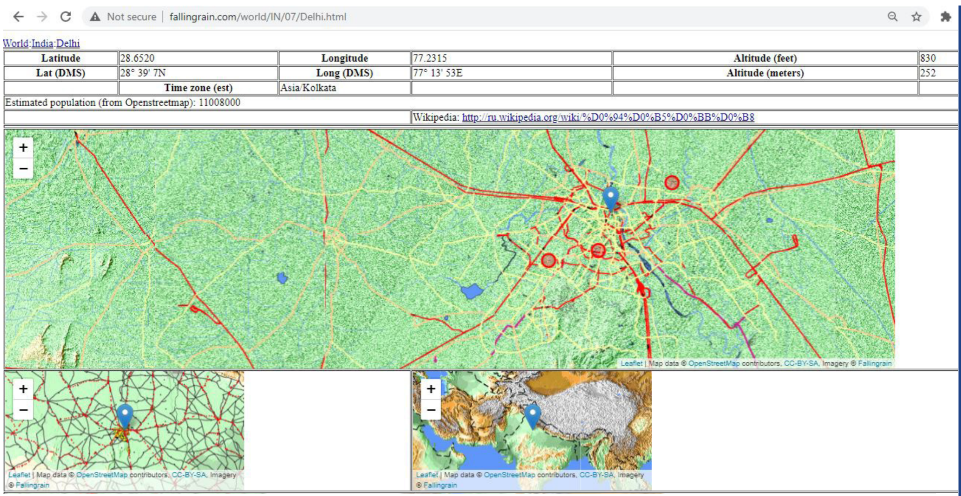
As specified earlier (2.2 Methodology), the causes of heat stress in Indian cities need to be identified on the basis of their climatic conditions and contextual challenges. According to the Indian Meteorological Department, a heat wave is declared if the maximum temperature of the recording station reaches at least 40°C or more for the plains, 37°C or more for coastal regions and 30°C or more for hilly regions. While urban neighborhoods experience rising temperature during the day, shaded areas and air conditioning help in coping with the heat. In contrast, congested low-income neighbourhoods with fewer green spaces are unprotected from heat even at night.

Local governments are generally adept at handling the contextual challenges. However, understanding the climatic conditions is a critical task. The toolkit, therefore, provides guidance about the aspects that need to be studied to understand heat stress in a city and the sources of data for the same.

Which aspects should be considered for analyzing the climatic conditions?
The climatic conditions of a city can be analysed by studying the following aspects:

1. **Topography of the city**: It is important to consider the topographical conditions of a city in order to understand the need for and to identify relevant solutions. The topographical conditions in India are classified as hilly regions, plains and coastal regions5. The topography of a city can be identified on the basis of two factors:
    - Coordinates of the city.
    - Topographical maps. (Open Series Maps)
    - The local government can also identify the topography based on the city profile and the surrounding terrain, as revealed by satellite images.

2. **Variation in the air temperature and precipitation**: Temperature and precipitation variations need to be calculated from time series data of the last 30 years, available with the Indian Meteorological Department. The range of 30 years is recommended by meteorological studies undertaken globally to understand the trends. The spikes in summer temperatures and the corresponding rainfall for the year help in understanding the trend of increase in the actual atmospheric temperature and its effect on the rainfall. For example, if the graph shows a spike for a year 2010, correlate the same with the extreme weather events that have occurred in the same year along with the trend for precipitation.



Data sources:

http://fallingrain.com/,

https://shop.geospatial.com/product/01-IN-AH-India-250000-Topographic-Maps,

http://www.surveyofindia.gov.in/pages/display/246-publications

Figure 5: The topographical map on fallingrain.com

- Maximum, minimum and the average annual temperature of the selected year (for summer months).
- Average annual rainfall for the selected year (for the rainy season).
- Repeat the steps (a) and (b) for a 30-year time series data.
- Overlap the plots generated from the steps (A) and (b).

Data sources:http://fallingrain.com/ and https://www.meteoblue.com/en/weather/

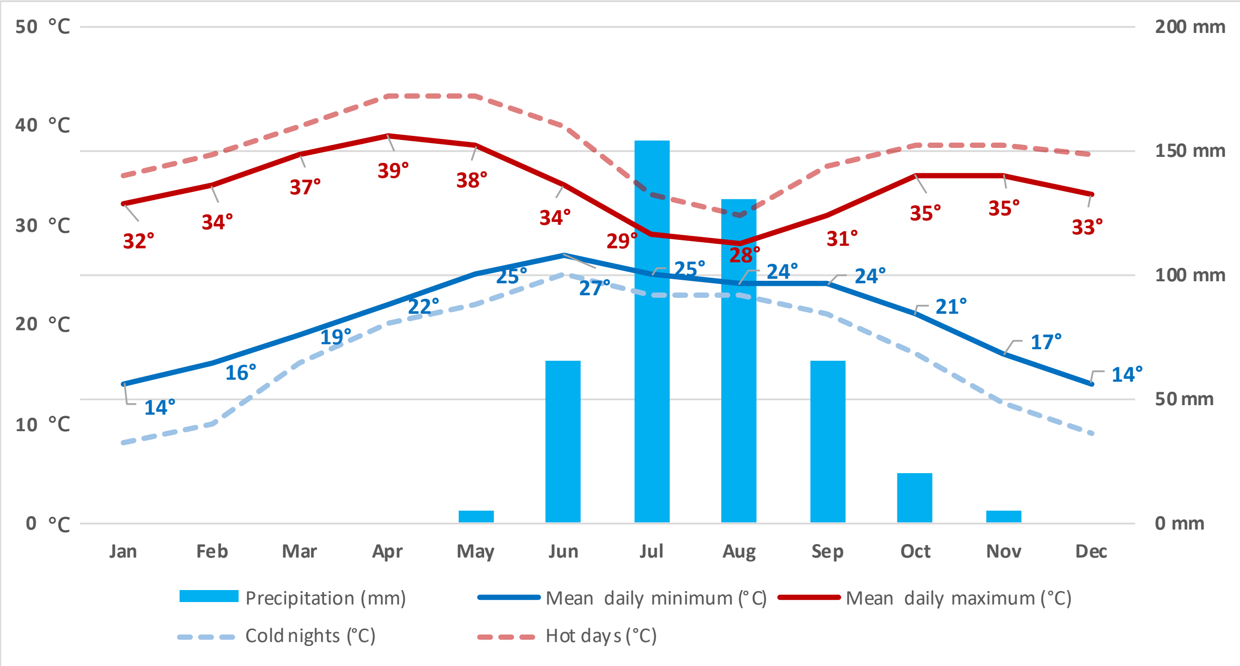


Figure 6: Illustration of the data for temperature and precipitation

3. **Humidity profile:** It is important to consider the relative humidity, since the rise in temperature and its collusion with relative humidity is the major reason for the increasing heat stress in coastal cities. Therefore, as specified earlier, the Heat Index is an important consideration for the human body's comfort.
   When temperatures rise, the human body perspires to cool itself. If the perspiration does not evaporate, the body cannot regulate its temperature. In humid conditions, perspiration evaporates slowly and consequently, the body heats up.
   There is a direct relationship between temperature, relative humidity and the heat index: the heat index increases with rise in temperature and relative humidity. Therefore, as Figure 7 shows, the higher the heat index, the more is the heat stress. The higher the number of such days, greater is the heat stress risk for the city.

Source: Articles published by UHCRC

Relative Humidity (%)

Temperature (°F)	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
80	77	78	78	79	79	79	80	80	80	81	81	82	82	83	84	84	85	86	86	87
81	78	79	79	79	79	80	80	81	81	82	82	83	84	85	86	86	87	88	90	91
82	79	79	80	80	80	80	81	81	82	83	84	84	85	86	88	89	90	91	93	95
83	79	80	80	81	81	81	82	82	83	84	85	86	87	88	90	91	93	95	97	99
84	80	81	81	81	82	82	83	83	84	85	86	88	89	90	92	94	96	98	100	103
85	81	81	82	82	82	83	84	84	85	86	88	89	91	93	95	97	99	102	104	107
86	81	82	83	83	83	84	85	85	87	88	89	91	93	95	97	100	102	105	108	112
87	82	83	83	84	84	85	86	87	88	89	91	93	95	98	100	103	106	109	113	116
88	83	84	84	85	85	86	87	88	89	91	93	95	98	100	103	106	110	113	117	121
89	84	84	85	85	86	87	88	89	91	93	95	97	100	103	106	110	113	117	122	
90	84	85	86	86	87	88	89	91	92	95	97	100	103	106	109	113	117	122	127	
91	85	86	87	87	88	89	90	92	94	97	99	102	105	109	113	117	122	126	132	
92	86	87	88	88	89	90	92	94	96	99	101	105	108	112	116	121	126	131		
93	87	88	89	89	90	92	93	95	98	101	104	107	111	116	120	125	130	136		
94	87	89	90	90	91	93	95	97	100	103	106	110	114	119	124	129	135	141		
95	88	89	91	91	93	94	96	99	102	105	109	113	118	123	128	134	140			
96	89	90	92	93	94	96	98	101	104	108	112	116	121	126	132	138	145			
97	90	91	93	94	95	97	100	103	106	110	114	119	125	130	136	143	150			
98	91	92	94	95	97	99	102	105	109	113	117	123	128	134	141	148				
99	92	93	95	96	98	101	104	107	111	115	120	126	132	138	145	153				
100	93	94	96	97	100	102	106	109	114	118	124	129	136	143	150	158				
101	93	95	97	99	101	104	108	112	116	121	127	133	140	147	155					
102	94	96	98	100	103	106	110	114	119	124	130	137	144	152	160					
103	95	97	99	101	104	108	112	116	122	127	134	141	148	157	165					
104	96	98	100	103	106	110	114	119	124	131	137	145	153	161						
105	97	99	102	104	108	112	116	121	127	134	141	149	157	166						
106	98	100	103	106	109	114	119	124	130	137	145	153	162	172						
107	99	101	104	107	111	116	121	127	134	141	149	157	167							
108	100	102	105	109	113	118	123	130	137	144	153	162	172							
109	100	103	107	110	115	120	126	133	140	148	157	167	177							
110	101	104	108	112	117	122	129	136	143	152	161	171								
111	102	106	109	114	119	125	131	139	147	156	166	176								
112	104	107	111	115	121	127	134	142	150	160	170	181								
113	104	108	112	117	123	129	137	145	154	164	175									
114	105	109	113	119	125	132	140	148	158	168	179									
115	106	110	115	121	127	134	143	152	162	173	184									
116	107	111	116	122	129	137	146	155	166	177										
117	108	112	118	124	132	140	149	159	170	181										
118	108	113	119	126	134	142	152	162	174	186										
119	109	114	121	128	136	145	155	166	178											
120	110	116	122	130	138	148	158	170	182											
121	111	117	124	132	141	151	162	174	187											
122	111	118	125	134	143	154	165	178												
123	112	119	127	136	146	157	169	182												
124	113	120	129	138	148	160	172													
125	114	121	130	140	151	163	176													

Heat Index

Extreme Danger	Heat stroke likely.
Danger	Sunstroke, musde cramps, and/or heat exhaustion likely. Heatstroke possible with prolonged exposure and/or physical activity.
Extreme Caution	Sunstroke, musde cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity.
Caution	Fatigue possible with prolonged exposure and/or physical activity.

Figure 7: Reference table for calculating Heat Index

Heat Index Calculator: https://www.wpc.ncep.noaa.gov/html/heatindex.shtml
Data sources: http://www.fao.org/nr/water/infores_databases_climwat.html, http://www.en.tutiempo.net/ and https://www.accuweather.com/

4. **Changing patterns of the summer season:** This refers to the early onset of and prolonged duration of summer. Over the last decade, the winter season has been ending by February, accompanied by a slow rise in temperature that lasts till July in various cities of India. For example, Delhi experiences outdoor heat from mid-February and continues to experience heat stress till October; this explains why the city experiences high temperatures even during the rainy season, when high levels of humidity increases the heat index, affecting body heat and indoor temperatures.

   Therefore, it is important to consider these changing patterns of the summer season. A time series data set of 30 years is ideal for analysing these trends. The data related to the above-mentioned factors needs to be studied in detail here. While the above-mentioned factors consider the yearly data, the monthly temperatures for each year need to be analysed to study the changes in seasons. The steps to be followed are:

   - Select the range of yearly data to be analysed (e.g., 1990-2020).
   - Observe the daily temperature of each month for a selected year (e.g., from July to October).
   - Identify the month where the increase in temperature was observed (above the average yearly temperature of the city).
   - Identify the month where the temperature is "=" or "<" the average yearly temperature of the city.
   - The period of heat stress is, therefore, identified for the year (e.g., Year 1990).
   - Repeat the steps (a) to (d) for all the selected years.
   - Plot the months of heat stress.
   - Analyse the changing pattern of heat days and delays in the summer season for the city.

3.3 What are the most important causes of heat stress in cities?

Considering the analysis, the decadal variability in the ambient air temperature is not enough to explain the occurrence of heatwaves in India. Increased air pollution, with aerosols blocking the sunlight, trapping the heat at the Urban Boundary Layer (UBL) and increase in evaporation are some of the leading causes of heat stress. These factors impact the health and infrastructure services and the environment, adding to economic losses. These effects are better described when the temperature and relative humidity are studied together in the form of Heat Index or Wet Bulb Temperature. The analysis of these effects is important to prioritise the causes and to identify relevant solutions. The most important causes of heat stress are broadly classified as:

1. **Increase in the impervious areas:** Solar reflectance (albedo) of paved/ concrete surfaces contributes to the increase in surface temperature, resulting in the Urban Heat Island Effect (UHIE). In a built environment that experiences hot weather and is large enough to develop a heat island, thermal reflectance plays a crucial role in mitigating heat stress. It also results in an increase in the night temperature. However, tall buildings in a cluster may block the natural wind flow, thereby reducing heat dissipation. While these buildings provide shade, they also inhibit the cooling effect of wind in coastal cities.

2. **Increase in the waste heat/ external energy inputs:**
   An increase in the use of private vehicles results in higher emissions. Road traffic has a strong implication for the severity and degree of the UHIE in a city. These emissions contain harmful gases such as SO2 and NO2, besides CFCs from air conditioners and PM2.5/ PM10. The emissions from industries constitute other toxic gases. The emissions and the particulate matter trap the heat within the UBL and increase heat stress. The increase in the amount of CFC emissions from centralized and decentralized air conditioning systems is leading to global warming.

Data sources:http://www.fao.org/nr/water/infores_databases_climwat.html, https://www.meteoblue.com/en/weather/and http://www.imdpune.gov.in/

toxic gases. The emissions and the particulate matter trap the heat within the UBL and increase heat stress. The increase in the amount of CFC emissions from centralized and decentralized air conditioning systems is leading to global warming, which is one of the major causes of global warming.

2. **Lack of vegetation cover and water bodies:** Satellite images of the urban space can highlight the lack of adequate green cover in a city. According to the World Health Organisation (WHO), it is recommended that every city should provide a minimum of 9 sq.m of green space per capita to maintain the balance between the built and green areas. Strategically located green spaces are major recreational open spaces that have landscape features that remain undeveloped due to their natural character or cultural significance, for example, ridges, woods, watercourses, historical places, reserve parks and estates. Additionally, street trees, green borders, pocket and local parks, house gardens (developed on roof-tops and balconies), exercise parks and playgrounds also work as green spaces. Some cities in India have less than 9sqm per capita green and open space, which indicates an increased percentage of built surfaces. An increase in the air temperature along with relative humidity leads to trapping of heat inside buildings during the day. Lack of green spaces, therefore, fails to minimise this effect and increases heat stress in urban areas.

3.4 How to analyze the cause according to context of a city?

The above- mentioned causes of heat stress can be observed across the country and therefore, it is important to understand the ways to study and analyze them.

1. **Increase in impervious areas and lack of vegetation cover and water bodies:** It is an effect of buildings blocking ventilation corridors and accumulating heat. Tall buildings in a clustered area may block the path of the wind, thereby reducing heat dissipation from the atmosphere. Coastal cities need to recheck its vertical landscape at the wind-ward side and ensure no high-rise development in such areas. These kinds of observations can feed into city development and landscape planning.

   Impervious areas can be identified and measured through:

   - Satellite imagery
   - Open and built space mapping
   - Land use and land cover analysis
   - Existing and proposed development plan reports
   - District census handbook (district level data for tree and forest cover).

2. **Increase in waste heat/ external energy inputs:** This is an effect of the anthropogenic heat generated by the increasing number of vehicles and air-conditioning units. Vehicular traffic has a strong impact on the severity and degree of the UHIE in a city. It is crucial to map and monitor the spatio-temporal heat patterns arising from vehicular traffic in a city. This can be measured by:

   - Recording vehicular density and the speed of vehicles using Passenger Car Equivalent (PCE) or Passenger Car Unit (PCU) as the common unit of calculation. The data on density of vehicles and speed helps in determining the amount of fuel being consumption and thereby the heat generation (in terms of joules). This will provide a macroscopic idea of heat generation for a given span of urban space.

   - Conducting a trend analysis on the per capita consumption of electricity for two time periods each year – the summer months that bring high temperatures (April to June) and any other time of the year. The comparison should be able to show excess consumption of electricity during the summer months, indicating use of air- conditioners. It should be noted that some cities such as Delhi may experience extreme temperatures in summer and winter. In such cities, there might be high electricity consumption from the use of room heaters. Thus, the analysis should be city specific.

   - Mapping urban thermal stress, using multiple regression analysis of different components including population density, land-use zoning, building's total floor area, land cover type, sky view factor and impervious surface ratio, mobile and fixed-point meteorological measurements. However, this method does not reveal the impact of heat from vehicles and air-conditioning units

Miyawaki model micro forest launched in Kerala to reduce Urban Heat Island effect - Source -traveltradejournal

04 IDENTIFICATION OF THE SOLUTIONS

4.1 What is the approach for identifying solutions?

To identify the actions relevant for a city, the best approach is to understand and learn from other cities around the world. It is important to study and understand the innovative solutions, the implementation technique and the maintenance requirements of the interventions. Therefore, a few national and international case studies to reduce heat stress are provided here.

International case studies:

Public awareness-raising in Dhaka, Bangladesh
In May 2017, BBC Media Action led a 16-day campaign to increase awareness among the youth regarding extreme heat risks in Bangladesh. The campaign focused on heat-related risks and heat-risk reduction strategies by developing short videos with practical messages in the local language. It also provided a platform for the youth to engage with policymakers.

In May 2017, BBC Media Action led a 16-day campaign to increase awareness among the youth regarding extreme heat risks in Bangladesh. The campaign focused on heat-related risks and heat-risk reduction strategies by developing short videos with practical messages in the local language. It also provided a platform for the youth to engage with policymakers.

Key Learnings: Simple but efficient use of social media can also be very effective in addressing and spreading awareness regarding heat stress in cities.

References: https://ui.adsabs.harvard.edu/abs/2017AGUFMPA12A..06A/abstract, https://www.bbc.co.uk/mediaaction/where-we-work

Selecting forecast-based actions for heat waves in Hanoi, Vietnam

Like many other cities, Hanoi faces multiple challenges, including heatwaves. The city's outdoor workers, older people, children below five years of age and individuals in care centres and hospitals are among the sections of population most vulnerable to heat waves.

The Vietnam Red Cross Society and partners are working with the Vietnam Institute of Meteorology, Hydrology and Climate Change to *co-create the heat wave forecasts for the city*. In addition, the Red Cross in Vietnam has conducted an extensive knowledge, attitude and practice survey to understand the current capacity of the population to cope with heat risks. The survey was supplemented by a comprehensive stakeholder analysis to identify the potential partners as well as with the geographic information system (GIS) mapping to show the locations of vulnerable people. Working with healthcare providers and local communities, the Red Cross in Vietnam has also identified cooling centres for communities and household retrofitting (e.g. covering tin roofs with white plastic tarpaulin and using sprinklers during the daytime) as well as providing cooling fans with ice tanks for use at night by the most vulnerable households as some of the early actions needed to

Figure 8: Cooling Centres in Hanoi

Key Learnings: In July 2019, Hanoi was affected by a heatwave with an HI of 47.5°C. The heatwave forecasting system helped the Vietnam Institute of Meteorology, Hydrology and Climate Change to issue warnings, following which the Red Cross cooling centres were opened. Thus, having a forecast-based early warning system can help in undertaking preventive measures for heatwaves.

References: https://www.forecast-based-financing.org/2019/07/24/heat-wave-activation-in-hanoi/,

Spray parks for cooling in Cape Town, South Africa

Heat risks, including heat waves and a higher number of very hot days, are becoming an increasing problem in Cape Town, South Africa. Most residents do not have access to air conditioning or swimming pools at home to help them cope with the heat. Beaches provide opportunities for swimming but can be dangerous for inexperienced swimmers. Disadvantaged neighbourhoods in the city also tend to lack trees and green vegetation that could provide shade for cooling.

To overcome these challenges, the City of Cape Town installed six spray parks within recreational spaces in the city's lower income areas. During a heatwave, children, ranging from toddlers to teens, can cool down in spray parks. Unlike swimming pools, people with disabilities can access the spray parks too, which, interestingly, use only 15–20 per cent of the water used by a medium-sized municipal pool. This is an important consideration for water- stressed cities.

Figure 9: Spray Park in Cape Town

Key Learnings: The water-wise spray parks act as the cooling centres for a city in case of heat stress. These can also be used as amusement parks in the post-summer months. It is a great way of integrating heat stress actions into recreational spaces.

References: https://www.capetownmagazine.com/water-wise-spray-parks

Tree audit and forestry management plan in Kampala, Uganda

Kampala, Uganda, is among the fastest growing cities in Sub-Saharan Africa, expanding at 5% annually. By 2050, it is estimated that the city will be home to 10 million people. However, unplanned and rapid urbanization has greatly impacted the city's residents and ecosystems, exposing them to various hazards, including heat and floods.

In 2016, the Kampala Capital City Authority developed a Climate Change Strategy that aimed to mainstream climate change into all city services as a step towards low-carbon development. Recognizing the multiple benefits of trees, the city conducted a tree audit to gauge the tree stock and identify new planting areas. City officials have also mobilised communities and institutions to increase the tree density from the current 13 trees per acre to 20 trees per acre over the next 10 years. Increased tree- canopy cover provides shade and enhances cooling through evapotranspiration, protecting the city's residents and infrastructure from devastating heat. In addition, the trees and shrubs remove smoke, dust and other pollutants from the atmosphere, improving air quality.

Key Learnings: All cities can formulate a climate change strategy for the service delivery systems and for managing the green cover. For instance, forest policy statements for Kampala were also developed, which recognized the need for the development and sustainable management of forests on private lands within urban areas.

References: https://www.mwe.go.ug/sites/default/files/National%20Forest%20Plan%20Uganda.pdf

Green Roof Pilot Project in eThekwini Municipality, South Africa

In 2004, eThekwini Municipality, South Africa, initiated the Green Roof Pilot Project as part of its *Municipal Climate Protection Programme*. Since then, the project

Figure 10: Green roof for Municipality Building

has shown tangible benefits, such as lowering the temperature inside buildings, reducing the need for air-conditioning, rainwater attenuation and slowing the release of this water into the stormwater system, reducing flood risk; increased inner-city biodiversity; and, improved visual appeal of buildings, especially of roofs. The other potential benefits of green roofs can now be harnessed, such as the production of food crops on the rooftops to support food security.

Key Learnings: The green roofs or roof gardens are efficient in reducing the indoor temperature and thermal reflectance. On the other hand, they increase the green cover for the city. This is paramount to curbing the heat island phenomenon, as green roofs improve the energy efficiency of buildings with poor thermal insulation.

References: https://www.greenroofs.com/projects/ethekwini-municipality-green-roof-pilot-project/

Case studies from India:

Creation of Oxy-zone in Raipur, Chhattisgarh

The city of Raipur in India has demolished old government buildings in the core area to create an urban forest. As much as 18 acres of land have been set apart to create an oxy-zone. The land value is approximately INR 1000 crores (10 billion). This natural forest will provide much-needed fresh air for this city, which carries the taint of being the seventh most polluted city in the world. Raipur comprehends the risks that it faces, and is leaving no stones unturned to reverse this situation. The idea of creating an oxy- zone was floated by a citizens' group.

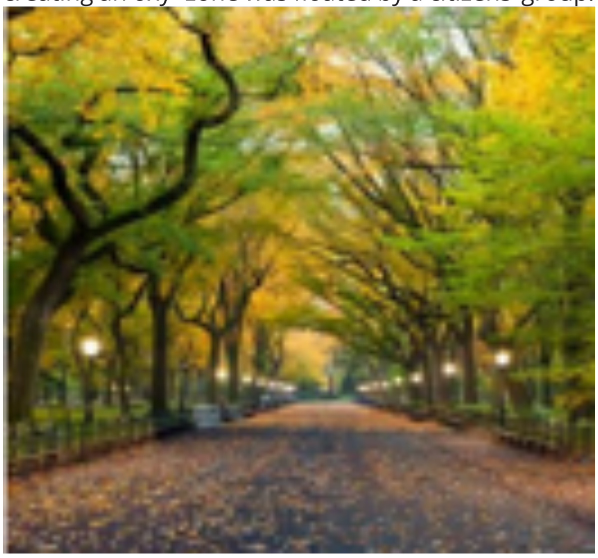


Figure 11: Oxyzone Park - Raipur

Key Learnings: This is an example of the successful creation of a microforest on a vacant plot after the demolition of a government building in the core city area. It is a cost-efficient and low-maintenance solution and can act as a heat sequestration area.

References: https://homegrown.co.in/article/801296/raipurs-growing-an-18-acre-oxy-zone-forest-right-at-the-heart-of-the-city, https://www.thebetterindia.com/104935/raipur-oxyzone-natural-forest/

Airshed Park, Delhi

Sweccha India, a city-based NGO, has converted an abandoned piece of land into a microforest over a period of 10 years. The green cover in this area had been low as five percent. Now, with more than 95 per cent green cover, it is a lush green mini-forest that is home to more than 300 species of flora, with 10,000 native fruit-bearing trees, herbs, shrubs, host and nectar plants, air-detox plants as well as vegetables. The team did not rely on any chemicals or unnatural resources to rejuvenate the park. They followed the principles of permaculture9 to create a self-sufficient ecosystem to ensure that the park can survive and regenerate on its own, even in the absence of maintenance.

Figure 12: Airshed Park - Vasant Kunj, Delhi

Key Learnings: This neglected piece of land in the city was reclaimed and converted into a micro-forest. It took 10 years for the plants to achieve their full growth. The park requires minimum investment and maintenance and was an initiative by a team of environmentalists. They did not use any chemical fertilisers or unnatural resources while rejuvenating the area.

Reference: http://swechha.in/project/airshed-development/, https://www.thebetterindia.com/188843/delhi-lifestyle-park-airshed-how-to-grow-mini-forest-city-india/

Cool Roofing Project, Indore

As the population of Indore city increased, with the rising density in some areas, vulnerable communities faced the challenge of poor ventilation. Their homes, made of low-cost building materials such as tin for roofs, often retained indoor heat and humidity, making life almost intolerable in the summer months. The expansion of the city has led to increasing heat island and climate change effects to be felt by the people every summer over the last decade. While green housing is being promoted, a significant proportion of the houses built over the past three decades or more have minimal provisions for passive space cooling.

Figure 13: Coolroofing of a bungalow in Indore

Consequently, Indore has been promoting cool roofing and passive ventilation technologies in the state and central government low-income housing schemes through advocacy and support. Cool roofing systems take solar reflectance and thermal emittance into consideration, but no two buildings are the same in the residential, industrial and commercial sectors. As a result, there are multiple types of cool roofing designs to suit various building designs and structural components.

Key Learnings: This cool roofing system is an efficient and quick solution for urban areas. It can be implemented by individual house owners and requires minimum cost and maintenance. This project benefitted all the end users, especially slum dwellers and those living in informal settlements who have low capacity to invest in cooling devices.

References: https://www.weadapt.org/placemarks/maps/view/928

Heat wave early warning system and action plan, Ahmedabad

To improve the heat disaster response planning at the local level, the development of an inter-agency heat action plan, including longer-term forecasting that would provide early warnings for extreme temperatures and increase heat-related capacities in local health centres, was considered. Based on research that identified the city's most vulnerable residents (including children, elderly people, slum communities and outdoor workers), a heat action plan to increase the heat resilience within the city was developed.

Key Learnings include three key strategies:

1. Building public awareness and community outreach on the risks of heat waves and practices to prevent heat-related illnesses.
2. Initiating an early warning system to alert residents and to coordinate an interagency emergency response.
3. Increasing the capacity of among medical professionals to recognise and respond to heat-related illnesses.

Training helped medical professionals to diagnose and treat heat-related cases and to reduce mortality and morbidity with standard surveillance protocols. Advance warnings helped health professionals to be on alert for heat-stress patients and to prepare additional resources such as ice packs.

References: http://www.ghhin.org/assets/case_study_pdf/WHO-WMO_Case_Stage_6_CH6a.pdf, https://www.nrdc.org/sites/default/files/ahmedabad-heat-action-plan-2018.pdf

4.3 What are the probable actions/ solutions to reduce heat stress?

The actions or solutions are based on the key learnings from the case studies. These solutions are classified as technological, infrastructural solution, institutional and capacity solutions. They can also be categorised on the basis of implementation levels, such as individual actions or government policy actions. Additionally, the implementation varies as per the hierarchy of implementation, the institutional framework, financial planning as well as technological support.

For this purpose, we have identified the following matrix that considers a three-way approach:

1. X-axis – Area of intervention: This axis helps in identifying the actions relevant for the existing development areas, new development areas and peripheral areas of the city. This aspect is considered in order to classify the actions according to the development within the city. The actions for peripheral areas can be more of implementation and urban planning, whereas the actions for existing development areas generally include retrofitting.

2. Y-axis - Type of intervention: This axis explains potential interventions as technological solutions, institutional reform and strategies for creating awareness. The financial solutions and policy reforms can be discussed for all the three aspects together. It will help in classifying and prioritizing the solutions.

3. Z-axis – Scale of the intervention: This axis considers the scale of the interventions needed at the neighbourhood, city and region levels. Since the actions or plans differ in implementation according to these scales, this consideration helps in understanding the ease of implementation of the solutions.

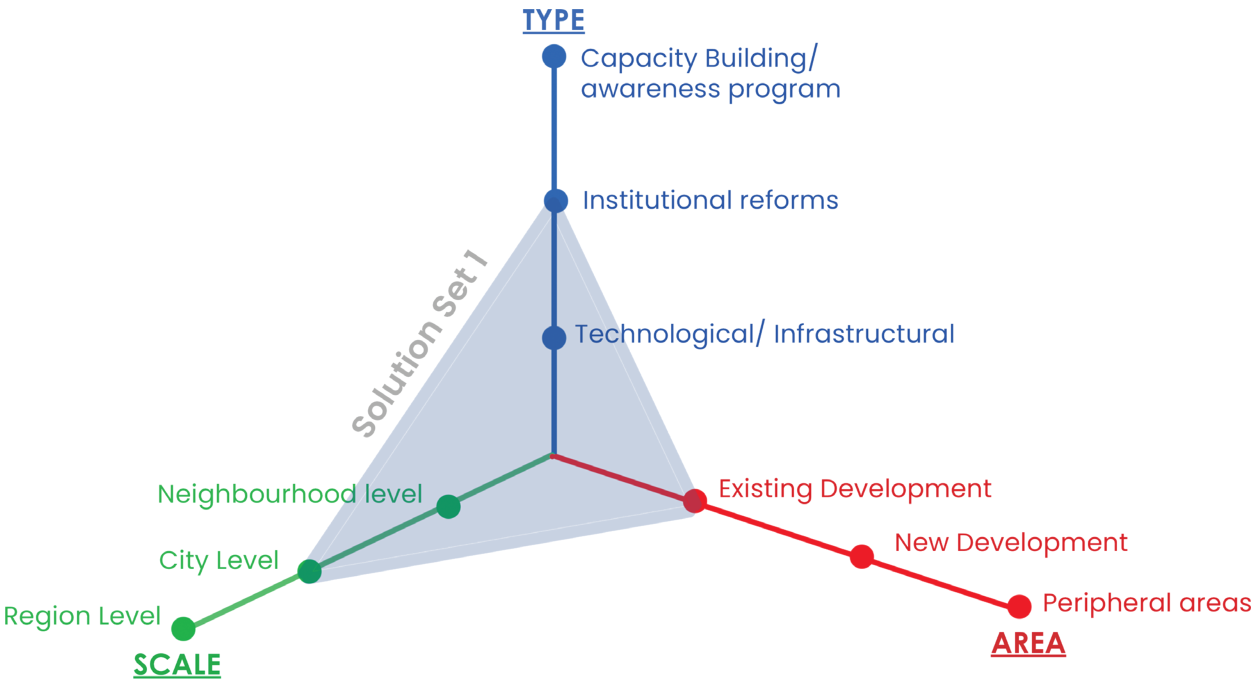


Figure 14: Framework for identifying solutions for the root causes

With the help of above-mentioned case studies and framework, the following probable solutions for creating resilience towards heat stress can be considered:

- **Awareness regarding extreme heat risks**
- **Cooling centres for communities**
- **Spray parks for cooling**
- **Green roofs**
- **A tree audit to gauge the current tree stock**
- **Creation of an urban forest**
- **Cool roofing by painting roofs**

Villagers struggling with water crisis amidst heat stroke- Source-patrika.com

05 PRIORITISATION OF THE SOLUTIONS

The climate of a city, such as a coastal or a hot- dry climate, helps in deciding the importance of natural ventilation over thermal insulation of habitats. For coastal cities, having humid conditions, natural ventilation would be of high importance, whereas for hot-dry areas, thermal insulation and the use of solar radiating surfaces are of significance. To implement a comprehensive list of solutions, a city needs to prioritise these actions.

5.1 What are the criteria for prioritizing the solutions?

When the local government identifies the causes as per the context, the next step towards implementation is to prioritise the intervention/ action. Therefore, it is essential to have a pre-decided criterion for prioritising the solutions. As per the secondary research and stakeholder consultations, four criteria need to be considered:

1. **Impact of the solution on public health and environment:** This criterion prioritises the effect of the intervention on public health, followed by the environment. The health benefits are prioritised for the obvious reason of helping the vulnerable population. There is a high probability that solutions that benefit public health also benefit the environment. For example, reducing indoor temperatures through green roofs benefits the public by controlling the body temperature and facilitating an increase in vegetation cover.

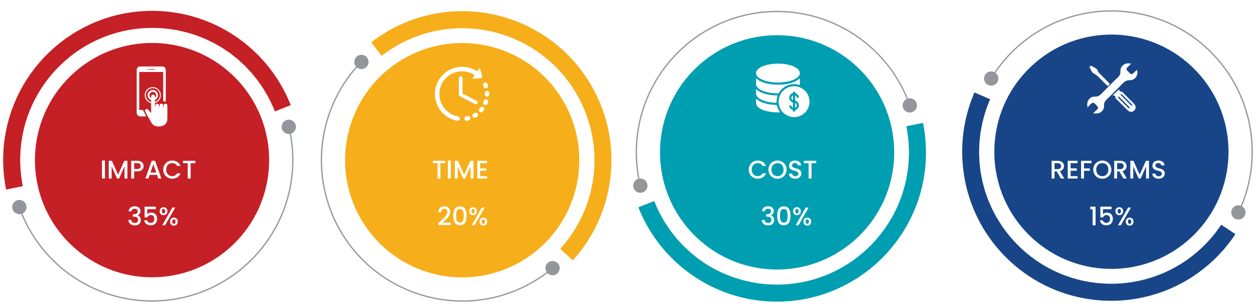
2. **Time span of implementation:** The time span refers to short-term, medium-term and long-term projects. Interventions that can be implemented within five years are considered as short term. Interventions with a 5- 10 year implementation period are considered to be medium-term, while long-term interventions require more than 10 years.

3. **Cost of Investment for the local government:** This is the most important aspect to be considered for prioritising the interventions, as the cost of investment and returns on them are of prime importance for the local government. It can also be calculated on the basis of a cost-benefit analysis of the interventions prioritised from the first two criteria. The cost of investment, therefore, helps the city to understand the available funds and willingness of the local government to spend on the intervention.

4. **Reforms the existing project/ program:** It is easier for the local government to implement interventions, organise funding options and maintain them if reforms/ additions to an ongoing project/ programme are also undertaken. For example, design guidelines and material specifications for affordable housing schemes within a city to reduce indoor temperatures can be added as a regulation to the guidelines for the (ongoing schemes under the Pradhan Mantri Awas Yojana (PMAY) programme (a Government of India initiative that intends to provide affordable housing to the urban poor by 2022).

Evaluating the criteria:

To prioritise the solutions with the help of the above-mentioned criteria, it is important to understand and give weightage to each and then score them accordingly. A total of all the scores therefore will help to prioritise the solution. Here, the impact and cost of implementation are of the highest priority, followed by the time span of implementation and finally, the reforms in ongoing projects. Hence, the weightage for each criterion is as follows:



ANNEXURE 1
VULNERABLE POPULATION

VULNERABLE POPULATION	RISK FACTORS
Adults over 65	Less aware and less adaptable to extreme heat
Individuals with chronic medical conditions	These conditions include heart disease, lung and kidney conditions and mental illness. Those taking medications that can worsen the impact of extreme heat are especially vulnerable
Children under five years old	Sensitive to the effects of extreme heat and must rely on others to keep them cool and hydrated
Women and girls	May not have access to a variety of media; sleep in poorly ventilated rooms; and lack private bathing space, especially during menstruation
Pregnant and lactating women	Pregnant women are more likely to go into early labour in the week following a heatwave. This risk rises with more consecutive days of extreme heat. *Lactating women require more drinking water as breastfeeding is extremely dehydrating
Outdoor workers (inlc. Traffic police and security guards)	Often engaged in strenuous labour while directly exposed to sunlight as well as heat and air pollution. More likely to become dehydrated and suffer from heat-related illnesses
People living alone	May not be able to get help quickly
Individuals with disabilities	May not be able to get help quickly
Overweight and obese individuals	May be more sensitive to extreme heat and have difficulty in thermoregulating their bodies
Individuals of low socio-economic status	May not have access to clean drinking water and other cooling measures. May not be able to access information about heatwaves and cooling centres
Migrants and refugees	May not have access to current information about heat advisories and health risks, or may experience heat conditions that are different from their place of origin
Homeless people	May not receive warning messages, may be unaware of cooling centres and may have limited access to other cooling measures (e.g. cool showers or baths)
Individuals unable to read and non-native language speakers	Cannot read current information about heat advisories and health risks. Non-native language speakers also may not be able to understand advisories broadcast on TV and radio
Tourists	May not be able to understand advisories in local languages. May not know how to access cooling centres, green spaces or other resources, including emergency management systems. May be from cooler climates and less adapted to the heat.
Animals/ pets	Dependent on their owners for adequate protection from heat.

*Adapted from the Kansas Extreme Heat Toolkit

ANNEXURE 2
CORRELATION OF HEAT STRESS AND SDGs

1 NO POVERTY	Low-income groups such as agricultural workers, labourers, casual workers in urban areas and people residing in informal settlements in the central and southern parts of India are the worst affected. Social protection in these areas is of prime importance
2 ZERO HUNGER	Low-income groups such as agricultural workers, labourers, casual workers in urban areas and people residing in informal settlements in the central and southern parts of India are the worst affected. Social protection in these areas is of prime importance.
3 GOOD HEALTH AND WELL-BEING	The effects on the health of vulnerable populations and the outbreak of viral diseases is a serious issue
4 QUALITY EDUCATION	Extreme heat affects the health of schoolchildren due to their exposure to the sun, and eventually leads to underperformance and lack of attention at school. These students and their teachers are less likely to learn and provide quality education, respectively.
5 GENDER EQUALITY	Various outdoor heat-exposed occupations as well as activities affect women and men differently. Pregnancy and the menstruation cycle adds to the risks posed by heat exposure for women and girls.
8 DECENT WORK AND ECONOMIC GROWTH	Extreme heat affects working conditions, productivity and economic growth, which, in turn, make it more difficult to ensure compliance with international standards and guidelines on the occupational safety and health of workers. The economic consequences
10 REDUCED INEQUALITIES	Generally, the temperate regions are affected to a far lesser extent than the warm and humid, and the hot and dry regions. Therefore, it counteracts efforts to reduce inequalities.
11 SUSTAINABLE CITIES AND COMMUNITIES	Heat extremes pose several challenges to the built environment and its sustainability, including the impacts listed above in the figure related to the infrastructural services as well as forest/ green spaces in a city.
13 CLIMATE ACTION	The need to undertake actions to combat climate change and its impacts on the vulnerable population and the urban environment is yet to be effectively recognised and addressed.

ANNEXURE 3
LIST OF TIER I AND TIER II CITIES

STATES/ UTs	CITIES CLASSIFIED AS "X" (TIER – I)	CITIES CLASSIFIED AS "Y" (TIER – II)
Andhra Pradesh	Hyderabad	Vijayawada, Warangal, Vishakhapatnam, Guntur
Assam		Guwahati
Bihar		Patna
Chandigarh		Chandigarh
Chhattisgarh		Durg-Bhilai, Raipur
Delhi	Delhi	
Gujarat		Ahmedabad, Rajkot, Jamnagar, Vadodara, Surat
Haryana		Faridabad
Jammu and Kashmir		Srinagar, Jammu
Jharkhand		Jamshedpur, Dhanbad, Ranchi
Karnataka	Bengaluru	Belgaum, Hubli-Dharwad, Mangalore, Mysore
Kerala		Kozhikode, Kochi, Thiruvananthapuram
Madhya Pradesh		Gwalior, Indore, Bhopal, Jabalpur
Maharashtra	Mumbai	Amravati, Nagpur, Aurangabad, Nashik, Bhiwandi, Pune, Solapur, Kolhapur
Orissa		Cuttack, Bhubaneswar
Punjab		Amritsar, Jalandhar, Ludhiana
Pondicherry		Pondicherry
Rajasthan		Bikaner, Jaipur, Jodhpur, Kota
Tamil Nadu	Chennai	Salem, Tiruppur, Coimbatore, Tiruchirappalli, Madurai
Uttar Pradesh		Moradabad, Meerut, Ghaziabad, Aligarh, Agra, Bareilly, Lucknow, Kanpur, Allahabad, Gorakhpur, Varanasi
Uttarakhand		Dehradun
West Bengal	Kolkata	Asansol

ANNEXURE 4
REGISTERED VEHICLES IN TOP 10 CITIES

Number of Registered Cars and Motor Vehicles (in millions) in Selected Cities - March 2016

Source: http://www.knowindia.net/auto.html

CITY	CARS PER SQ. KM.	ALL MOTOR VEHICLES PER SQ. KM.
Ahmedabad	0.5	3.66
Delhi	2.73	8.85
Bengaluru	1.19	6.11
Chennai	0.86	4.94
Kolkata	0.33	0.74
Hyderabad	0.40	2.37
Pune	0.41	2.52
Lucknow	0.25	1.82
Surat	0.34	2.67
Jaipur	0.33	2.42
Vadodara	0.23	1.90
Mumbai (Greater)	0.86	2.82

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