Promote innovations to improve light, ventilation, and thermal comfort

CONTEXT

Houses in low-income communities are constructed with tin, plastic, tarpaulin, or asbestos sheet roofs that trap heat and require more energy to cool down. A 2020 study by the geo-analytics team of World Resources Institute (WRI) on microclimatic changes and temperature variation in Mumbai has established that slums in the city are six degrees warmer than neighboring housing societies (WRI India & Chatterjee, 2020). Heat stress is a prominent impediment for homeworkers living in slum settlements as it reduces their ability to work for the desired duration. MHT's focus group study on home-based livelihood indicated a productivity reduction of 50% in summers, among women who mostly work in the afternoon (Mahila Housing SEWA Trust). Moreover, every degree rise above 25°C (77°F) results in a 2% loss in productivity (Vellingiri et al. 2014, 26). In addition to creating thermal discomfort indoors, the tightly packed houses get polluted with dust, ash, smoke, and chemicals. Home-based workers face the impact of the indoor pollutants the most due to greater time spent indoors and are prone to diseases like pneumonia, stroke, and lung cancer (Maharana et al., 2018). Located in densely packed urban settlements, the houses have limited openings that further provide minimal scope for natural lighting. Slum residents depend on artificial lighting even during the daytime (Rawal et al., 2020). Living in such environments with inadequate lighting or air ventilation makes the residents prone to health hazards and hinders their ability to reap economic benefits from their livelihood activities.

Low-income communities living in public housing encounter similar issues of heat, light, and ventilation. There is a minimum focus on housing layouts, opening sizes, shading structures, and choice of materials that create an unfavorable environment for residents to maintain the productivity of their home-run businesses. They have fewer options available to combat the negative impacts of heat stress, interior lighting, and lack of natural ventilation.

Moreover, residents belonging to the economically weaker section often lack access to information on technologies and products that can improve overall thermal comfort. They remain unaware of extreme environmental changes that hamper their livelihood. For instance, a study of slum communities in Ahmedabad demonstrated a lack of access to information about impending heatwaves and subsequently they have limited opportunity to prepare for extreme heat events or change their behavior in its anticipation (Jaiswal et al. 2013). To broaden the access to efficient and required technologies, the supply side needs to be strengthened by linking slum residents, local governments, and service providers. In addition to facilitating pro-poor technological innovations, there is a need to build social capital among slum residents and equip them with the right knowledge and information to take action towards improving their thermal comfort and resilience to climate.

MHT'S APPROACH

Mahila Housing SEWA Trust (MHT) recognizes the complex challenges of improving thermal comfort and climate resilience in poor vulnerable communities. Their strategy is threefold: 1) aiding slum households through proactive and efficient adaptation of the existing built environment, 2) working with innovators and technology/service providers to strengthen the supply side, and 3) learning from their grassroots experience to inform policy.

Advancing evidence-based research on thermal comfort in dense settlements

MHT advocates with the government to enable scalable policy change that benefits disenfranchised communities. This advocacy is supported by strong research to understand the policy gaps for different cities and identify the best way to address them. MHT's partnership with academic experts focuses on building a culture of evidence-based actions that are driven by the demand of communities. In the last five years, MHT has partnered on several research studies

Table 1: Evidence-based research with academic universities

Name of the study	Affiliated University/ Institution	Year
Developing cool roofing solutions in Delhi slums to bring down the indoor temperature and allow slum dwellers to conserve energy and improve their productivity and quality of life	University of Chicago	2016
Combating climate change-induced heat stress: Assessing cool roofs and their impact on the indoor ambient temperature of the households across slums of Ahmedabad	Indian Institute of Public Health (IIPH)	2019
Thermal Comfort, Energy Consumption, and Code Compliance - A study in the Context of Affordable Housing	Centre for Advanced Research in Building Science and Energy (CARBSE)	2020
Cool Roofs: Protecting Local Communities and Saving Energy	National Research Development Corporation (NRDC)	2017
Women's Action Towards Climate Resilience of Urban Poor in South Asia, Volumes 1 and 2	School of City and Regional Planning, Georgia Institute of Technology	2018
Women's Action Towards Climate Resilience of Urban Poor in South Asia: The Longitudinal Study Report	School of City and Regional Planning, Georgia Institute of Technology	2020

Box 1

Thermal comfort, energy consumption, and code compliance -
A study in partnership with CARBSE on the context of affordable housing
Ahmedabad, Gujarat

The Indian affordable housing domain has seen a national-level push with the Pradhan Mantri Awas Yojana (PMAY). Many cities in India are leveraging national subsidies made available under the program to construct public housing units for lower-income groups. The units are either used to house resettled families or sold to eligible families at subsidized rates. However, there is a concern that there may not be any takers for these units if they are not comfortable and if they add to the families' electricity burden. This study on thermal comfort and energy consumption focuses on affordable housing in Ahmedabad, where the indoor temperature substantially impacts livelihood and household activities. The study captures indoor temperature, humidity, and perceived thermal comfort of sixteen families residing in public housing complexes over one year.

The study suggests that the occupants preferred the temperature range of 26-30°C. 43% of respondents wanted a "cooler environment" and attributed their discomfort to a combination of high relative humidity, high temperature, and low air velocity. The most common adaptive strategy, which was the preferred choice for 57% of the respondents, included keeping the ceiling fan "on". Respondents also preferred moving out of the house to sit in sunlight during the winter season. This was observed even during summers when respondents got out and slept on a building terrace as the RCC walls radiated heat indoors during night-time causing discomfort.

Since the occupants were relocated from slums where they were conditioned to extreme weather conditions, they had lower comfort expectations. This was reflected in their low energy use. Moreover, this reveals the varying comfort levels and specifically the adaptive nature of housing occupants. This result calls attention to solutions that are specific to the context and the residing communities. There is a need to arrive at solutions that are locally relevant to tackle the challenges of thermal comfort.

to document and evaluate the impact of MHT's work with low-income communities in improving thermal comfort and climate resilience (Table 1). These research studies have helped identify scalable solutions that work (or do not) in the context of low-income communities. The knowledge material is also a useful resource for other NGOs, government actors, and other stakeholders involved in designing policies that cater to the needs of slum communities.

The three research studies undertaken in partnership with Georgia Tech under the Global Resilience Partnership Project (GRP) outline and document the impact of MHT's many interventions under the multi-year program focussed on supporting low-income communities in building climate resilience. Undertaken in tandem with MHT's action research program, the reports capture underlying stakeholder dynamics of implementing multi-stakeholder projects and provide learnings for process replication by grassroots-oriented actors. The CARBSE study (Box 1) shows that occupants of public housing are often uncomfortable due to a combination of high relative humidity, high temperature, and low air circulation. The NRDC report addresses the success of cool roof programs in Ahmedabad, especially MHT's work in engaging communities and responding to their local conditions. The study with the University of Chicago demonstrated the favorable outcome of Modroof in low-income communities of Delhi. Women who had installed modroof were seen to recommend the product to their neighbors. It documents how MHT's approach in extending financial and technical assistance, encouraged families to adopt new solutions.

By collaborating with local civil society, academic institutions, and policy think tanks to conduct research-based evaluations, MHT is increasingly focusing on systematically capturing important evidence and reflections from their grassroots work to inform both their grassroots and advocacy work in the future.

Promoting the adoption of heat resilient products and technologies

Gathering from the results of evidence-based research with partnering universities, MHT promotes and validates solutions to provide low-income communities with options that reduce heat stress, bring in natural light and ventilation, and help reduce energy consumption. The designs are cost-effective, planned for density, and aligned with the existing infrastructure. MHT partners with service providers and gives them the platform to test the prototype directly with slum communities by supporting pilot demonstrations (Table 2). It enables further innovations and improvements to these innovations by sharing feedback from community testing and validation exercises. Following the initial pilot projects, MHT supports low-income households to access these technologies by providing financial assistance through microloans.

In working with product innovators to make technologies available, MHT has recognized the challenge of scaling them up. For instance, many products are not readily accepted by slum communities owing to the perception that they are inferior to mainstream solutions. Low-income households aspire to improve their living and working environment to match the familiar standards. However, MHT has met with moderate success with the Modroof system in Ahmedabad and has supported more than

DILSHAD BANU
KITE MAKER

Behrampura,
Ahmedaabad

"Earlier we had a tin sheet roof that made our house very hot. When our entire family of seventeen people is at home, the heat affects our capacity to work. With no windows, we had no daylight or air circulation inside the rooms. MHT supported us to install a Modroof with Airlite ventilation. Now we get respite during summers as it is cooler inside. The Airlite vents also let in light and help the air circulation in the inside rooms. We are now more productive in our kite-making business."

Table 2: MHT initiated pilots for heat resilient products

Technology	Innovator	Demonstration City
Modular roof (Modroof)	Re-Materials, Ahmedabad	Ahmedabad, Delhi, Surat, Bhopal, Ranchi, Jaipur
Airlite Roof Ventilation	Eco Footprints	Ahmedabad, Delhi, Surat, Bhopal, Ranchi, Jaipur
Bamboo Roof	Eco-Shelter	Ahmedabad, Surat
Solar Reflective White Paint	Abstract Chemicals, Raycoat	Ahmedabad, Delhi, Surat, Bhopal, Ranchi, Jaipur
Compressed Agro Based Panels for Roofs and Walls	Stawcture Eco	Ahmedabad
Compressed Agro Based Panels for Roofs annd Walls	Eco-board	Bhopal
Puff Sheet and Honeycomb Panels for Roofs and Walls	Industrial Foams, Covestro	Bhopal, Surat

Box 2

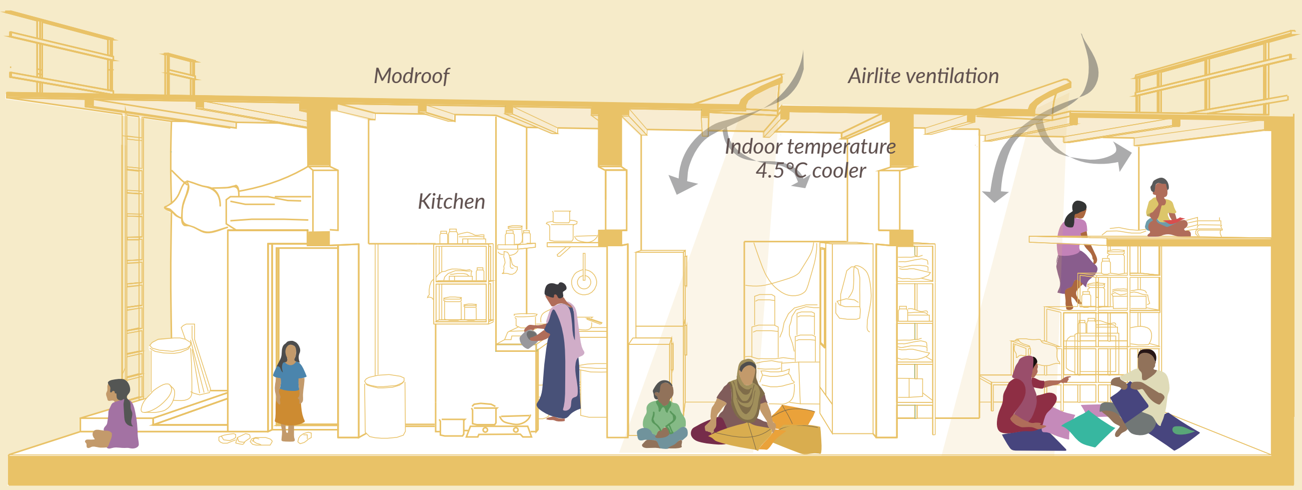
Supporting incremental improvements in a kite-making household to reduce indoor heat stress

Dilshad Banu, Behrampura, Ahmedabad

Dilshad Banu, and her family of five, moved to Behrampura in 1999. When they moved in, the house had three rooms 3 m wide with a kitchen arranged linearly, and a tin sheet roof. She and her family have been engaged in the home-run business of kite-making since 2008. They work year-round except for one or two months at the start of the year, for six hours a day producing two thousand kites per day for INR 200 (USD 2.5). Her employer delivers the raw materials to her house and collects the finished product daily.

MHT has helped improve Dilshad Banu's house, starting with fixing doors in 2006 costing approximately INR 10,000 (USD 135). The kitchen in the central room increased the indoor heat stress and compounded the effects of thermal discomfort. In 2011, with an expenditure of approximately INR 30,000 (USD 403), they shifted the kitchen to the first room. This also had a safety reason as the move distanced the cooking appliances away from the electricity meter (later shifted outdoors). But the house had a tin roof that hampered productivity due to indoor heat build-up during summers and inadequate indoor lighting. Moreover, the water leakage during the monsoon damaged their kites and burdened their storage capacity. In 2016, Dilshad Banu, with her family, replaced her tin roof with a Modroof, with technical assistance from MHT. The Modroof is a modular cool roof solution designed by Re-Materials, an Ahmedabad-based product startup. The Modroof was supplemented with Airlite vents that gave the family a respite from hot and dark indoor spaces. The roof covered the entire 12 m span of the house and cost INR 1.2 lakhs (USD 1,613), paid in installments of INR 15,000 (USD 201), with a maintenance guarantee from MHT for an additional INR 2,000 - 3,000 (USD 27- 40) in five to six year intervals. Additionally, Re-Materials also supported Dilshad Banu's family with modular and efficient storage facilities to suit the needs of her large family and her home-based livelihood.

As one of the first pilot projects of Modroof technology that Re-Materials undertook with MHT, the roof structure has started showing signs of distress. The roof product has seen many improvements in the last five years. The community feedback from beneficiaries like Dilshad Banu has played a crucial role in updating the product and adding further innovations to meet their specific needs. Dilshad Banu, with the support of MHT, is currently working with Re-Materials to replace her Modroof with recent innovations.



Modroof with Airlite vents installed with support from MHT

three hundred families to invest in this modular roof technology (Mahila Housing Trust, 2018, 97).

Advancing pro-poor resilience building policies and their implementation

MHT's work for the past twenty-five years has centered on a demand-based approach by understanding the needs and aspirations of low-income families. Now, MHT is leading its action to the city level by advocating for city-level policies and working on building bridges for the low-income communities with the city and state governments. Two key avenues through which MHT has been able to successfully bring attention to thermal comfort needs of the poor have been the policy advocacy around the Heat Action Plan (HAP) for Ahmedabad and the Energy Conservation Building Code (ECBC) for Public Housing.

In the HAP, MHT drew the attention of Ahmedabad Municipal Corporation (AMC) to the specific needs of the poor during extreme heat conditions. The first Heat Action Plan prepared by the AMC in 2013 focused on generating awareness on risks of heatwaves, early warning systems, and building the capacity of healthcare professionals to respond to heat-related illnesses. "Promoting adaptive measures" was also outlined as a strategy but there was little direction on putting it to action. MHT had a deep understanding of how extreme heat conditions impacted women of slum communities, especially those who spend the bulk of their time indoors. MHT actively engaged on the issue with AMC and organizations that helped develop the plan (IIPH and NRDC) for more than five years. The HAP now includes a cool roofs program that promotes adaptive measures to heat stress for low-income housing and vulnerable communities. Cool roofs help in keeping the indoor temperatures lower by 2°C to 5°C and offer a cost-effective solution, covering 2% of Ahmedabad's low-income households (Centre for Research and Development Foundation, CEPT University, 2014).

Similarly, MHT looked at the Energy Conservation Building Code for Residential Buildings (ECBC-R), one of the flagship programs of the Bureau of Energy Efficiency, Ministry of Power, through the lens of low-income communities. The aim of the code is to promote energy efficiency in the design and construction of high-rise apartment buildings. The code initially posited limited direction in applying the standards to affordable housing, especially state-supported public housing. Public housing in Ahmedabad is often constructed with cast-in-place concrete construction systems. A study by the Centre for Science and Environment has revealed that monolithic panels made of poured concrete (with a thickness of 100 mm wall) can have a heat gain 60% higher than the conventional brick wall.

MHT is advocating for thermal comfort in public housing and exploring how it can be included within the scope of energy conservation codes. They continue to educate the developers and advance awareness about the technical nuances outlined in Energy Conservation Building Code (ECBC) and the importance of design, using the right materials, orientation, and shading materials to ensure that indoor environments in these buildings remain comfortable and productive.

NIRMALA DUBEY
GROCER

Himadri Mills, Ahmedabad

"We moved to Himadri Mills after our house in Bapunagar chaali was demolished. We live on the first floor here, yet it gets very hot during summers because of the RCC building. The buildings are very close and there is limited cross ventilation. Our electricity bill has also increased to INR 3600 (USD 48) for two months, much more than what we paid in our earlier house. Also we could rest outdoors and get some fresh air during summers in Bapunagar. Here we can't just step out."

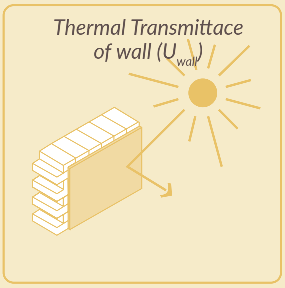
Box 3

Promoting strategies to make public housing units thermally comfortable

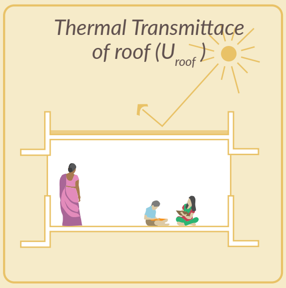
MHT's partnership with AMC and private developers, Ahmedabad

MHT works with AMC and private developers to implement in-situ redevelopment of informal settlements. Over six years, MHT has successfully established synergistic relationships with developers and is working to implement measures that make buildings responsive to the specific needs of their occupants. The redeveloped housing is typically characterized by high density and multi-storied residential blocks with the size of housing units varying from 30 to 45 sq m (Mahila Housing Trust, 2020). MHT recognizes that ensuring thermal comfort to occupants through design is of prime importance. They worked with the developers and architects to gather results from monitoring and simulation studies of typical housing blocks, from which emerged parameters to assess the heat gain or loss through ventilation and daylighting. MHT then worked with architects to outline cost-effective, scalable strategies that would help in keeping the indoor temperatures lower during extreme heat situations.

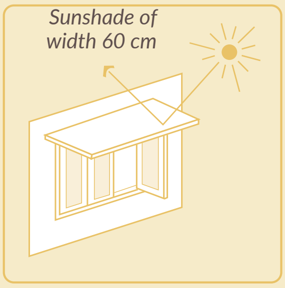
AMC has recognized the positive impact of MHT's recommendations on both the living and working conditions of the residents and is readily promoting the guidelines for upcoming slum redevelopment projects.



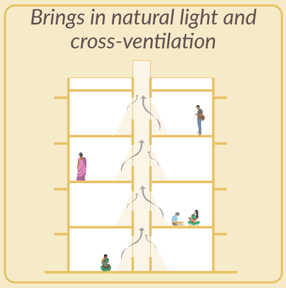
Solar reflective paint on walls



Solar Reflective Index (SRI) paint or Mosaic tiling



10% Window to floor area ratio, partially glazed to diffuse radiation



Light and Ventilation shafts

LEARNING AND DIRECTION OF FURTHER ADVOCACY

1) According to the Global Climate Risk Index of 2020, India is the fifth most vulnerable of 181 countries to the effects of climate change, with its poorest being the most at risk. Grassroots NGOs like MHT have emerged as important actors engaging with the issue of resilience building in urban slum settlements. But they find that knowledge about climate change, thermal comfort, and building energy efficiency is often loaded with scientific language and technical jargon, limiting it to academic circles. New research, policy, and regulations (like the ECBC) need to be simplified, synthesized, and made accessible to important non-technical actors including governments, NGOs, citizen groups, and private developers in understandable formats. Grassroots actors can play an active role in extending the learning to communities and enable implementation on the ground.

2) Solutions to tackle challenges arising from inadequate levels of light, ventilation and thermal comfort among low-income communities should be aspirational, in addition to being affordable, user-friendly, and accessible. There is an emergence of "eco-friendly" building products that are being targeted to low-income communities with funding support from Foundations and Corporate Social Responsibility (CSR) initiatives. However many products are not readily accepted owing to the perception that they are inferior. Low-income households aspire to improve their living and working environment to match the familiar standards. That the products are "sustainable" or "eco-friendly" does not mean much to low-income communities unless they offer tangible benefits over mainstream solutions, justifying their higher costs. The Modroof, adopted by more than three hundred families, is a testament to the willingness of low-income households to invest in innovative products that are durable, attractive, and offer real solutions to

"When our new house was being constructed MHT suggested that we use an agro-based panel for our walls. But I wasn't really convinced. This panel is so thin, looks like wood. Does it offer benefits over a brick wall? The semi-open verandah is where we would be frying the *puris*, wont it catch fire? And will it survive the rains? Won't it warp?"

their challenges. The scalability of other solutions is yet to be seen.

3) There are 1.1 crore (11 million) houses sanctioned under the Pradhan Mantri Awas Yojana (PMAY). A significant percentage of these will be in public housing. An increased focus on building these units quickly and cost-effectively is leading to the use of technologies like monolithic concrete wall panels and AAC blocks that contribute to much higher heat gain. The ambitious targets have sidelined thermal comfort within these units which impacts the occupants' health and work productivity. The concrete panel walls often used to fast-track the construction also reduce the flexibility to alter layouts. Providing timely affordable housing options for the poor should not compromise their living standards and increase their operational cost burden. Thermal performance criteria for public housing should be made a priority.

References

Centre for Research and Development Foundation, CEPT University. (2014). *Ahmedabad Slum Free City Action Plan*. CRDF.

Groundwork Architecture, Mahila Housing Trust, & Selco Foundation. (2018). Sustainable Habitat Solution. Mahila Housing Trust.

Gujarat Mahila Housing Sewa Trust. (n.d.). Combating climate -change induced Heat stress: Assessing cool roofs and its impact on the indoor ambient temperature of the households across slums of Ahmedabad. Mahila Housing SEWA Trust.

Jaiswal, A., Knowlton, K., & Casey-Lefkowitz, S. (2013). *Rising Temperatures, Deadly Threat: Recommendations for Slum Communities in Ahmedabad*. NRDC- Issue Brief.

Maharana, S. P., Paul, B., Garg, S., Dasgupta, A., & Bandyopadhyay, L. (2018). Exposure to indoor air pollution and its perceived impact on health of women and their children: A household survey in a slum of Kolkata, India (3rd ed., Vol. 62). Indian Journal of Public Health. 10.4103/ijph.IJPH_259_18

Mahila Housing SEWA Trust. *Technologies to Combat Heat Stress*. Mahila Housing SEWA Trust.

Mahila Housing Trust. (2018). Women's Action towards Climate Resilience of Urban Poor in South Asia: A Case Analysis Report. Mahila Housing SEWA Trust.

Mahila Housing Trust. (2020). RETV Assess of PMAY projects in Ahmedabad. Mahila Housing SEWA Trust.

Rawal, R., Asrani, S., Shukla, Y., Soladhara, T., S, P., & Maheriya, B. (2020). Thermal comfort, Energy consumption and Code Compliance - A study in the context of Affordable Housing. Centre for Advanced Research in Building Science and Energy (CARBSE), CEPT University.

Mahila Housing SEWA Trust, Selco Foundation, & Groundwork Architecture. (2018). *Sustainable Habitat Solutions*. Mahila Housing SEWA Trust.

Vellingiri, S., Dutta, P., Singh, S., LM, S., Pingle, S., & Brahmbhatt, B. (2014). *Combating Climate Change-induced Heat Stress: Assessing Cool Roofs and Its Impact on the Indoor Ambient Temperature of the Households in the Urban Slums of Ahmedabad*. Indian Journal of Occupational and Environmental Medicine, 24(1), 25-29.

WRI India & Chatterjee, B. (2020, November 20). Mumbai slums are 6 degrees Celsius warmer than neighboring housing societies in October: Study. Hindustan Times. https://www.hindustantimes.com/mumbai-news/mumbai-slums-are-6-degrees-celsius-warmer-than-neighbouring-housing-societies-in-october-study/story-wo22fMA4bIUjzvV5OldamN.html#:~:text=The%20city's%20slum%20settlements%20are,environment%20group%20World%20Resour

Banu, D. (2021, January 11). Personal Interview.

Dubey, N. (2021, March 04). Personal Interview.

Sarvadevabhatla, P. (2020, December 17). Personal Interview.

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City Collab team: Vanishree Herlekar, Tulsi Lashkari, and Anagha Devanarayanan