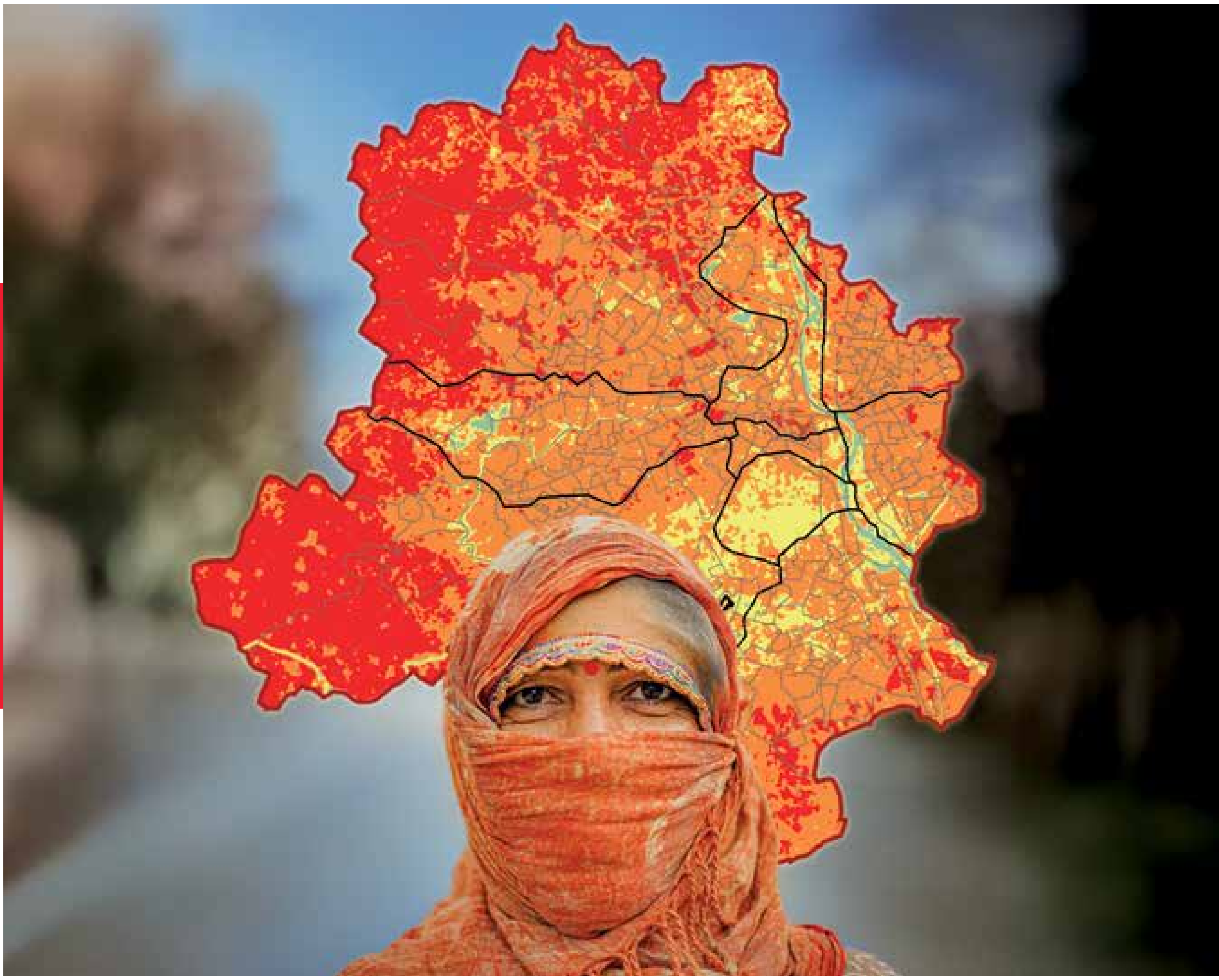
HEAT SOLUTIONS

Unboxing Learnings on Heat Resilient Housing from Urban Poor Women in Delhi NCR



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environmental research and action group

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ABOUT CHINTAN ENVIRONMENTAL RESEARCH AND ACTION GROUP

Chintan is a non-profit **Circular Society Do-Tank** that **improves the lives, livelihoods and leadership** of the people who contribute the least to environmental pollution and climate change while combating the excessive and inequitable consumption that causes it.

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CONTENTS

LIST OF ACRONYMS

AI .... Artificial Intelligence
AWS .... Automatic Weather Station
DELHI NCR.............. Delhi-National Capital Region
GDP .... Gross Domestic Product
GIS .... Geographic Information System
ILO............................. International Labour Organization
IMD .... India Meteorological Department
NbS............................ Nature-based Solutions
PMAY-U.................... Pradhan Mantri Awas Yojana-Urban
RAMA....................... Refrigeration and Air Conditioning Manufacturers Association
SRI .... Solar Reflective Index
STS Global .... SEEDS Technical Services Pvt Ltd
WBT .... Wet-Bulb Temperature
WHO .... World Health Organization

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SUMMARY

THE SEVERITY AND frequency of heatwaves have seen a significant increase in the past few decades in the country. Between 1992 and 2015, the number of heatwave events in India increased 2.5 times with severe heatwaves becoming an annual phenomenon. Studies by public health experts found that up to 1,116 people have died every year between 2008 and 2019 due to heat.

Long-term projections indicate that Indian heatwaves could cross the survivability limit for a healthy human resting in the shade by 2050. Moreover, they will impact labour productivity, economic growth, and quality of life of around 310-480 million people.

Between 2001 and 2020, India lost around 259 billion hours of labour annually due to humidity and heatwaves, costing India Rs 46 lakh crores in total, notes a 2022 discussion paper by think tank Social Policy Research Foundation (SPRF) India.

The International Labour Organization (ILO) estimates that India will lose around 5.8% of its total labour hours in 2030 due to heat and humidity. The loss of labour hours due to heat stress has severe implications for India since approximately 90% of the labour force is engaged in the informal sector, and most of this labour is employed in physically demanding occupations.

The urban poor are especially at risk from both the direct and indirect health impacts of climate change due to several contributing factors. Their livelihoods are often informal, unstable and based on daily earnings. Their housing conditions are self-made with basic, low cost materials and offer substandard protection. They lack adequate resources to mitigate climate effects or access healthcare. Extreme heat may force them to reduce their working hours or stop work altogether, leading to lost income. For women, the additional task of caregiving means they might lose income even if they are able to work.

Persistent heat exposure has numerous negative health effects, and can aggravate chronic disease. Heat also increases ground-level ozone concentrations, which is directly linked to respiratory disease.

Meanwhile, 'heat poverty' is a growing threat in India as more and more urban poor are being forced to borrow money at high interest rates to buy air-conditioners (ACs) to cool down their homes so that their families can sleep and go to work the next day. Market studies by India's Refrigeration and Air Conditioning Manufacturers Association (RAMA) indicate that AC prices will decline below Rs 8,000 through low-cost payment plans comparable to TVs and cellphones. The pent-up discontent fuelled by exclusion from basic thermal comfort is seen as pent-up market demand by RAMA.

CHINTAN'S GENDER TRANSFORMATIVE APPROACH TOWARDS HEAT MANAGEMENT

Chintan Environmental Research and Action Group (Chintan) identifies gender transformative approaches as a key accelerator to achieving sustainability. Hence, when it started work on heat resilience and thermal comfort in 2020, it had a clear vision — heat is an intersectional issue and it disproportionately impacts some groups over others, like poor communities or women. Heat management, thus, needs intersectional heatplans,

MARIA CASSAGNE/UNSPLASH

Women in India currently lose 19% of their paid working hours due to heat.

and urban poor women have a major role to play in it.

Women wastepickers are additionally vulnerable as they face the double brunt of marginalisation and lack access to multiple resources due to their socio-economic status, but also experience gender-based discrimination. Hence, long-term heat resilience building for communities requires focused interventions and leadership development with women. This includes building their knowledge and capacity on a variety of inter-connected issues from climate change and heat to health to climate justice.

Thus, in its work to build heat resilience amongst urban poor communities in Delhi-National Capital Region (NCR), Chintan, and its technical partners SEEDS Technical Services Pvt Ltd (STS Global) and cBalance Solutions Pvt Ltd, centered the participation and buy-in of women. The project, which started in June 2022 and ended in December

2024, had a participation of 1,000 urban poor women.

To build the capacity of women and nudge behaviour change for heat resilience, Chintan and its partners organised a series of knowledge-based training on climate change and heat to raise awareness about these issues among the wastepicker women, many of whom have received no education, formal or informal.

These women wastepickers were trained to map heat hotspots along with the team. A group of women were also trained to set up a community-level automatic weather station (AWS) with the support of the community youth. These urban poor women not only issued heatwave alerts but also actively participated in interventions for building heat resilient housing.

THE INTERVENTIONS WERE MADE IN THE FOLLOWING THREE BROAD PHASES:

RISK ASSESSMENT: The initial step involved conducting heat-vulnerability assessments using GIS-based heat mapping and surveys in Delhi-NCR. These assessments helped identify high-risk areas, particularly informal settlements, and allowed targeted interventions where they were most needed (*See Chapter 3*).

COMMUNITY ENGAGEMENT AND WEATHER MONITORING: Chintan and STS Global established a community-based weather monitoring system using AWS in one informal settlement in Delhi. Women from the community were trained to operate the AWS, monitor and share real-time data with the community through WhatsApp and personal communication. Youth from the community helped the women, as they were educated and comfortable with handling new technology. In the process, women felt empowered and became central to disseminating heat warnings and ensuring the community's preparedness (*See Chapter 4*)

STRUCTURAL INTERVENTIONS AND OWNERSHIP BUILDING AMONGST COMMUNITIES: The structural interventions focused on heat-resilient roofing systems in informal settlements, with community members, particularly women, involved from the planning and installation phases. Using locally available recycled materials, such as jute, cardboards, etc, promoted sustainability. Meanwhile, women's participation fostered community ownership of the interventions (*See Chapter 5*).

CHINTAN'S ON-GROUND INTERVENTIONS IN HOMES OF URBAN POOR

Chintan made structural interventions to improve thermal comfort of residents in five identified settlements via three sets of interventions. It worked with two technical and implementation partners — cBalance Solutions Pvt Ltd, and STS Global (Details of these interventions and their results are in Chapter 5 of this report).

The rationale and methodology included the following:

- Pilot demonstrations were conducted to check feasibility and efficacy of various cool roof installations prior to scaling up. It is important to test out the solution and if it works in the local or urban poor context of the informal settlement before a scale up.

- Local women were trained to understand the science and benefits of roof interventions to ensure buy in and participation to install and maintain these roofs.
- Data loggers were installed in three settings — houses with cool roof intervention, houses without cool roof intervention, and outdoors temperatures to measure the efficacy in terms of temperature reduction.
- Physical check-ins and interviews were conducted with women to receive feedback and take note of any challenges that they experienced.

cBalance partnered with Chintan for installation of 5 different types of roofs: (i) Water filled PET bottles on the roof, (ii) Cement bonded wood-wool panel under the roof, (iii) aluminised foil under the roof, (iv) Chain Sprocket mechanism with Ecoboard on the roof, and (v) Ecoboard Static-Retrofit in the existing roof.

STS Global demonstrated its cool roof interventions via three models in the identified wastepicker settlement in South and Central Delhi. While each of the three interventions proved to be effective, model 2, which used a layer each of tarpaulin, existing tin, insulation sheet, cardboard, bamboo and jute, was most effective, with a 13°C temperature difference between a cool roof and a no-cool roof house.

Chintan and STS Global also made an intervention in the 'common area' in informal settlement where women sit down together to do chores such as chop vegetables and other collective activities. The team used old textile waste to put up a cloth roof that allowed air to come in but created partial shade so that women avoid working in direct sun.

Chintan also did a pilot on cool roofs based on white reflective paints at two of the intervention settlements in North Delhi and South Delhi. However, in its latest assessment, conducted in April 2025, Chintan found that not even a single painted cool roof was in good condition, with 'good' defined as 'almost fully white, as initially applied'.

The assessment also showed that slightly more than 10% of the cool roofs were currently being used for storage of items such as segregated waste life plastics, tires, tin boxes and various domestic goods like earthen pots, plants, etc.

KEY INSIGHTS

Based on the bottoms-up work that Chintan has been practising on heat and thermal comfort in slums of Delhi NCR in close collaboration with urban poor women, the following key insights emerge:

1. GOING BEYOND ROOFS: Roofs are key to reducing heat inside homes, as almost 80% of all heat is absorbed via the roof. However, women often spend time at their doorsteps while doing specific tasks such as preparing vegetables for cooking and sewing, amongst others. Often, they use the time outside with other women engaged in similar tasks, an act that enables them to strengthen social resilience, seek support and learn from and share information with peers.

Hence, cooling open spaces within individual homes in an informal settlement is important from a gendered perspective. The work on the ground comprised used textile waste cut into medium sized flags, attached to a grid of jute ropes, about 10 feet from the


Roofs play a crucial role in reducing indoor heat, with nearly 80% of heat entering homes through them.

ground. The women were able to set it up under instruction. The device allowed evening breeze but prevented direct sun. However, it dismantled in the heavy rains. Locally appropriate, low cost devices can be developed and used every year in this context.

2. ALL ROOFS NEED ANNUAL REPAIR: Every kind of cool roof in the project needed repair. This was for two reasons. One, the material itself became weathered. White reflective paint peeled off and multi-layered roofs were damaged in the rain and with time. Hence, a budget for annual maintenance is essential.

3. WHITE ROOFS ARE NOT FOR EVERYONE: While painting roofs with white reflective paint is widely favoured as an easy and impactful way to reduce heat stress inside the house, Chintan found that several families use the roof for storage. Infact, even if they clear the roof for painting, they tend to eventually use it due to pressing storage needs. Multi-layered roofs were able to manage storage better, but this needed some training and instructions. It is important to do a recce and document the roof storage before uniformly applying one technique across a settlement.

4. WET BULB PHENOMENON IS IMPORTANT: Much of the focus around heat is on high temperatures. However, the wet bulb phenomenon is also vital to protect health. This kicks in under conditions of high humidity, when even temperatures not considered extreme can cause heat stress, such as the body not being able to sweat to cool. The study found it useful to install AWS that enabled the community to know about heat (temperatures) and wet bulb conditions.

The project advised women to avoid coolers during this period, switching to fans as well as other basic protocols. No household used an air-conditioner, hence all of them were hit by wet bulb stress. Under the circumstances, a protocol for wet bulb conditions, along with a separate warning, is important.

5. INCLUDING LITERATE YOUTH FOR HYPER-LOCAL ACTION: Literacy levels amongst women in urban informal settlements are low. However, the project observed that children and youth are able to read, analyse and triangulate data at the very least. This capacity is a community asset and should be part of all interventions, including those that require reading automatic weather stations, hyper local warning systems, information about desirable action during heat stress and wet bulb, and any other information sharing.

FUTURE DIRECTIONS

The following future directions have been identified based on Chintan's grassroots work with women in informal settlements.

These are nuanced, aimed at specifically being part of bigger heat action plans, with the objective that millions of people who live in hot and poorly ventilated informal settlements can lead dignified lives, sleep at night, earn their daily wage the next day, and reduce their spendings on the increasing disease burden due to heat-related ailments.

1. INFORMAL SETTLEMENT HOUSING POLICY WITHIN HEAT PLANS AND BUDGETS FOR REPEAT: This report clearly demonstrates how some pockets in cities are hotter than the others. These are mostly informal settlements and slums. The heat challenges of these highly vulnerable zones are different from the rest of the urban centre.

Heat action plans must be inclusive of those in informal settlements by earmarking specific resources for gendered heat stress needs in informal settlements as well as mapping local climatic zones and addressing informal settlements in the most heat stressed zones on priority.

As informal settlements phase out and affordable housing schemes increase coverage, government housing schemes, including Pradhan Mantri Awas Yojana-Urban (PMAY-U) and schemes within it, such as Affordable Rental Housing Complexes, under the Ministry of Housing and Urban Affairs, which is a credit-linked subsidy scheme by Government of India to facilitate access to affordable housing for the low and moderate-income residents of the country, must have a mandatory provision for cool roofs and homes.

2. SURVEILLANCE OF INDEXED HEAT AND HEALTH: It is known that heat as measured may not be heat as experienced, due to several factors, including housing quality, heat island effect, green cover and wetlands, wind direction and more. This gap can have an impact on the most vulnerable. Hence, surveillance of indexed heat and its computation, which can be roughly understood as 'feels like,' is important to compute and share. This also underscores the need for localised heat warnings as temperatures may be experienced differently across a city or district.

3. ESTABLISH PROTOCOLS FOR EMERGENCY HEALTH RESPONSE: While several instructions for preventing heat strokes and reducing heat stress exist, these must be upgraded to include :

- Protocols for shifts in outdoor work to reduce heat impact
- Protocols for specific kinds of work (such as working with ovens, tandoors and in certain industries) to prevent heat stress

- Protocols for reducing heat stress inside informal settlements and individual homes
- Protocols for health case institutions for managing heat stress and illness by the urban poor and workers
- Protocols for wet bulb conditions across homes, work and healthcare institutions.

The health system, including frontline health workers and 'jhola-chap doctors', should be trained to understand and handle climate-linked physical and mental health issues.

4. FLEXIBLE BUDGETARY PROVISIONS: The heat action plans must include budgetary provisions for repairing and upgrading interventions in informal settlements if they are to have any impact.

5. ENCOURAGE NATURE-BASED SOLUTIONS AROUND INFORMAL SETTLEMENTS TO BRING DOWN AMBIENT TEMPERATURES: Since the spatial characteristics of a city influence its climate, urban design can be deployed to mitigate the combined effects of climate change and urban heat island effects in slum pockets. Creating a comfortable microclimate in slums should be a high priority.

Nature-based Solutions (NbS) are an effective tool to reduce urban vulnerability to climate risks and, at the same time, develop more liveable urban areas and slum pockets within them. Nature-based solutions such as green (vegetation) and blue (waterbodies) infrastructure, including in combination, are cost-effective and sustainable strategies for managing the heatwaves risks.

These should be planned and rolled out to reduce heat stress and improve health outcomes for all low income housing, formal or informal. This should also be brought under the ambit of CSR (corporate social responsibility) funding to unlock further resources.

6. SKILLING AND TRAINING FOR GREEN JOBS AROUND COOL HOMES FOR URBAN POOR: As this report demonstrates, multiple ways exist to bring down temperature inside and around homes in informal settlements. Small changes can yield big results, such as adoption of cool roofs. But structural interventions need trained humanpower across every level.

In this context, livelihoods entrenched within the green economy are vital. In a scenario of rising heat, a need to create a local cadre of masons, plumbers, carpenters, tailors, who can be trained and skilled to set up a range of cool roofs and similar interventions will enable policy roll out at the grassroots.

Cost will always be a constraint while working with urban poor, who are already being pushed into 'heat poverty'. Hence, every effort has to be made to use locally sourced materials to keep the retrofitting costs low. This will also enable homeowners to undertake such interventions on their own.

7. CAPACITY BUILDING FOR PASSIVE COOLING INTERVENTIONS IN INFORMAL SETTLEMENTS: Whereas a lot of work has happened on passive cooling solutions in cities that focus on economically well-off populations, such solutions for informal settlements and urban poor housing are still emerging. There is a need to enable the capacities and skills of organisations that work with slum populations and marginalised communities to intervene for thermal comfort.

8. STRENGTHEN DEMAND FOR THERMAL COMFORT AMONGST THE URBAN POOR: Chintan was able to undertake intense training with wastepicker and other women in informal settlements, along with children. This enabled the women to seek out, collaborate and understand the importance of thermal comfort, instead of assuming this is 'normal' and their 'fate.' However, this may be a challenge to scale up.

An impactful strategy is likely to be to create 'cool' schools and mainstream learnings on heat in all educational institutions. Teachers and other staff must also be trained to impart learnings around beating the heat and creating a resilient environment to avoid growing eco-anxiety among school children (read Chintan publication, *The Future We Want*, November 2024).

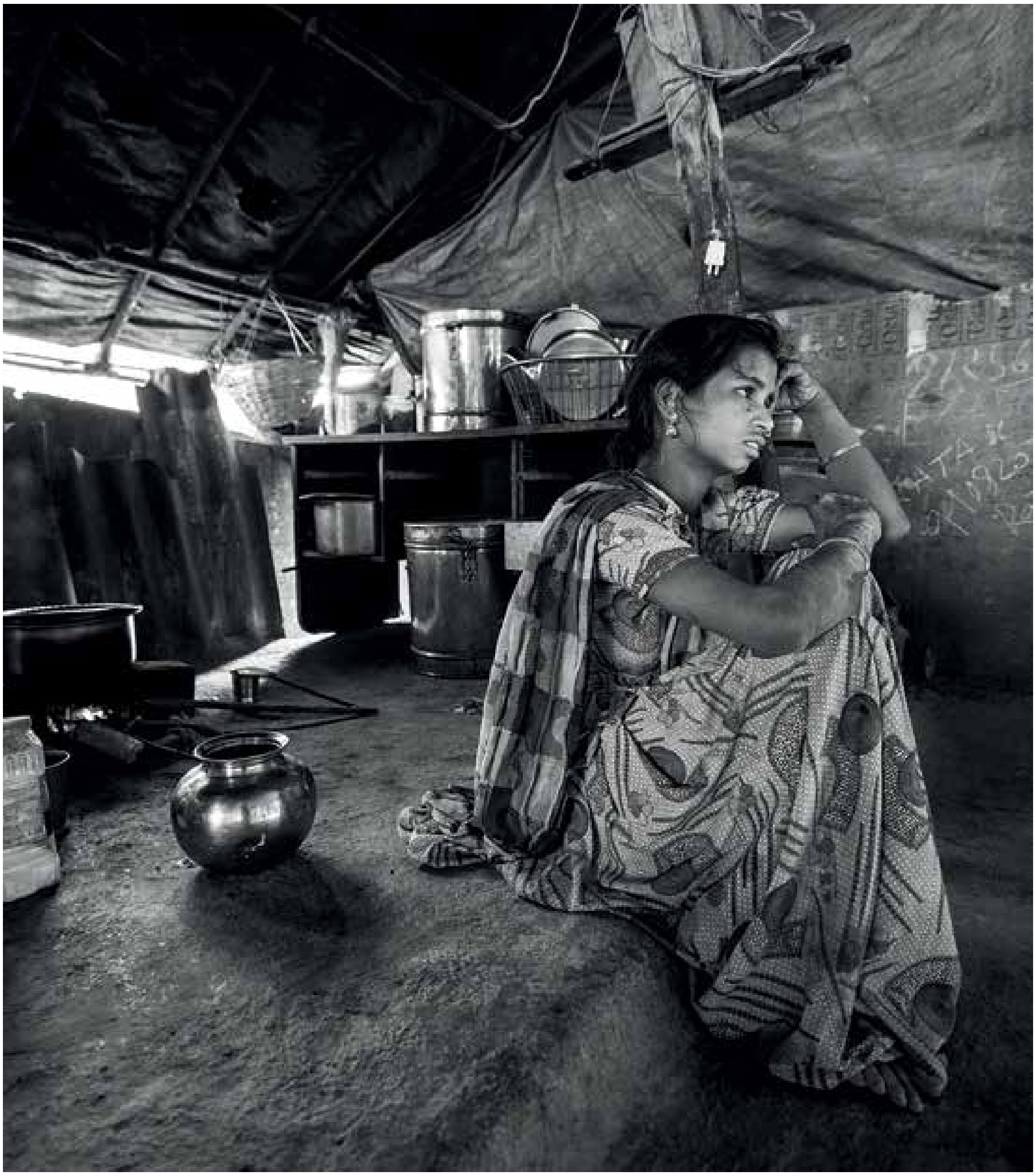
9. FISCAL MEASURES FOR THE URBAN POOR: While it is a challenge for many to work, the urban poor are particularly hard hit. Their work often requires them to be outdoors, undertake work that requires significant physical effort or requires them to be near sources of heat (such as recycling or cooking). Heat stress not only prevents them from directly working but also increases their caregiving tasks, which also prevents them from working. This amounts to significant income loss, exacerbated for the many who depend on daily earnings.

Compensating them for heat based income losses prevents them from sliding below the poverty line. In order to do so, the following are essential :

- A robust, acceptable measurement of productivity loss
- Developing an innovative finance package including including parametric insurance
- Setting up a heat mitigation fund which can also receive funds from multiple global sources. India must expand mandates of existing funds such as the Loss and Damage fund for supporting such investments.

India has invested significantly in the poor, bringing 24.82 crore Indians out of multidimensional poverty in the last nine years, enabling them to own a house, access education foodgrains, and more. Heat, as a manifestation of climate change, can derail this progress. Cool roofs for those living in informal settlements along with allied interventions can offer significant push back against this national threat.

1 RISING HEAT, INFORMAL SETTLEMENTS & URBAN POOR



SANTOSH JAY/UNSPLASH

India lost around 259 billion hours of labour annually due to humidity and heatwaves, between 2001 and 2020, costing the country ₹46 lakh crores

INDIA IS FACING multiple cumulative climate hazards co-occurring due to its size, urbanisation rate, and biophysical characteristics. Heatwaves fuelled by climate change have become a huge public health concern and it threatens to derail the country's economic growth.

Heatwaves are one of the extreme temperature events commonly referred to as "silent killers" as their impact is observed to increase later with time on public health, economy, environment, and infrastructure components.[1]

According to the World Health Organization (WHO), extended periods of high daytime and nighttime temperatures create cumulative physiological stress on the human body which exacerbates the top causes of death globally, including respiratory and cardiovascular diseases, diabetes mellitus and renal disease.[2]

In India, heatwaves typically occur from March to June, and in some rare cases, even extend till July (*see Box 1: Measuring Heat*). On an average, five to six heatwave events occur every year over the northern parts of the country. Single events can last weeks, occur consecutively, and can impact a large population.[3]

The severity and frequency of heatwaves have seen a significant increase in the past few decades in India. Between 1992 and 2015, the number of heatwave events in India increased 2.5 times with severe heatwaves becoming an annual phenomenon.[4] Studies by public health experts estimates up to 1,116 people died annually between 2008 and 2019 due to heat.[5]

Another 2021 study revealed that heat-related deaths have significantly increased over time in India. In 2001-2005, there were 3,014 heat-related fatalities among men and 849 among women. By 2011-2015, these figures had risen to 5,157 for men and 1,254 for women. This study, published in *Journal of Thermal Biology*, also found that the number of deaths due to extreme heat surpassed those caused by other natural disasters like avalanches, earthquakes, and floods, highlighting the growing threat of heatwaves to public health.[6]

Long-term projections indicate that Indian heatwaves could cross the survivability limit for a healthy human resting in the shade by 2050. Moreover, they will impact the labour productivity, economic growth, and quality of life of around 310-480 million people. Estimates show a 15% decrease in outdoor working capacity (i.e., working outdoors in high temperatures, such as construction workers and wastepickers) during daylight hours due to extreme heat by 2050.[7]

Furthermore, a research article published in *PLOS Climate* Journal mentions that heatwaves are projected to intensify from these 2050 baseline estimates and affect around 600 million Indians by 2100. The increased heat is expected to cost India 2.8%, and 8.7% of its Gross Domestic Product (GDP) and depressed living standards by 2050 and 2100, respectively.[8]

BOX 1: MEASURING HEAT

THE INDIA Meteorological Department (IMD), established in 1875, is the official weather forecasting agency of the country.

In 2023, the IMD launched a heat index, recognising the impact of humidity on heat and elevated temperatures (wet bulb phenomenon). The colour coded index records the following temperature from safe (green) to extreme heat (red).[9]

FIGURE 1 : HEAT ALERT AS ISSUED BY IMD

COLOUR CODE	ALERT	WARNING	IMPACT	SUGGESTED ACTIONS
Green (No action)	Normal Day	Maximum temperatures are near normal	Comfortable temperature. No cautionary action required	Normal activity
Yellow Alert (Be updated)	Heat Alert	Heat Alert conditions at isolated pockets persists for 2 days	Moderate temperature. Heat is tolerable for general public but moderate health concern for vulnerable people e.g. infants, elderly, people with chronic diseases	(a) Avoid heat exposure. (b) Wear lightweight, light-coloured, loose, cotton clothes. (c) Cover your head
Orange Alert (Be prepared)	Severe Heat Alert for the day	(i) Severe heat wave conditions persists for 2 days (ii) Through not severe, but heat wave persists for 4 days or more	High temperature. Increased likelihood of heat illness symptoms in people who are either exposed to sun for a prolonged period or doing heavy work. High health concern for vulnerable people e.g. infants, elderly, people with chronic diseases.	(a) Avoid heat exposure- keep cool. Avoid dehydration (b) Wear lightweight, light-coloured, loose, cotton clothes (c) Cover your head (d) Drink sufficient water- even if not thirsty (e) Use ORS, homemade drinks like lassi, torani (rice water), lemon water, buttermilk, etc. to keep yourself hydrated (f) Avoid alcohol, tea, coffice and carbonated soft drinks, which dehydrates the body (g) Take bath in cold water frequently. In case of SUNSTROKE: Lay the person in a cool place, under a shade. Wipe her him with a wet cloth/wash the body frequently. Pour normal temperature water on the head. The main thing is to bring down the body temperature. Consult a Doctor immediately.
Red Alert (Take Action)	Extreme Heat Alert for the day	(i) Severe heat wave persists for more than 2 days. (ii) Total number of heat/severe heat wave days exceeding 6 days	Very high likelihood of developing heat illness and heat stroke in all ages.	Along with suggested action for Orange Alert, Extreme care needed for vulnerable people.

1.1 IMPACT ON URBAN POOR

Heatwaves adversely affect the regional economy, human mortality, and the surrounding ecosystem. But the experience of heat varies from person to person, depending on the place of living.[10]

Particularly impacted are cities which become urban heat islands, where dense population, and construction materials like concrete and asphalt trap and amplify the heat.[11] The lack of green spaces adds to this. As a result, urban areas experience prolonged periods of extreme heat with some cities crossing over 49 degree celsius (°C) in the summer months.

The urban poor are especially at risk from both the direct and indirect health impacts of climate change due to several contributing factors. Their livelihoods are often unstable, housing conditions are substandard, and they lack adequate resources to mitigate climate effects or access healthcare.

As the global urban population is projected to increase dramatically — from 4.4 billion in 2020 to an estimated 6.3 billion by 2050, with nearly 82% of this growth occurring in less developed regions — the health risks posed by climate change are expected to be particularly severe for urban poor communities. This situation will exacerbate existing health issues and deepen social inequities, leading to entrenched health disparities in urban areas of developing nations.[12]

An estimated 60 million residents will reside in Indian cities by 2030.[13] The United Nations Human Settlements Programme UN- Habitat identifies urban poor as waste pickers and recyclers, construction workers, domestic workers, home-based small scale industry workers, daily wage labourers, migrant workers, street vendors and hawkers.[14]

These groups, lacking formal employment and social security benefits, are highly susceptible to socio-economic and environmental risks, including health hazards and exploitation. Their living conditions in informal settlements exacerbate their vulnerabilities to heatwaves, pollution, and other environmental issues.[15]

The urban poor face a combination of environmental and occupational risks. Unlike middle and high income communities, they are less protected from extreme heat in both their homes and workplaces. Many are daily wage workers employed in informal jobs that require long hours outdoors (*see Box 2: Heat and productivity losses in India*).

With limited financial resources, they are unable to afford cooling solutions like air conditioners and live in small and poorly ventilated spaces. As a result, extreme heat may force them to reduce their working hours or stop work altogether, leading to lost income. This deepens their economic hardship while also increasing their vulnerability to heat-related health problems caused by climate change.[16]

1.2 RISING HEAT AND URBAN POOR WOMEN

Women face structural, systemic barriers, which are now being exacerbated by heat. From earning less income to their lower labour force participation, women are financially and economically disadvantaged.

As a consequence, they are more vulnerable to economic losses when rising temperatures make it physically difficult—if not impossible—to work, notes a report, *The scorching divide: How extreme heat inflames gender inequalities in health and income*, by the Atlantic Council's Climate Resilience Center (formerly the Arsht-Rock Resilience Center).[21]

BOX 2: HEAT AND PRODUCTIVITY LOSSES IN INDIA

THE INTERNATIONAL Labour Organization (ILO) estimates 2.41 billion workers, comprising 71% of the world's working population, are exposed to excessive heat due to climate change. This translates to a death toll of 18,970 deaths and 22.85 million injuries annually.[17]

Heat stress is emerging as a lethal killer. Acute health issues like heat exhaustion, heatstroke, and in extreme cases, fatalities are associated with it. Long term exposure to high temperatures can result in chronic health problems affecting the cardiovascular, respiratory, and kidney systems. Workplace injuries, risks of accidents as well as mental health distress are also impacts to be considered.[18]

Between 2001 and 2020, India lost around 259 billion hours of labour annually due to humidity and heatwaves, costing India Rs 46 lakh crores in total, notes a Discussion Paper by SPRF India, an intersectional think tank bridging public policy and academic research.[19]

The ILO estimates that India will lose around 5.8% of its total labour hours in 2030 due to heat and humidity. The loss of labour hours due to heat stress has severe implications for India since approximately 90% of the labour force is engaged in the informal sector, and most of this labour is employed in physically demanding occupations.[20]

This makes the Indian economy highly vulnerable to the effects of heatwaves.

As temperatures rise, the heat-related challenges women in India face, particularly in terms of labour productivity and health, are expected to intensify (*see Box 3: Heat and mental health*). With some cities experiencing extreme temperatures as high as 48°C, the ability to work outdoors is significantly reduced, impacting economic development and reducing overall working hours. This further compounds the existing inequalities, as women already shoulder a disproportionate burden in terms of labour and care responsibilities (*see Box 4: Impacts of heat on pregnant women*).

Women in India currently lose 19% of their paid working hours due to heat, resulting in an annual economic loss of 0.8% of the country's GDP, or approximately $67 billion. By 2050, it is projected that this loss will increase to 22% of their paid working hours, costing the Indian economy 1% of its GDP, equivalent to INR 20.75 lakh crore (USD 250 billion) each year, warns the Arsht-Rock report.[22]

According to the World Bank, India's female labour force participation rate is just 24%. This is amongst the lowest for developing economies and nearly half that of men's participation rates. The UN Women further estimates that when women are employed, they typically earn 35% less than men for similar work, reflecting a significant gender pay gap.[23]

Systemic gender inequalities in terms of low workforce participation, gender pay gap, low wages for equal work, etc further entrench the undervaluation of women's work. This restricts their economic advancement as well as makes them vulnerable to climate-related risks that threaten the economy.

Gendered socio-economic disparities mean women have fewer resources to recover from climate-induced losses, increasing their risk of chronic poverty and poor health outcomes.[24]

BOX 3: HEAT AND MENTAL HEALTH

ACCORDING TO the *National Health Action Plan on Climate Change and Mental Health*, prepared by the Ministry of Health and Family Welfare, heat stress directly caused by heat-waves has been associated with mood disorders, anxiety, and related consequences. Extreme heat events and humidity have increased hospital admissions for mood and behavioural disorders, including schizophrenia, mania, and neurotic disorders.[25]

Heat-related mental health morbidity tends to occur most often in people with pre-existing mental health illnesses and problems, people taking psychotropics like lithium, neuroleptics and anticholinergic drugs and those with substance abuse problems. People with mental illness were three times more likely to risk death from a heatwave than those without mental illness, notes the National Health Action Plan.

BOX 4: IMPACTS OF HEAT ON PREGNANT WOMEN

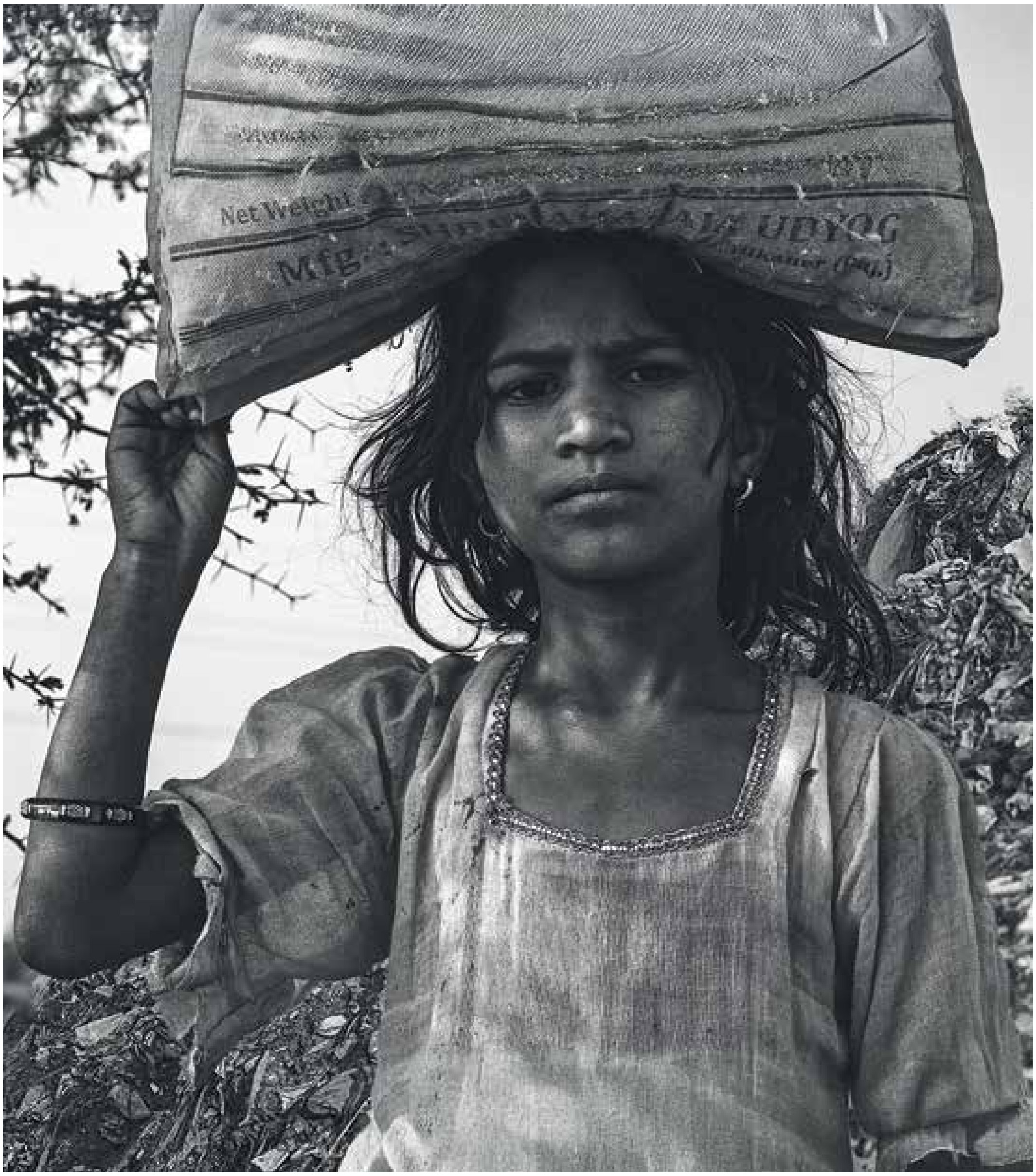
PREGNANT WOMEN are particularly heat vulnerable. A recent study involving 800 pregnant women in India revealed that nearly half (47%) experienced high heat exposure during work. This exposure was linked to an increase in their core body temperature and signs of moderate dehydration, highlighting potential health risks for both the mother and the developing baby.

Pregnant women working under heat stress conditions were found to have at least double the risk of experiencing miscarriages, pregnancy complications, and negative birth outcomes for the baby compared to those not exposed to such conditions. These findings underscore the severe impact of excessive heat on maternal and fetal health.[26]

Importantly, extreme heat also poses health risks for a pregnant woman and her developing foetus. There is increasing evidence that extreme heat can increase the risk for preterm birth, low birth weight, fetal death, and infant mortality.[27]

Heat in Pregnancy—India (HiP-India) is a multi-disciplinary project designed to understand how extreme heat leads to adverse pregnancy outcomes. Its team consists of experts across institutions in the UK and India, who will use state-of-the-art climate, imaging, and laboratory diagnostics to assess how heat exposure affects maternal, placental, fetal and lactation function.[28]

2 GENDER TRANSFORMATIVE APPROACHES TO HEAT MANAGEMENT



DEVANSHU VERMA/UNSPLASH

Gender plays an important role in determining heat exposure and urban poor women face the double brunt of marginalisation and gender-based discrimination.

GENDER TRANSFORMATIVE APPROACHES seek to challenge gender inequality by transforming harmful gender norms, roles and relations, while working towards redistributing power, resources, and services more equally.[1]

Chintan Environmental Research and Action Group (Chintan) identifies gender transformative approaches as a key accelerator to achieving sustainability. Hence, when it started work on heat resilience and thermal comfort in 2020, it had a clear vision — heat is an intersectional issue and it disproportionately impacts some groups over others, like poor communities or women. Heat management, thus, needs intersectional heat-plans, and urban poor women have a major role to play in it.

An intersectional approach to heat resilience and climate adaptation acknowledges that climate events affect different sectors of society in distinct ways, especially for marginalised communities with multiple layers of disadvantage.[2]

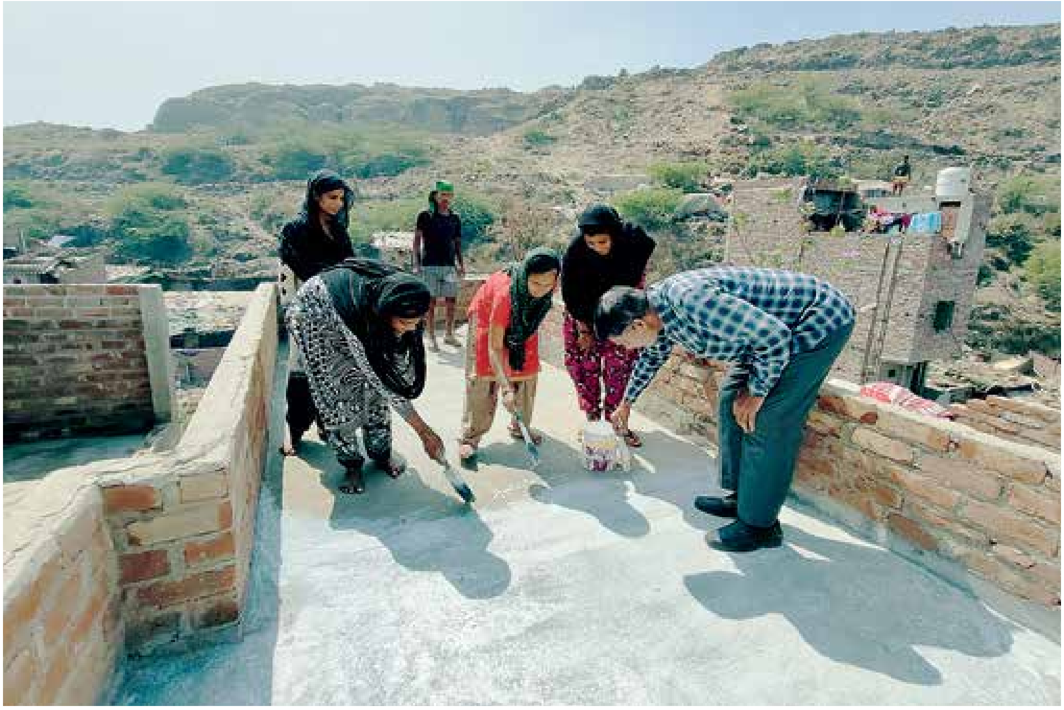
Urban and rural poor are often disproportionately exposed to overheating due to low quality housing and lack of access to cooling, notes the WHO.[3] Due to building materials, informal settlements are often hotter than other urban areas in some cities. Gender can play an important role in determining heat exposure, for example where women are primarily responsible for cooking indoors during hot weather.

People with low socioeconomic resources, such as waste-picking communities, often living in poorly insulated, densely populated urban areas, are particularly vulnerable during extreme heat events. They work outdoors and walk several kilometres a day collecting waste, and are less likely to have access to cooling systems or private transportation.

2.1 GENDERED APPROACH TO HEAT RESILIENCE BY CHINTAN

Women wastepickers are additionally vulnerable as they face the double brunt of marginalisation and lack access to multiple resources due to their socio-economic status, but also experience gender-based discrimination. Hence, long-term heat resilience building for communities requires focused interventions and leadership development with women. This includes building their knowledge and capacity on a variety of inter-connected issues from climate change and heat to health to climate justice.

Thus, in its work to build heat resilience amongst urban poor communities in Delhi-National Capital Region (NCR), Chintan, and its technical partners SEEDS Technical Services Pvt Ltd (STS Global) and cBalance Solutions Pvt Ltd, centered the participation and buy-in of women. The project, which started in June 2022 and ended in December 2024, had a participation of 1,000 urban poor women.



Long-term heat resilience building for communities requires focused interventions and leadership development with women.

To build the capacity of women and nudge behaviour change for heat resilience, Chintan and its partners organised a series of knowledge-based trainings on climate change and heat to raise awareness about these issues among the wastepicker women, many of whom had never been to a school and have received no formal education.

These women wastepickers were trained to map heat hotspots along with the team. A group of women was also trained to set up a community-level automatic weather station (AWS) with support of youth from the community. These urban poor women not only issued heatwave alerts but also actively participated in interventions for building heat resilient housing.

Apart from training to raise awareness on rising heat and heat resilience, skill-based training on leadership, advocacy, and communications for women were also organised to operationalise the knowledge.

Thus, through this unique project of Chintan on heat resilient housing for urban poor, women were not only trained on heat resilience, they also became key leaders in their communities, acquiring both technical knowledge and advocacy skills. Leadership training empowered them to demand better public services, such as water and cooling stations, while also sharing information on heat stress prevention, making it an issue within the community

This gender transformative approach adopted by Chintan has amplified women's roles as community advocates and champions of climate resilience.

2.2 HEAT RESILIENT HOUSING & INTERVENTIONS ON THE GROUND BY CHINTAN

As part of its interventions on heat resilient housing for urban poor in Delhi-NCR, Chintan and its technical partners implemented the project in three broad phases (details in following chapters) with active participation of trained wastepicker women. These phases include:

I. RISK ASSESSMENT: The initial step involved conducting heat-vulnerability assessments using GIS-based heat mapping and surveys in Delhi-NCR. These assessments helped identify high-risk areas, particularly informal settlements, and allowed targeted interventions where they were most needed (See Chapter 3).

II. COMMUNITY ENGAGEMENT AND WEATHER MONITORING: Chintan and STS Global established a community-based weather monitoring system using Automatic Weather System (AWS) in one informal settlement in Delhi. Women from the community were trained to operate the AWS, monitor and share real-time data with the community through WhatsApp and personal communication. Youth from the community helped the women, as they were educated and comfortable with handling new technology. In the process, women felt empowered and became central to disseminating heat warnings and ensuring the community's preparedness (See Chapter 4)

III. STRUCTURAL INTERVENTIONS AND OWNERSHIP BUILDING AMONGST COMMUNITIES: The structural interventions focused on heat-resilient roofing systems in informal settlements, with community members, particularly women, involved from the planning and installation phases. Using locally available recycled materials, such as jute, cardboards, etc, promoted sustainability. Meanwhile, women's participation fostered community ownership of the interventions (See Chapter 5).

The following chapters in the report expand on each of these three components of the project implemented in select informal settlements in Delhi NCR.

3 RISK ASSESSMENT AND HEAT MAPPING

AHMED FAHMI/UNSPLASH

The negative health impacts of heat are predictable and largely preventable with specific public health and multi-sectoral policies and interventions.

HEAT IS AN important environmental and occupational health hazard. According to the WHO, heat stress is the leading cause of weather-related deaths and can exacerbate underlying illnesses including cardiovascular disease, diabetes, mental health, asthma, and can increase the risk of accidents and transmission of some infectious diseases. Heatstroke is a medical emergency with a high-case fatality rate.[1]

Vulnerability to heat is shaped by both physiological factors, such as age and health status, and exposure factors such as occupation and socio-economic conditions.[2]

The negative health impacts of heat are predictable and largely preventable with specific public health and multi-sectoral policies and interventions, says WHO. Action on climate change combined with comprehensive preparedness and risk management can save lives now and in the future.

3.1 IDENTIFYING HEAT HOTSPOTS

The first step in the process of heat preparedness is to conduct a heat-risk or heat-vulnerability assessment to scientifically identify the areas requiring heat resilience interventions.

As part of this project, Chintan and STS Global undertook a GIS-based vulnerability assessment exercise to identify heat hotspots in Delhi-NCR. A GIS (geographic information system) is a mapping technology for capturing, storing, checking, and displaying data related to positions on Earth's surface.

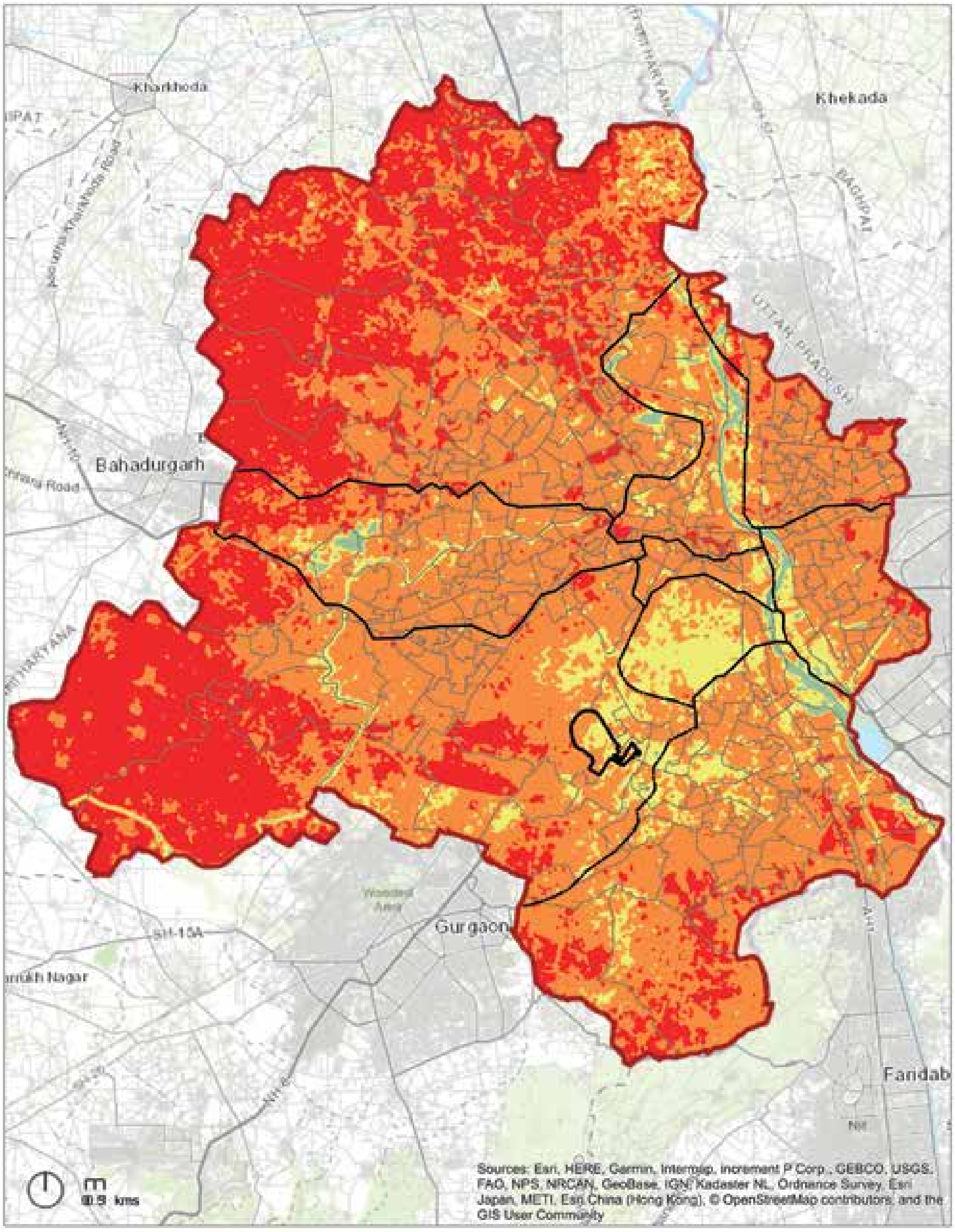
Heat mapping, from a GIS perspective, is a method of showing the geographic clustering of a phenomenon (in this case, land surface temperatures).[3] Sometimes it is also referred to as hotspot mapping.

A heat map shows locations of higher densities of geographic entities which can then help undertake focused and hyperlocal intervention in high heat areas. The higher the heat density in the area, the more it would require interventions for cooling and thermal comfort.

Figure 2 (Heat map of Delhi) depicts heat hotspots in Delhi based on average maximum land-surface temperatures recorded in the month of May, from 2013 to 2021. Most of Delhi is coded orange (43°C—47°C) indicating the severity of heat in the city. Deep red depicts land surface temperatures above 47°C, thus making them extreme heat hotspots in the city.

The heat map of Delhi shows that heat hotspots are located primarily in north and north west Delhi, which includes the Bhalswa landfill as well as several pockets of informal settlements in the national capital.

FIGURE 2: HEAT MAP OF DELHI



Vasant Vihar Ward
NCT Boundary
Districts Boundary
Ward Boundary

May LST (2013-21)

33.1-39 | 43.1- 47 | <33 | 39.1-43 | >47

Source: SEEDS India and Landsat 8

Note: Based on maximum land surface temperature for the month of May, from 2013 to 2021.

Based on GIS mapping and Chintan's area of operation, five informal settlements were identified for the present study on heat resilient housing for urban poor (*see Figure 3: Areas of heat resilience intervention by Chintan in informal settlements in Delhi*). These settlements are inhabited primarily by wastepickers, a traditionally marginalised and disadvantaged community of urban poor, informal, outdoor workers.

THE FIVE INFORMAL SETTLEMENTS INCLUDE:

(1) Bhalswa landfill (North West Delhi)
(2) Nizamuddin Basti (South East Delhi)
(3) Vivekananda Camp in Chanakyapuri (New Delhi)
(4) Hanuman Mazdoor Camp in RK Puram (South West Delhi)
(5) Sihani in Ghaziabad (Delhi NCR)

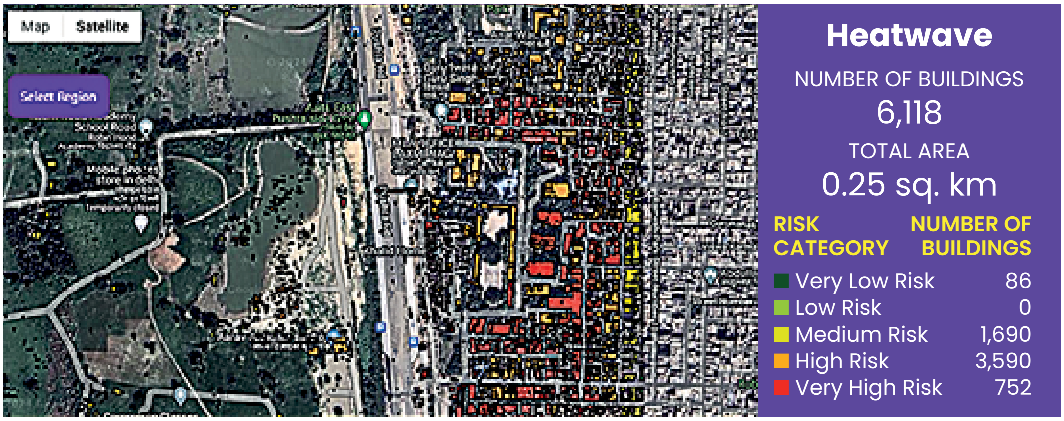
3.2 FIELD SURVEYS, WALK-THROUGHS & TRANSECT WALKS

Once the five urban poor settlements for intervention were identified, a further understanding of the vulnerability of the settlements was undertaken.

The first step was to evaluate knowledge, action and perception of the inhabitants regarding heat, climate change, and climate action to respond to and reduce their impacts. This exercise also helped in assessing openness to interventions and a participatory approach to building heat resilience.

FIGURE 3: AREAS OF HEAT RESILIENCE INTERVENTION BY CHINTAN IN INFORMAL SETTLEMENTS IN DELHI

FIGURE 4: EXAMPLE OF AI-BASED MAPPING OF HEAT RISK IN AN INFORMAL SETTLEMENT IN DELHI



A team of Chintan and STS Global surveyed 484 people living in identified wastepicker settlements. The aim of this survey was to not only gauge knowledge, experience, perception, and action, but also gain insights on the kinds of interventions communities would find most useful and would want to collaborate on.

Some of the key findings of the survey are as following:

- 100% of the respondents reported facing health impacts due to heatwaves.
- While 45% of the respondents reported fainting and nausea when exposed to heat, 32% reported a constant sense of fatigue and weakness.
- 27% of people reported breathlessness and asthma which intensified during the peak summer months.
- 77% of respondents welcomed an early warning system for heatwaves, with 99% of them wanting to be informed through public announcements in the community.

Along with a survey, walk-throughs and transect walks were also conducted to understand which buildings and areas in the informal settlements were most at risk. A transect walk is a group exercise that entails walking between two points to intentionally cross or transect a community. The group explores environmental and social resources, conditions and systems by observing, asking, listening, looking and producing a transect diagram.[4]

3.3 AI-BASED MAPPING OF HEAT RISK

Thereafter, STS Global used an artificial intelligence (AI)-based model, SunnyLives, for heat risk information for people living in the intervention informal settlements (*see Box 5: SunnyLives*). The AI model gives a risk map for a particular area. A key focus is assessing home vulnerability based on roof types.[5]

SunnyLives leverages AI's power to provide hyper-local disaster risk insights. It analyses high-resolution satellite imagery, employs advanced data analytics, and machine

BOX 5: SUNNYLIVES[6]

ONE OF the most pioneering features of SunnyLives is its capacity to offer near real-time warning advisories. The moment the trajectory of an impending disaster is predicted, the model springs into action. It rapidly processes data, generating risk scores for individual houses within affected areas in a matter of hours. This enables disaster response teams to prioritize their efforts and provide timely warnings to communities at risk.

SunnyLives is not limited to data analysis alone; it empowers vulnerable communities by delivering actionable information. Advisories are disseminated in local languages, ensuring that residents comprehend the risks they face and are equipped with the knowledge needed to protect themselves. These advisories offer comprehensive guidance on securing homes, seeking shelter, and taking necessary precautions in the lead-up to an impending disaster.

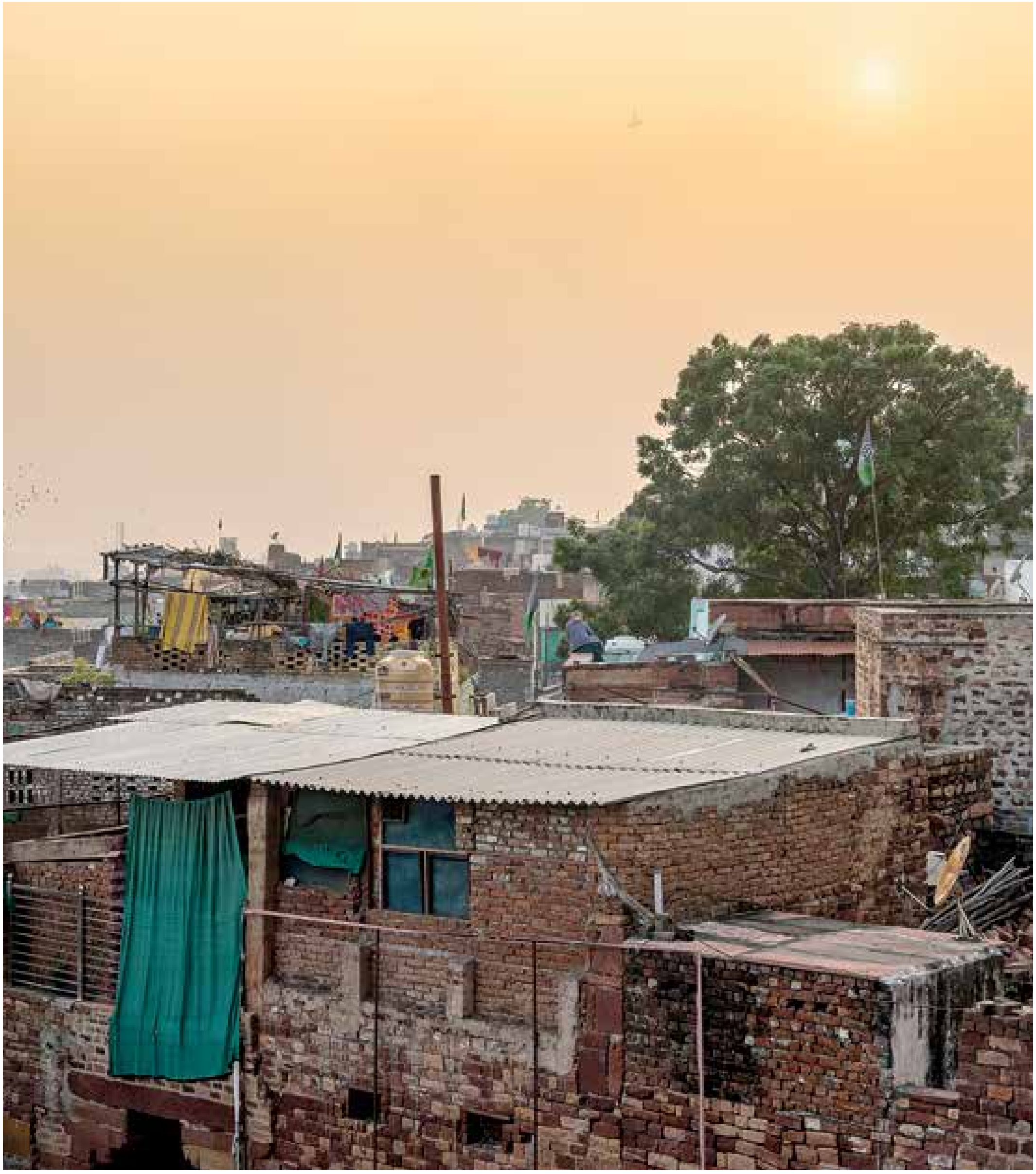
A core focus of this innovative model has been the identification of vulnerable homes based on their roof types. Roofs serve as a proxy for evaluating a building's vulnerability.

learning to identify disaster-prone areas. On the risk map, each building is colour-coded according to its 'risk score' (*see Figure 4: Example of AI based mapping of heat risk in an informal settlement in Delhi*).

Built-up density, vegetation, proximity of the house to a water body, roof-type classification — these are some of the key parameters that comprise the matrix that were used to calculate the risk score of settlements using SunnyLives. The rooftop material, with its attendant heat-absorbing capacity, is a crucial data point; buildings/houses are identified, classified, and mapped based on this capacity.

Using all these methods, a data-based and actionable understanding of heat risk faced by the selected informal settlements in a city were mapped.

4 AUTOMATIC WEATHER STATION & COMMUNITY-BASED HEAT MONITORING



Hyper-local mapping and community-based monitoring of heat is important for preparedness and resilient action because informal settlements are way hotter than the formal settlements in cities.

COMMUNITY-BASED WEATHER monitoring is critical to building local resilience, especially in informal settlements that often experience extreme micro-climates, and may not have access to any information about extreme weather events.

Given the density of the dwellings and other low-rise infrastructure, lack of ventilation, overcrowding, and buildings made of heat absorbing materials, informal settlements often become a heat island within the city.

Studies have found that informal settlements experience higher temperatures than the formal settlements in major cities in India. For instance, a WRI India analysis found temperatures in one of Mumbai's informal settlement averaged 6°C (11°F) warmer than neighbouring areas.[1] Also, 37% of Mumbai's households with metal roof structures are exposed to a risk of a high rise in temperatures or heat risk post-monsoon.[2]

Given the additional risk of heat stress faced by the inhabitants, hyper-local monitoring is important for preparedness and resilient action. This also came during the survey conducted by Chintan and STS Global (*see Box 6: Demand for community-based weather monitoring*).

Hence, after conducting GIS-based vulnerability assessment and heat mapping of hotspots in Delhi NCR, the next step was setting up an automatic weather station (AWS) for community-based weather monitoring.

An AWS was installed in an identified wastepicker settlement in Delhi. Only one such installation was done to test the idea and see if women would participate in it, given their low literacy levels. The women were a part of the entire exercise, right from installation of the AWS to monitoring real time data and issuing advisories to the community.

4.1 AWS: FOCUS ON HEAT INDEX AND WET BULB TEMPERATURE

An AWS is a device or network of devices that collects and records meteorological data automatically and without human intervention. These systems are designed to measure various weather parameters and environmental conditions, providing real-time and continuous weather information.

The AWS monitors air temperature, air humidity, wind direction (monitored by the wind vane), wind speed, air pressure, rainfall (monitored using rain collector as on the device), and can operate fully automatically and normally in unattended harsh environments all day long.

BOX 6: DEMAND FOR COMMUNITY-BASED WEATHER MONITORING

IN THE CHINTAN-STS Global survey with 484 wastepickers living in informal settlements identified for interventions, 70% of them highlighted the need for community-based weather monitoring and an early warning system. Some of the reasons provided by the respondents include:

TIMELY INFORMATION COULD HELP THEM PREPARE FOR THE DAY ACCORDINGLY: Wastepickers reported that if they received timely information about heatwaves, they would plan their day and route for waste-picking accordingly. For instance, they would work in the non-peak heat hours, or they would plan their journey such that they could rest in shaded locations, or be near drinking water facilities through the day. They would also carry caps/dupattas and water bottles to protect themselves from the heat.

BUILDING ACCESS FOR COOLING STATIONS, WATER, AND OTHER HEAT STRESS MANAGEMENT FACILITIES: If pre-warned about heatwaves, wastepickers reported that they would carry out efforts to procure or inform and push their local authorities to provide adequate water and cooling facilities. Also, early warning helps them prepare better to face the challenges due to rising heat.

The AWS identified by Chintan-STS Global did not focus merely on reporting dry temperatures. Its focus was to highlight humidity and provide early warnings based on the wet-bulb temperature (WBT), which takes into account multiple atmospheric variables, including temperature, humidity, wind speed, sun angle, and cloud cover.[3] Wet-bulb temperature and heat index is increasingly being used to measure heat and its impact on human health globally. The AWS also captured wind-speed, which determines how fast heat dissipates.

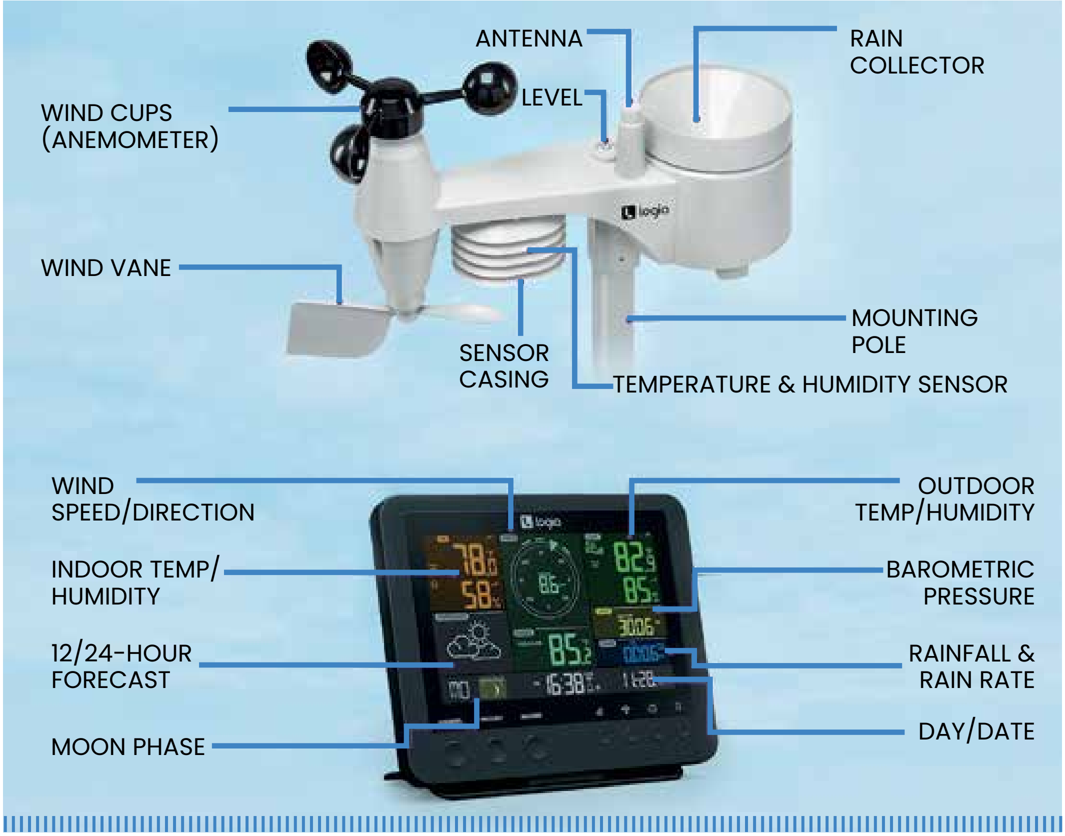
Wet-bulb temperature combines dry air temperature (as seen on a thermometer) with humidity. The term comes from how it is measured. If you slide a wet cloth over the bulb of a thermometer, the evaporating water from the cloth will cool the thermometer down. This lower temperature is the WBT, which cannot go above the dry temperature.

If humidity in the surrounding air is high, however – meaning the air is already more saturated with water – less evaporation will occur, so the WBT will be closer to the dry temperature. The real purpose of monitoring WBT is to measure how well people will be able to cool themselves by sweating.[4]

For community-based weather monitoring, heat index should be the focus. Heat index is what the temperature feels like to the human body when relative humidity is combined with the air temperature (*see Figure 6: Heat Index (Temperature X Humidity)*).[5]

Further, since the AWS does not require manual inputs or data feeding, it is a useful tool in informal settlements where literacy levels may usually be low. However, for this automated system to function well, a location with good network connectivity is required apart from internet/Wi-Fi to run this.

FIGURE 5: IMAGES OF AN AUTOMATIC WEATHER STATION



4.2 STEPS TO INSTALL AWS

The following steps were followed while setting up an AWS in an informal settlement:

- Assessment of the site to identify a suitable location for setting up AWS. This should include:
  - An area with good network and power connectivity
  - Central location in the community for quick communication of information
  - Buy-in and consent from the individual in whose house or property AWS is being set up in.
  - A location which has access to the outdoors to monitor humidity, wind speed and other parameters effectively.
- Installation of the AWS based on the manual guide available along with the packaging box.
- Installation of an internet card or Wi-Fi to ensure sync with live weather servers.
- Training community members for maintenance, recording, and reporting the weather.

FIGURE 6: HEAT INDEX (TEMPERATURExHUMIDITY)

Relative Humidity %	Air temperature °C										
	21	24	27	29	32	35	38	41	43	46	49
0	18	21	23	26	28	31	33	35	37	39	42
10	18	21	24	27	29	32	35	38	41	44	47
20	19	22	25	28	31	34	37	41	44	49	54
30	19	23	26	29	32	36	40	45	51	57	64
40	20	23	26	30	34	38	43	51	58	66	
50	21	24	27	31	36	42	49	57	66		
60	21	24	28	32	38	46	56	65			
70	21	25	29	34	41	51	62				
80	22	26	30	36	45	58					
90	22	26	31	39	50						
100	22	27	33	42							

Serious risk to health - heatstroke imminent
Prolonged exposure and activity could lead to heatstroke
Prolonged exposure and activity may lead to fatigue

4.3 ROLE OF WASTEPICKER WOMEN

Chintan recognised the importance of centering women, the primary caregivers and also frontline impacted due to heatwaves (*see Box 7: Community women breaking barriers*). Hence, it focused on training women wastepickers around installation of AWS and monitoring data. This process was alongside the community weather monitoring exercise and the roof interventions (see Chapter 5) to simultaneously build local capacity and seed heat resilient behaviour in the community.

The training was divided into two parts — knowledge-based and skill-based.

I. KNOWLEDGE-BASED: A comprehensive training was developed in partnership with STS Global. The focus was on the causes and health impacts of heatwaves with a practicable understanding of vulnerability, heat stress and heat-related illnesses. Practical knowledge on responding to heat stress and related illnesses were provided so people could diagnose symptoms and act based on science.

II. SKILL-BASED: In order to help women operationalise the knowledge with their families and communities and amplify the messages, identified women leaders across the selected settlements were trained on leadership, public communication, and mobile journalism. The women were also trained in local advocacy and relationship building with local elected representatives to ask for basic amenities like water or cooling stations within their communities.

BOX 7: COMMUNITY WOMEN BREAKING BARRIERS

SHALINI IS a wastepicker. She lives in an informal settlement in Central Delhi. Her house is centrally located in the community with about 250 families. Shalini's house is where the AWS was installed.

Prior to the installation, Shalini's buy-in was sought along with other community members for setting up the AWS. They were informed about the purpose of setting up an AWS and its benefits. Once Shalini provided her informed consent, and understood her family's role as information-bearers, as well as responsibility to maintain the AWS, the installation was undertaken.

Shalini is not literate, so she willingly partnered with her son to read the AWS updates regularly and help disseminate it to the community members. Shalini and her family were provided extensive training to read parameters on AWS and also maintain it. Chintan and STS Global teams remained regularly in touch with Shalini to handhold her through the entire process until she gained confidence to do it on her own along with her son.

Apart from Shalini and her family, women and their school-going children in the community were also trained to read the weather parameters and relay the information to their circles and neighbours. The women were also connected on a WhatsApp group with each other for quick and easy information relay. A network of women passing on information amplified the efforts and ensured wider reach in the community.

FIGURE 7: Women reading the heat index to learn community-based weather monitoring

Based on the heat index, the women were provided a colour coded heat stress chart (as issued by India Meteorological Department, India's official weather agency) in their local language (Hindi) with dos and don'ts. The women were trained to change the colour-code based on the reading (green for safe, orange for severe, red for extreme) in three different locations.

The benefits from AWS have gone to all people in the community though it is a women-led effort, says Shalini. "My son helps me put the temperature and humidity level on our WhatsApp group and then based on the heat stress chart, we relay information to the whole community. I have also been raising a lot of awareness about heat stress and related illness in my community," she says confidently.

5 STRUCTURAL INTERVENTIONS FOR THERMAL COMFORT BY CHINTAN & ITS PARTNERS

Housing for urban poor is often temporary and does not meet quality standards of housing. Solutions for thermal comfort have to take into account this factor

OUR WORLD IS increasingly becoming urbanised as an estimated 1.4 million move into urban areas every week. Cities utilise 78% of the world's energy and are responsible for the production of more than 60% of greenhouse gas emissions. Urban areas account for 2% of the earth's surface, but they are home to more than 50% of its total population.[1] This is expected to reach 70% by 2050.[2]

Urban population is not spread equitably in cities. A large chunk of the global urban population lives in informal settlements with poor housing and lack of basic infrastructure. According to the United Nations Statistics Division, approximately 1.1 billion people currently live in slums or slum-like conditions in cities, with 2 billion more expected in the next 30 years.

According to the 17 goals under the 2030 Sustainable Agenda adopted by the UN Member States, Goal 11 focuses on 'Making cities and human settlements inclusive, safe, resilient and sustainable.'[3]

In poor settlements and slums resulting from India's rapid urban expansion, houses are densely clustered and have mostly tin sheets, asbestos or thin concrete roofs without sufficient ventilation. This makes it extremely hot inside in warm months, especially in regions like Delhi NCR where heatwaves are common during the summer months, and are also registering an increase.

The women of these areas face the brunt the most as they not only have to deal with heatwave but also have to make arrangements for services such as water.[6]

It is therefore important to build or make alterations to existing structures that are heat resilient. Interventions can vary from building cool roofs, increased green cover, or cool pavements. While making interventions in houses of urban poor, the following must be kept in mind:

- Solutions have to be cost effective. In urban poor contexts, solutions and installations cannot be expensive to implement and maintain. These have to be sustainable and easy to manage without incurring additional costs.
- While solutions must be technically sound, they must also be feasible and practical and developed with urban poor communities as collaborators. Their buy-in is mandatory.
- Urban poor housing is often temporary and not meeting quality standards of housing. Solutions have to take into account this factor.
- Materials commonly found like plastic, paper, jute and thermocol can be reused for frugal and cost effective innovation.

DELHI HEAT ACTION PLAN

ACCORDING TO Delhi Heat Action Plan 2024-25, prepared by the Delhi Disaster Management Authority, Delhi is one of the hottest cities in India and one of most vulnerable to impacts of heatwave due to its large population, high number of lower income groups.[4]

The Plan notes that heatwaves have increased in intensity, frequency and duration, along with the increased temperature and relative humidity. The number of heatwave days have also increased in Delhi. For instance, they have jumped by 35% from 90 days in 2018 to 174 days in 2019.[5]

Delhi Heat Action Plan 2024-25 has classified areas and populations that are more vulnerable to heatwaves. These include slums pockets & squatter settlements, and low income group areas. The plan notes that people living in these areas constantly suffer from heatwave due to the poor built up environment, limited access to basic services and housing materials that are good at absorbing and storing the sun's heat.

The night time outdoor microclimatic conditions along with poor housing structure and no access to services make it extremely difficult for people to cope with heatwave.

5.1 DEMONSTRATIONS OF HEAT RESILIENT HOUSING

Chintan worked with two technical and implementation partners — cBalance Solutions Pvt Ltd, and STS Global — and carried out four sets of intervejtons in five identified settlements.

The rationale and methodology included the following:

- Pilot demonstrations were conducted to check feasibility and efficacy of various cool roof installations prior to scaling up. It is important to test out the solution and if it works in the local or urban poor context of the informal settlement before a scale up.
- Local women were trained to understand the science and benefits of roof interventions to ensure buy in and participation to install and maintain these roofs.
- Data loggers were installed in three settings — houses with cool roof intervention, houses without cool roof intervention, and outdoors temperatures to measure the efficacy in terms of temperature reduction.
- Physical check-ins and interviews were conducted with women to receive feedback and take note of any challenges that they experienced.

5.1.A INTERVENTION SET 1

cBalance partnered with Chintan for installation of 5 different types of roofs based on participatory listening workshops to understand the community's needs and inspection of houses for the best suited installment.

These installments included — (i) Water filled PET bottles on the roof, (ii) Cement bonded wood-wool panel under the roof, (iii) Aluminized foil under the roof, (iv) Chain Sprocket mechanism with Ecoboard on the roof, and (v) Ecoboard Static-Retrofit in the existing roof.

Post installation feedback was collected using sensors. This set of five interventions was carried out at the selected settlement in Bhalswa landfill in North Delhi.

Data loggers for temperature mapping were installed in the house with roof installation, no cool roof installation (29°C), and the outdoor temperature (30°C) in the month of March 2023. A data logger is an electronic device that automatically records data over time or in relation to location, typically through built-in or connected sensors. In the context of a weather monitoring system, a data logger collects, stores, and processes information from various sensors (such as temperature, humidity, wind speed, etc.) at regular intervals. Table 1 shows the results of Intervention Set 1.

TABLE 1: INTERVENTION SET 1: RESULTS & FEEDBACK

S. NO.	ROOF TYPE	WORKING PRINCIPLE	FEATURES OF THE HOUSE	FEEDBACK
1	Water filled PET bottles (on the roof)- high thermal mass system	High specific heat capacity of water to create a thermal mass, helping to regulate temperature fluctuations inside the building.	Sturdy brick walls and stable roof which could bear weight on top	Temperature 3 °C lesser as compared to outdoors, and 2 °C lesser than a non-installation house. PET bottles got stolen for resale value and therefore isn't a sustainable solution.
2	Cement bonded wood-wool panel (under the roof)	Wood wool panels are made from wood shavings (or fibers) combined with cement as a binding material, creating a strong, durable, and insulating product.	Sturdy brick walls with stable roof and minimal leakage	Temperature 3-4 °C lesser as compared to outdoors, and 3 °C lesser than non-installation house.
3	Aluminized foil - Static (under the roof)	Material typically consists of foam covered with an aluminum foil coating, which has low emissivity and high reflectivity.	Temporary and weak roof	Temperature 2 °C lesser as compared to outdoors, and 1 °C lesser than non-installation house.
4	Chain Sprocket mechanism with Eco-board (on the roof) - Dynamic solution	Thermal insulation with both a radiant barrier and night sky radiation. This system works on the principle of adjustable louvers, which can be opened and closed based on the desired thermal conditions, controlled manually via a chain-sprocket system with a bicycle pedal.	Sturdy brick walls with stable roof and possibility of placing a parapet to let the chain sprocket mechanism work efficiently	Temperature 2 °C lesser as compared to outdoors, and 1 °C lesser than non-installation house. Chain sprocket needs constant greasing to work which may not be sustainable in the long run and incur additional costs.
5	Ecoboard Static - Retrofit in the existing roof	Practical retrofit solution for thermal insulation in existing buildings. Made from plastic and tetrapak, the layer reduces heat transfer to inside the house.	Hybrid housing type with permanent and temporary features	Temperature 3 °C lesser as compared to outdoors, and 2 °C lesser than non-installation house.

FIGURE 7: Insulation through water filled PET bottles

FIGURE 10: Eco-board static roof

FIGURE 8: Alufoil layering under roof

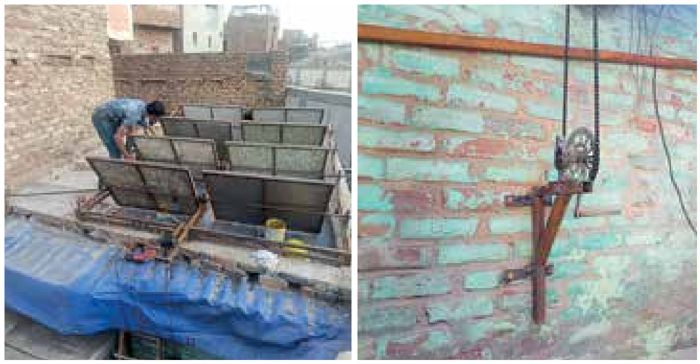


FIGURE 9: Chain-sprocket roof intervention

5.1.B INTERVENTION SET 2

STS Global demonstrated its cool roof interventions via three models in the identified wastepicker settlement in South Delhi. (*see Figure 11 on page 28: Prototypes of three roof installations by Chintan-STS pvt ltd*)

Data loggers for temperature mapping were installed in the house with roof installation, no cool roof installation (46°C) and the outdoor temperature (39°C) in the month of March 2023. The details of three models by STS Global are given in table 2.

While each of the three interventions proved to be effective, model 2 was most effective with a 13°C temperature difference between a cool roof and a no-cool roof house. However, the use of jute in informal settlements infested with pests caused these to destroy the roofs. Thus, this model won't work for pest infested areas or will have to be repeated every year.

Additionally, Chintan and STS Global also made an intervention in the 'common area' in informal settlement where women sit down together to do chores such as chop vegetables and other collective activities. The team used old textile waste to put up a cloth roof that allowed air to come in but created partial shade so that women avoid working in direct sun.

TABLE 2: INTERVENTION SET 2: RESULTS & FEEDBACK

S. NO.	ROOF TYPE	WORKING PRINCIPLE	FEATURES OF THE HOUSE	FEEDBACK
1	Layer each of Tarpaulin, Existing Tin, Insulation Sheet, Thermocol, Bamboo, Jute.	Model combines a waterproof tarpaulin with the existing tin roof, followed by an insulation sheet and thermocol for enhanced thermal insulation. Bamboo provides structural support, and jute at the bottom adds natural insulation and prevents condensation. The use of thermocol ensures high insulation by reducing heat transfer effectively.	Brick walls with tin roof	Temperature 5 °C lesser as compared to outdoors, and 12 °C lesser than a non-installation house.
2	Layer each of Tarpaulin, Existing Tin, Insulation Sheet, Cardboard, Bamboo, Jute	Model uses tarpaulin for waterproofing and retains the tin roof, but substitutes thermocol with cardboard for insulation (compared to Model 1), making it a more environmentally sustainable option. The insulation sheet, bamboo, and jute are used similarly to Model 1, providing insulation and structural support.	Brick walls with tin roof	Temperature 6 °C lesser as compared to outdoors, and 13 °C lesser than non-installation house. Use of jute caused a rat infestation in the roof as informal settlements often are pest infested.
3	Layer each of Tarpaulin, Cardboard, Bamboo, Existing Tin.	Model has fewer layers compared to the previous models. It uses a tarpaulin on top for waterproofing, followed by cardboard for insulation. Bamboo provides structural support underneath, while the existing tin roof remains as the base. This model focuses on providing basic insulation using cardboard as the primary thermal barrier.	Brick house with tin roof.	Temperature 2 °C lesser as compared to outdoors, and 9 °C lesser than non-installation house. Use of jute caused a rat infestation in the roof as urban poor settlements often are pest infested.

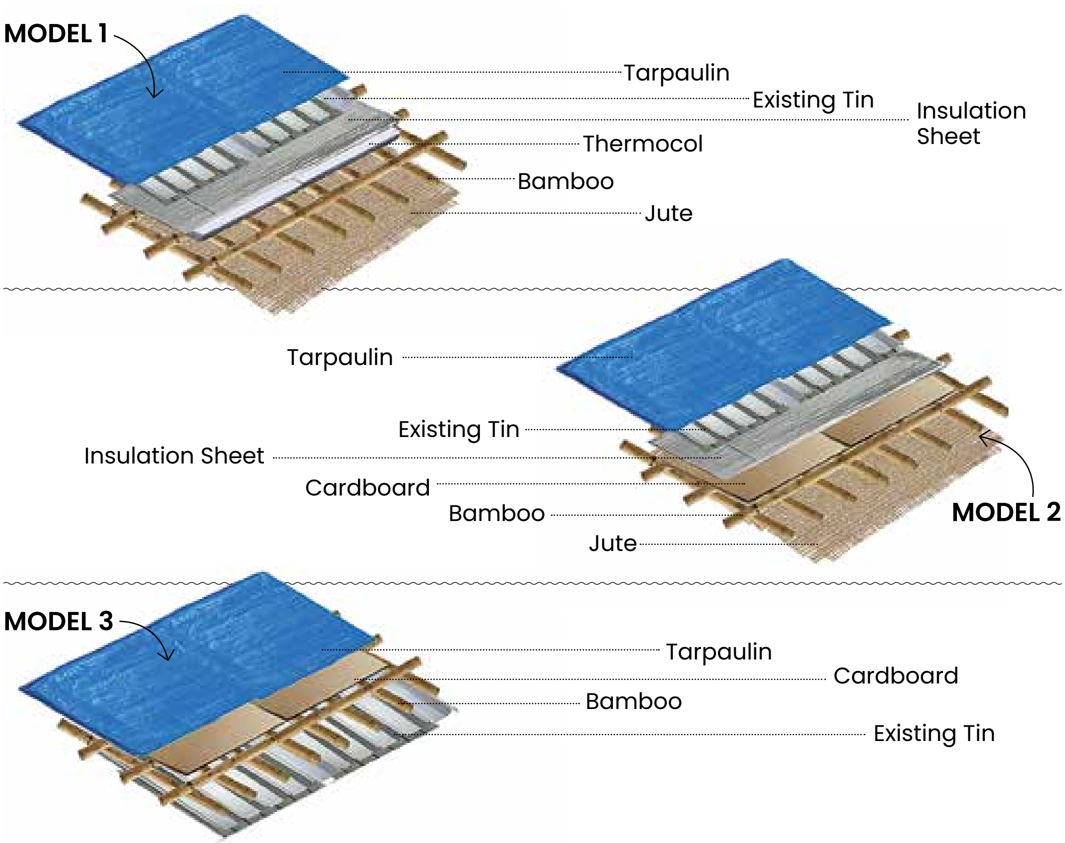
5.1.C INTERVENTION SET 3

Chintan also consulted with several other technical partners to pilot a cool roof initiative based on white reflective paints in 1,000 households in two of the intervention settlements in North Delhi and South Delhi.

The use of white reflective paint is one of the most tested and popular methods to reduce home temperatures via cool roofs. Studies report that applying cool roof paint, which reflects approximately 80-90% of sunlight, can significantly reduce indoor temperatures.[7]

Women from the community were involved in painting the roofs using SRI paints. SRI is termed as solar reflective index and is used to determine the heat reflecting capacity or power of a roof cooling paint.

FIGURE 11: PROTOTYPES OF THREE ROOF INSTALLATIONS BY CHINTAN-STS PVT LTD



The following results were noted as a result of the cool roof intervention based on data captured by data loggers:

- **STABLE TEMPERATURES IN HOUSES WITH COOL ROOF INTERVENTIONS:** The houses with white reflective paint cool roof interventions saw least amount of fluctuations in temperatures (up to 4°C fluctuations), while the temperature outside showed a 5+ °C fluctuation through the day, and houses without cool roof intervention had 6°C fluctuations.
- **LOWER TEMPERATURES IN HOUSES WITH COOL ROOF INTERVENTIONS:** Houses with cool roof interventions had the lowest maximum temperature (1.5°C lesser than non -intervention house temperature and 0.5 °C lesser than outdoor temperature).

CHALLENGES WITH PAINTED COOL ROOFS

In its latest assessment of the SRI paint cool roofs conducted in April 2025 in 200 households where this intervention was made, Chintan found that:

- Not even a single painted cool roof was in good condition, with 'good' defined as 'almost fully white, as initially applied'.

- 58.6% of cool roofs were in usable condition, with 'usable' defined as '65% intact, particularly at the centre'.
- 41.4% were destroyed, with 'destroyed' defined as 'less than 65% intact, centre damaged'.
- Slightly more than 10% cool roofs being used for storage purposes

Given the fact that not even a single coof roof is in 'good' condition, it highlights potential challenges in maintenance practices, exposure to harsh environmental conditions, or limitations of the intervention's durability. It is important to note that annual maintenance and sufficient budgetary provisions are essential to ensure the sustained effectiveness of the cool roof intervention, especially as a climate resilience measure against extreme heat.

The assessment also showed that slightly more than 10% of the cool roofs are currently being used for storage of items such as segregated waste life plastics, tires, tin boxes and various domestic goods like earthen pots, plants, etc. Thus, interventions have to be supplemented with awareness about the benefits of correct usage of roofs to encourage buy in and behaviour change.

Further, humidity reduces the reflective capacity and the lifespan of cool roofs, as the moisture in the air inhibits heat dissipation. This limits the roof's ability to lower indoor temperatures effectively, especially in regions with consistently high humidity levels. Thus, steps to address humidity like better ventilation are also required to complement reflective roofs.

5.1.D INTERVENTION SET 4

Another fabric-based intervention to reduce heat was undertaken between March 2024 and November 2024 by Chintan in 80 houses of two selected slums in Delhi. Among these, specifically, those houses were chosen which might not share common walls with the neighbours, or that were smaller in size, or were corner plots, or had enough space to plant poles to create a cloth-based roof cover.

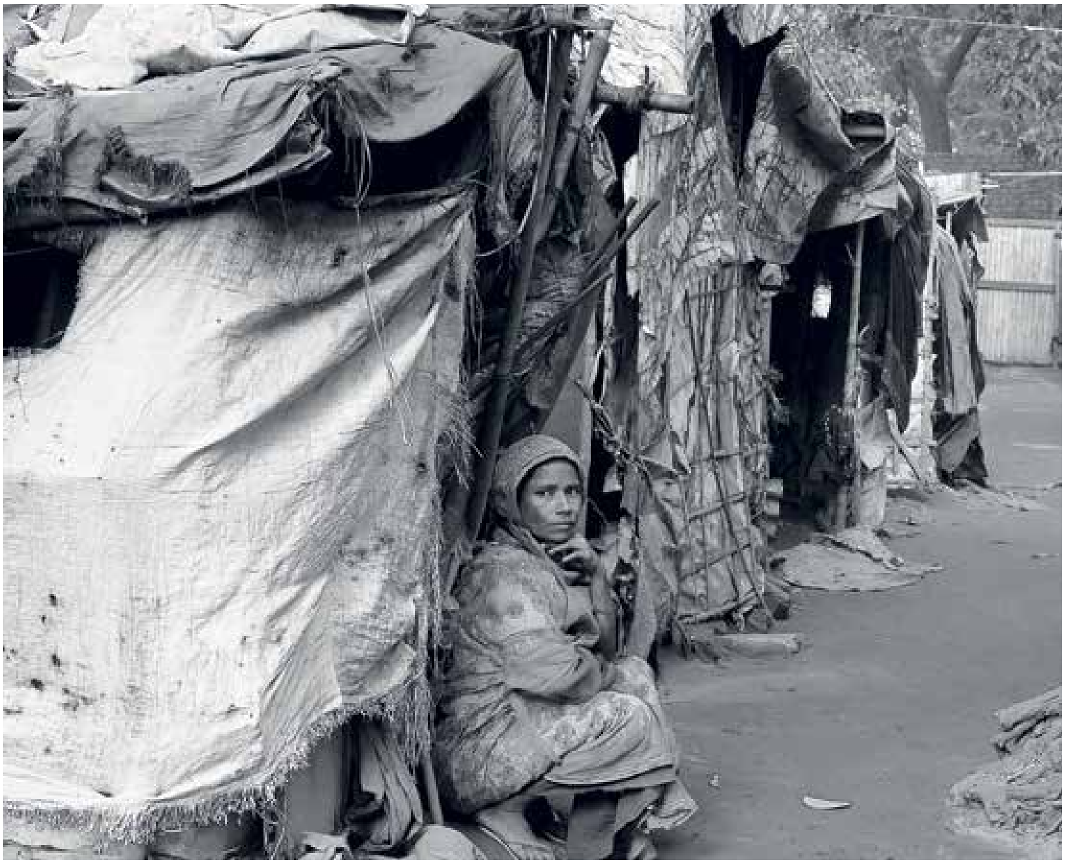
As part of the intervention, a large piece of cloth was tied to four poles, and firmly and tautly placed safely over the houses such that there was a shade on the roof. Approximately 5 to 6 feet was left between the roof itself and the shading. All the materials used were locally sourced, including bamboo and construction poles, and old sarees, etc.

These were done before the heat started, using mostly locally sourced thicker materials, including some large sheets and, in 10 cases, green mesh, and were expected to allow people to use their roofs as needed, such as for keeping a few plants.

In all cases, the second cloth-based roof was found to be faulty for the following reasons.

- With even mild rainfall, water accumulated and caused the cloth roof 'to sag'. This created a pool of water which could lead to breeding of mosquitoes.
- When there were strong winds just before monsoon and during monsoon, the poles were getting dislocated. Even a slight dislocation of one pole meant that the roof would no longer be taut and no longer served its purpose.
- It was extremely difficult to find enough space to fix poles and create an artificial roof in congested slum pockets.
- There was a need to dismantle it before the monsoon or any rain in order to prevent mosquitoes. But, in a city like Delhi, it is extremely hot even at the end of June and July when the rain starts. Hence, this intervention was found to be inadequate in the informal settlements of Delhi.

6 KEY INSIGHTS



MUMTAHINA TANNI/PEXELS

Informal settlements in urban India are densely packed, poorly ventilated, and uncomfortably warm.

AS ELABORATED IN previous chapters of this report, in poor settlements and slums in urban India, houses are densely clustered and have mostly tin sheets, asbestos or thin concrete roofs without sufficient ventilation. Some use plastic sheets in addition. This makes it extremely hot inside in warm months.

The rising heat disproportionately affects urban poor and marginalised communities due to existing socio-economic and health-nutrition challenges, and also systematic barriers that exclude them from cooling efforts. The challenges of rising heat are mammoth and no one solution will work in informal settlements.

Based on the bottoms-up work that Chintan has been practising on heat and thermal comfort in slums of Delhi NCR in close collaboration with urban poor women, the following key insights are presented here:

1. GOING BEYOND ROOFS: Roofs are key to reducing heat inside homes, as almost 80% of all heat is absorbed via the roof. However, women often spend time at their doorsteps while doing specific tasks such as preparing vegetables for cooking and sewing, amongst others. Often, they use the time outside with other women engaged in similar tasks, an act that enables them to strengthen social resilience, seek support and learn from and share information with peers.

Hence, cooling open spaces within individual homes in an informal settlement is important from a gendered perspective. The work on the ground comprised used textile waste cut into medium sized flags, attached to a grid of jute ropes, about 10 feet from the ground. The women were able to set it up under instruction. The device allowed evening breeze but prevented direct sun. However, it dismantled in the heavy rains. Locally appropriate, low cost devices can be developed and used every year in this context.

2. ALL ROOFS NEED ANNUAL REPAIR: Every kind of cool roof in the project needed repair. This was for two reasons. One, the material itself became weathered. White reflective paint peeled off and multi-layered roofs were damaged in the rain and with time. Hence, a budget for annual maintenance is essential.

3. WHITE ROOFS ARE NOT FOR EVERYONE: While painting roofs with white reflective paint is widely favoured as an easy and impactful way to reduce heat stress inside the house, Chintan found that several families use the roof for storage. Infact, even if they clear the roof for painting, they tend to eventually use it due to pressing storage needs. Multi-layered roofs were able to manage storage better, but this needed some training and instructions. It is important to do a recce and document the roof storage before uniformly applying one technique across a settlement.

4. WET BULB PHENOMENON IS IMPORTANT: Much of the focus around heat is on high temperatures. However, the wet bulb phenomenon is also vital to protect health. This kicks in under conditions of high humidity, when even temperatures not considered extreme can cause heat stress, such as the body not being able to sweat to cool. The study found it useful to install automatic weather stations (AWS) that enabled the community to know about heat (temperatures) and wet bulb conditions.

The project advised women to avoid coolers during this period, switching to fans as well as other basic protocols. No household used an air-conditioner, hence all of them were hit by wet bulb stress. Under the circumstances, a protocol for wet bulb conditions, along with a separate warning, is important.

5. INCLUDING LITERATE YOUTH FOR HYPER-LOCAL ACTION: Literacy levels amongst women in urban informal settlements are low. However, the project observed that children and youth are able to read, analyse and triangulate data at the very least. This capacity is a community asset and should be part of all interventions, including those that require reading automatic weather stations, hyper local warning systems, information about desirable action during heat stress and wet bulb, and any other information sharing.

7 FUTURE DIRECTIONS

FREEPIK

THE FOLLOWING FUTURE directions have been identified based on Chintan's grass-roots work with women in informal settlements. These are nuanced, aimed at specifically being part of bigger heat action plans, with the objective that millions of people who live in hot and poorly ventilated informal settlements can lead dignified lives, sleep at night, earn their daily wage the next day, and reduce their spendings on the increasing disease burden due to heat-related ailments.

1. INFORMAL SETTLEMENT HOUSING POLICY WITHIN HEAT PLANS AND BUDGETS FOR REPEAT: This report clearly demonstrates how some pockets in cities are hotter than the others. These are mostly informal settlements and slums. The heat challenges of these highly vulnerable zones are different from the rest of the urban centre.

Heat action plans must be inclusive of those in informal settlements by earmarking specific resources for gendered heat stress needs in informal settlements as well as mapping local climatic zones and addressing informal settlements in the most heat stressed zones on priority.

As informal settlements phase out and affordable housing schemes increase coverage, government housing schemes, including Pradhan Mantri Awas Yojana-Urban (PMAY-U) and schemes within it, such as Affordable Rental Housing Complexes, under the Ministry of Housing and Urban Affairs, which is a credit-linked subsidy scheme by Government of India to facilitate access to affordable housing for the low and moderate-income residents of the country, must have a mandatory provision for cool roofs and homes.

2. SURVEILLANCE OF INDEXED HEAT AND HEALTH: It is known that heat as measured may not be heat as experienced, due to several factors, including housing quality, heat island effect, green cover and wetlands, wind direction and more. This gap can have an impact on the most vulnerable. Hence, surveillance of indexed heat and its computation, which can be roughly understood as 'feels like,' is important to compute and share. This also underscores the need for localised heat warnings as temperatures may be experienced differently across a city or district.

3. ESTABLISH PROTOCOLS FOR EMERGENCY HEALTH RESPONSE: While several instructions for preventing heat strokes and reducing heat stress exist, these must be upgraded to include :

- Protocols for shifts in outdoor work to reduce heat impact
- Protocols for specific kinds of work (such as working with ovens, tandoors and in certain industries) to prevent heat stress
- Protocols for reducing heat stress inside informal settlements and individual homes
- Protocols for health case institutions for managing heat stress and illness by the urban poor and workers
- Protocols for wet bulb conditions across homes, work and healthcare institutions.

The health system, including frontline health workers and 'jhola-chap doctors', should be trained to understand and handle climate-linked physical and mental health issues.

4. FLEXIBLE BUDGETARY PROVISIONS: The heat action plans must include budgetary provisions for repairing and upgrading interventions in informal settlements if they are to have any impact.

5. ENCOURAGE NATURE-BASED SOLUTIONS AROUND INFORMAL SETTLEMENTS TO BRING DOWN AMBIENT TEMPERATURES: Since the spatial characteristics of a city influence its climate, urban design can be deployed to mitigate the combined effects of climate change and urban heat island effects in slum pockets. Creating a comfortable microclimate in slums should be a high priority.

Nature-based Solutions (NbS) are an effective tool to reduce urban vulnerability to climate risks and, at the same time, develop more liveable urban areas and slum pockets within them.[1] Nature-based solutions such as green (vegetation) and blue (waterbodies) infrastructure, including in combination, are cost-effective and sustainable strategies for managing the heatwaves risks.

These should be planned and rolled out to reduce heat stress and improve health outcomes for all low income housing, formal or informal. This should also be brought under the ambit of CSR (corporate social responsibility) funding to unlock further resources.

6. SKILLING AND TRAINING FOR GREEN JOBS AROUND COOL HOMES FOR URBAN POOR: As this report demonstrates, multiple ways exist to bring down temperature inside and around homes in informal settlements. Small changes can yield big results, such as adoption of cool roofs. But structural interventions need trained humanpower across every level.

In this context, livelihoods entrenched within the green economy are vital. In a scenario of rising heat, a need to create a local cadre of masons, plumbers, carpenters, tailors, who can be trained and skilled to set up a range of cool roofs and similar interventions will enable policy roll out at the grassroots.

Cost will always be a constraint while working with urban poor, who are already being pushed into 'heat poverty'. Hence, every effort has to be made to use locally sourced materials to keep the retrofitting costs low. This will also enable homeowners to undertake such interventions on their own.

7. CAPACITY BUILDING FOR PASSIVE COOLING INTERVENTIONS IN INFORMAL SETTLEMENTS: Whereas a lot of work has happened on passive cooling solutions in cities that focus on economically well-off populations, such solutions for informal settlements and urban poor housing are still emerging. There is a need to enable the capacities and skills of organisations that work with slum populations and marginalised communities to intervene for thermal comfort.

8. STRENGTHEN DEMAND FOR THERMAL COMFORT AMONGST THE URBAN POOR: Chintan was able to undertake intense training with wastepicker and other women in informal settlements, along with children. This enabled the women to seek out, collaborate and understand the importance of thermal comfort, instead of assuming this is 'normal' and their 'fate.' However, this may be a challenge to scale up.

An impactful strategy is likely to be to create 'cool' schools and mainstream learnings on heat in all educational institutions. Teachers and other staff must also be trained to impart learnings around beating the heat and creating a resilient environment to avoid growing eco-anxiety among school children (read Chintan publication, The Future We Want, November 2024).

9**. FISCAL MEASURES FOR THE URBAN POOR:** While it is a challenge for many to work, the urban poor are particularly hard hit. Their work often requires them to be outdoors, undertake work that requires significant physical effort or requires them to be near sources of heat (such as recycling or cooking). Heat stress not only prevents them from directly working but also increases their caregiving tasks, which also prevents them from working. This amounts to significant income loss, exacerbated for the many who depend on daily earnings.

Compensating them for heat based income losses prevents them from sliding below the poverty line. In order to do so, the following are essential :

- A robust, acceptable measurement of productivity loss
- Developing an innovative finance package including including parametric insurance
- Setting up a heat mitigation fund which can also receive funds from multiple global sources. India must expand mandates of existing funds such as the Loss and Damage fund for supporting such investments.

India has invested significantly in the poor, bringing 24.82 crore Indians out of multidimensional poverty in the last 9 years, enabling them to own a house, access education foodgrains, and more. Heat, as a manifestation of climate change, can derail this progress. Cool roofs for those living in informal settlements along with allied interventions can offer significant push back against this national threat.

GLOSSARY

Here is a quick explanation of terms commonly used in the context of heat and climate change.

HEATWAVES: Heatwaves are a period of unusually high temperatures as compared to what is normally expected over a region. Therefore, the temperatures at which heat-waves are declared differ from place to place based on the temperature climatology (historical temperatures) of that region.

According to IMD, a heatwave is declared in India when the maximum temperatures are at least 40 degree celsius or more in the plains, 30 degree celsius or more in hilly regions, and 37 degree celsius in coastal regions.

HEAT INDEX: The heat index, also known as the apparent temperature, represents how the temperature feels to the human body when the effects of relative humidity are combined with the air temperature. When the body heats up, it cools itself by sweating. If humidity is high, sweat evaporation slows down, making it harder for the body to cool off, and the temperature feels hotter. Conversely, in dry conditions, sweat evaporates faster, and the body feels cooler. As both air temperature and humidity increase, the heat index rises, making it feel hotter.

HEAT RESILIENT INFRASTRUCTURE: Heat-resilient infrastructure refers to buildings and urban design strategies that are adapted to withstand extreme heat. Examples include cool roofs, increased green spaces, and energy-efficient cooling systems that help reduce indoor temperatures and mitigate the urban heat island effect.

HEAT STRESS: Heat stress occurs when the body cannot get rid of excess heat through a natural process of cooling down. This is usually a result of prolonged exposure to elevated temperatures, high humidity, direct physical contact with hot objects and strenuous physical activity. When this happens, the body's core temperature rises and the heart rate increases. As the body continues to store heat, the person begins to lose concentration and has difficulty focusing on a task, may become irritable or sick, and dehydrated. The next stage is most often fainting and even death if the person is not cooled down.

HEAT VULNERABILITY: This refers to the susceptibility of certain populations to the adverse impacts of heat stress. Vulnerable groups include the elderly, children, outdoor workers, and people living in informal settlements or poor-quality housing.

URBAN HEAT ISLAND: An urban heat island is a phenomenon when the city is much hotter than the surrounding areas (at least 2 degrees celsius or above). This is caused due to the dense population buildings, and concrete infrastructure in the cities that traps heat.

WET BULB TEMPERATURE: Wet bulb temperature is the lowest temperature to which air can be cooled by the evaporation of water into the air at a constant pressure. It is therefore measured by wrapping a wet wick around the bulb of a thermometer and the measured temperature corresponds to the wet bulb temperature. The wet bulb temperature is representative of the moisture content present in the air. It is a meteorological measure of the combination of dry temperature and humidity.

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