Thermal Comfort Action Plan 2050

Quality Control Log

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Contents

Abbreviations

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers	NBC	National Building Code
BIS	Bureau of Indian Standards	NHB	National Housing Bank
BMTPC	Building Material and Trade Promotion Council	NIUA	National Institute of Urban Affairs
COP	Conference of Parties	NMSH	National Mission on Sustainable Habitat
CPWD	Central Public Works Department	PMAY (U)	Pradhan Mantri Awas Yojana (Urban)
CSCAF	Climate Smart Cities Assessment framework	RCP	Representative Concentration Pathway
DPR	Detailed Project Report	SDG	Sustainability Development Goal
DS(TCP)	Design Standard for Thermal Comfort Performance	SVF	Sky View Factor
IMD	Indian Meteorological Department	TCAP	Thermal Comfort Action Plan
IPCC	Intergovernmental Panel on Climate Change	TCPO	Town and Country Planning Organization
ISO	International Organization for Standardization	UDD	Urban Development Department
IT	Information Technology	UHIE	Urban Heat Island Effect
MBBL	Model Building Bye-laws	ULB	Urban Local Body
MoHUA	Ministry of Housing and Urban Affairs	UNFCCC	United Nations Framework Convention on Climate Change
NAPCC	National Action Plan on Climate Change	URDPFI	Urban and Regional Development Plans Formulation and Implementation

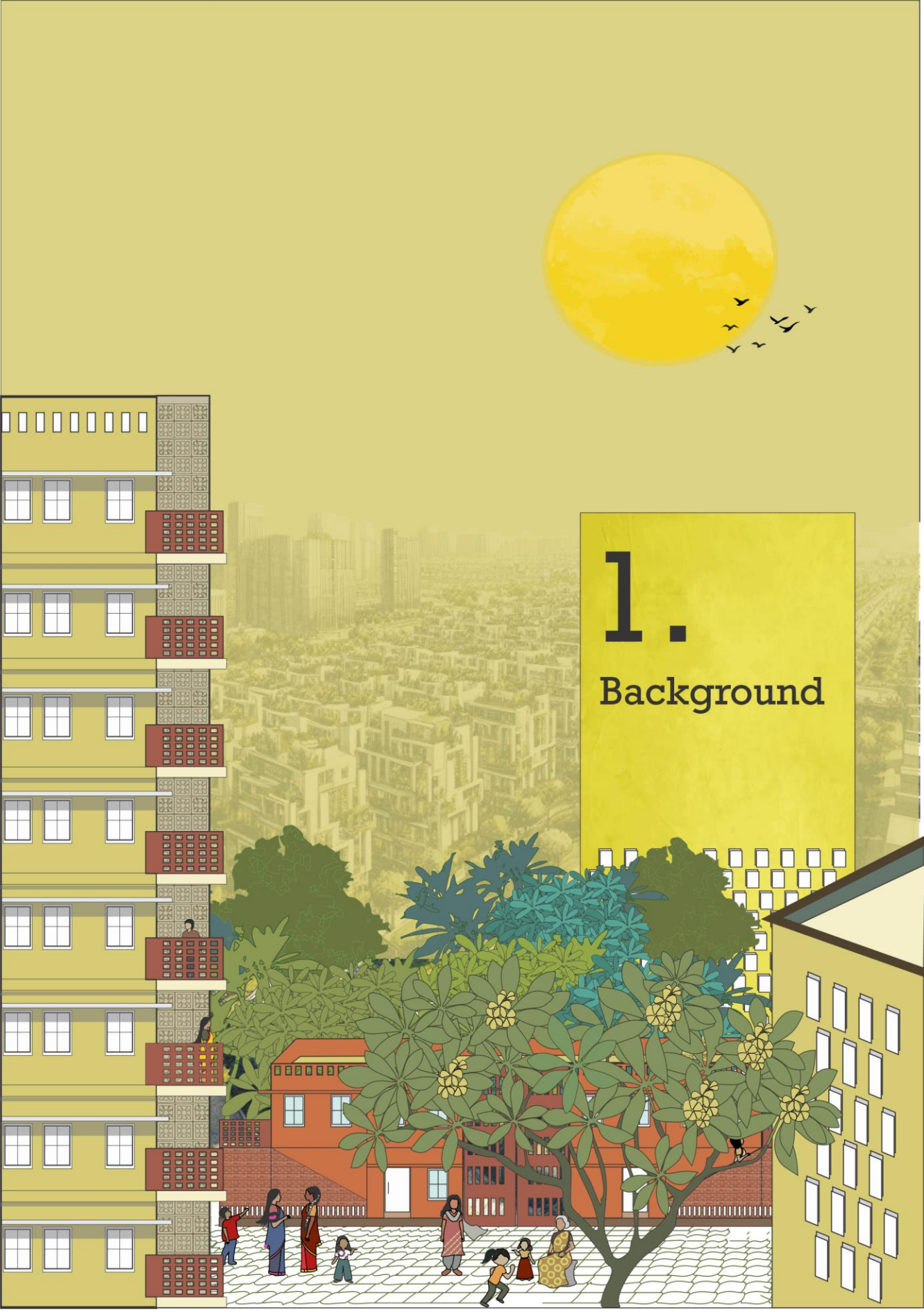
Foreword

Message from the minister

Message from the secretary

Message from the joint secretary

Message from GIZ



1.

Background

1 Background

Ahead of the Conference of Parties in 2023 (COP 28) on Climate Change by the UNFCC in Dubai, the unfulfilled pledges from the developed G20 nations have been stacking up. Amidst this, India shines as a beacon of commitment, steadfastly on track to fulfill its 2030 Paris commitments on mitigation.[1].

Despite India's significant progress in combating climate change, the relentless march of climate change continues unabated. World Bank and Mckinsey reports have highlighted that the frequency of severe heat waves in India is alarming, pushing the country to be *'one of the first places in the world to experience heat waves that break the human survivability limit.'*. The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) and the G20 Climate Risk Atlas further project a future marked by intensifying heat.[2][3].

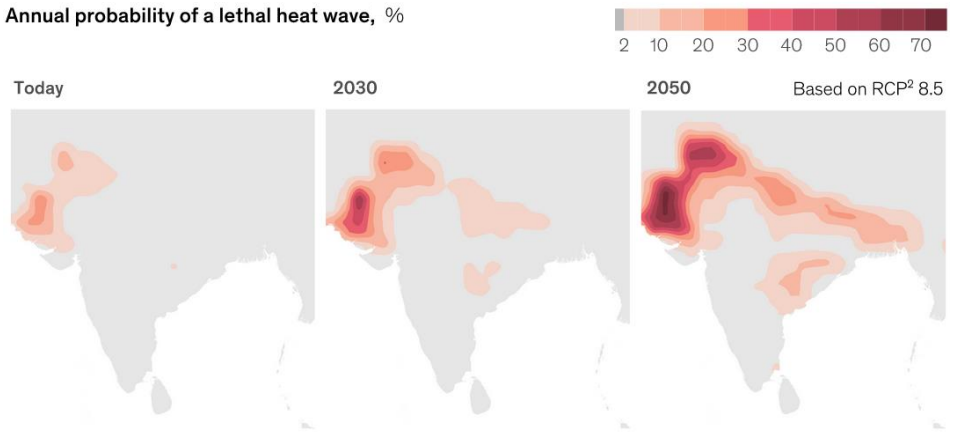


Figure 1 Heat waves are rising in India at an alarming frequency. Considering the Representative Concentration Pathway (RCP) 8.5, the probability of lethal heat-waves Indo-Gangetic plains and parts of East coast increases by up to 40%. Image source: Woods Hole Research Center.

With India yet to house 29 million (as of 2018)[4], the marginalized and the poor are bearing the brunt of climate change. Taking a mature view of the situation, the Government of India recognizes *sustainable cooling for all* as not only to

[1] Trimurti, T.S., As developed nations trail, India a beacon of hope on climate change, Hindustan Times, Accessed on Oct 28, 2023.
[2] World Bank. 2022. Climate Investment Opportunities in India's Cooling Sector. © Washington, DC. http://hdl.handle.net/10986/38340
[3] Mckinsey Global Institute. 2020 Will India get too hot to work?
[4] Indian Council for Research on International Economic Relations. (2020)

ensure thermal comfort, but to safeguard lives from severe heat stress[2]. A published journal further underscores this urgency by attributing a staggering human toll of 740,000 to climate change-induced heatwaves and cold waves in India.[5].

With the Pradhan Mantri Awas Yojana (PMAY) scheme, the Government of India has set out to close the housing shortage gap. Through this scheme the India's Ministry of Housing and Urban Affairs (MoHUA) attempts at uplifting the poor and marginalized communities crowding in inadequate and poorly ventilated shelters.

Complementing India's stellar success in housing the poor and setting in motion the world's first cooling action plan, this Thermal Comfort Action Plan, also one of the world's first is a testament to India's leadership in an increasingly warming world.

The Thermal Comfort Action Plan articulates the vision and actionable strategies to realize the stated vision. The action plan also maps the strategies with short- and long-term outcomes that will enable active monitoring of the action plan.

[5] Zhao, Q., Guo, Y., Ye, T., Gasparrini, A., Tong, S., & Overcenco, A. (2021, July). Global, regional, and national burden of mortality associated with non-optimal ambient temperatures from 2000 to 2019: a three-stage modelling study. The Lancet Planetary Health, 5(7), E415-E425

2.

Vision & Objectives

2 Vision & objectives of the Action Plan

The Thermal Comfort Action Plan puts forth a progressive vision that combines the ideas of 'Housing for all', 'Sustainable Cooling for all' and 'Thermal Comfort for all' into singular focus of *'Thermally Comfortable Housing for All'*. It encompasses all housing to include the gamut of urban-rural, low income-luxury, private-public, conditioned-unconditioned and existing-future stock. The Action Plan recognizes that addressing the entire housing spectrum is imperative in meeting social equity for all.

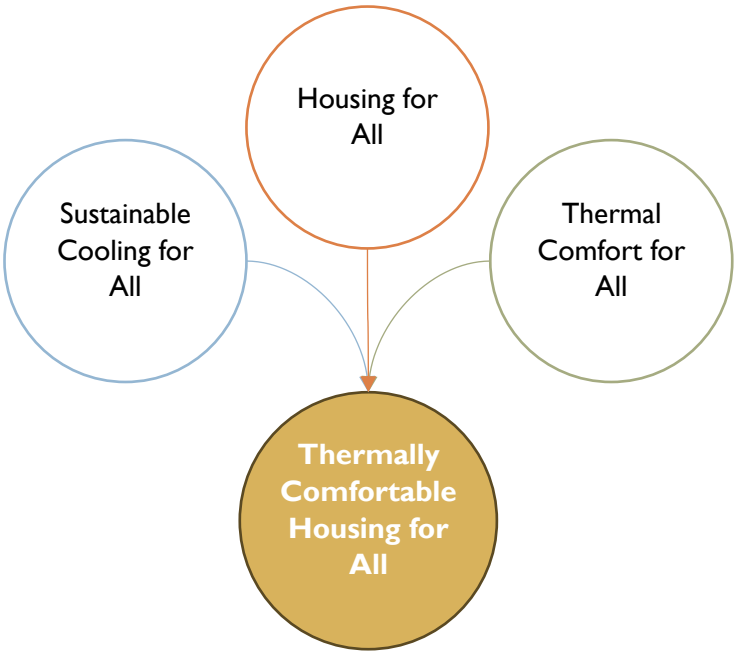


Figure 2 Comprehensive vision that combines synergistic ideas to catalyse action on climate change mitigation.

In line with the Action Plan, the objectives in sequential progression are:

1. *Developing an enabling policy environment.*
   An enabling policy framework recognizes the need for thermally comfortable housing and provides a top-down impetus critical for bringing state actors and other stakeholders together. Further, underscoring 'Thermally Comfortable Housing for All' as a national mission will catalyze the realization of the Action Plan.
   The enabling policy environment paves way for a robust implementation framework.

2. *Developing robust implementation frameworks that ensures coordinated action for smooth implementation.*

   The success of Thermal Comfort Action Plan hinges on the complex web of inter-relationships between Governments (Centre and states), its ministries, the private sector and international agencies to name a few. A far-sighted, focused, and equally important - organized leadership is essential to architect an organizational framework for implementation that facilitates collaboration, action, monitoring and verification.

3. *Developing/modifying urban environments that foster liveable micro-climates around buildings.*

   The microclimate surrounding a building, largely dictated by urban planning, serves as a potent modifier of climate. Through the application of sound urban planning principles, the urban environment can effectively mitigate climate impacts and enhance thermal comfort potential. As a result, buildings situated within these environments exert less effort to maintain thermally comfortable conditions. However, the converse is also true. Even buildings designed with careful consideration struggle to meet thermal comfort requirements when situated in unfavorable microclimates. This struggle often leads to the use of mechanical conditioning equipment, which in turn exacerbates the microclimate, creating a vicious cycle.
   Therefore, the development or modification of urban environments that foster livable microclimates around buildings is a prerequisite to sustainable urban living. It underscores the importance of holistic planning that takes into account buildings and their interaction with the surrounding environment.

4. *Promote passive design & low-energy systems in residential buildings.*

   Passive design is proven to improve indoor comfort conditions. Passive design leverages building physics and outdoor climate to naturally heat or cool indoor spaces. The building envelope, building form, its siting and orientation are effective modifiers of the indoor conditions. While passive design alone is sufficient in mild climates, the extreme climates require mechanical conditioning systems to supplement comfort requirements. Although extreme climates necessitate supplementary comfort systems, these need not be conventional cooling systems. Low-energy systems that complement passive design, offer a hybrid approach that provides enhanced comfort without putting undue strain on the environment.

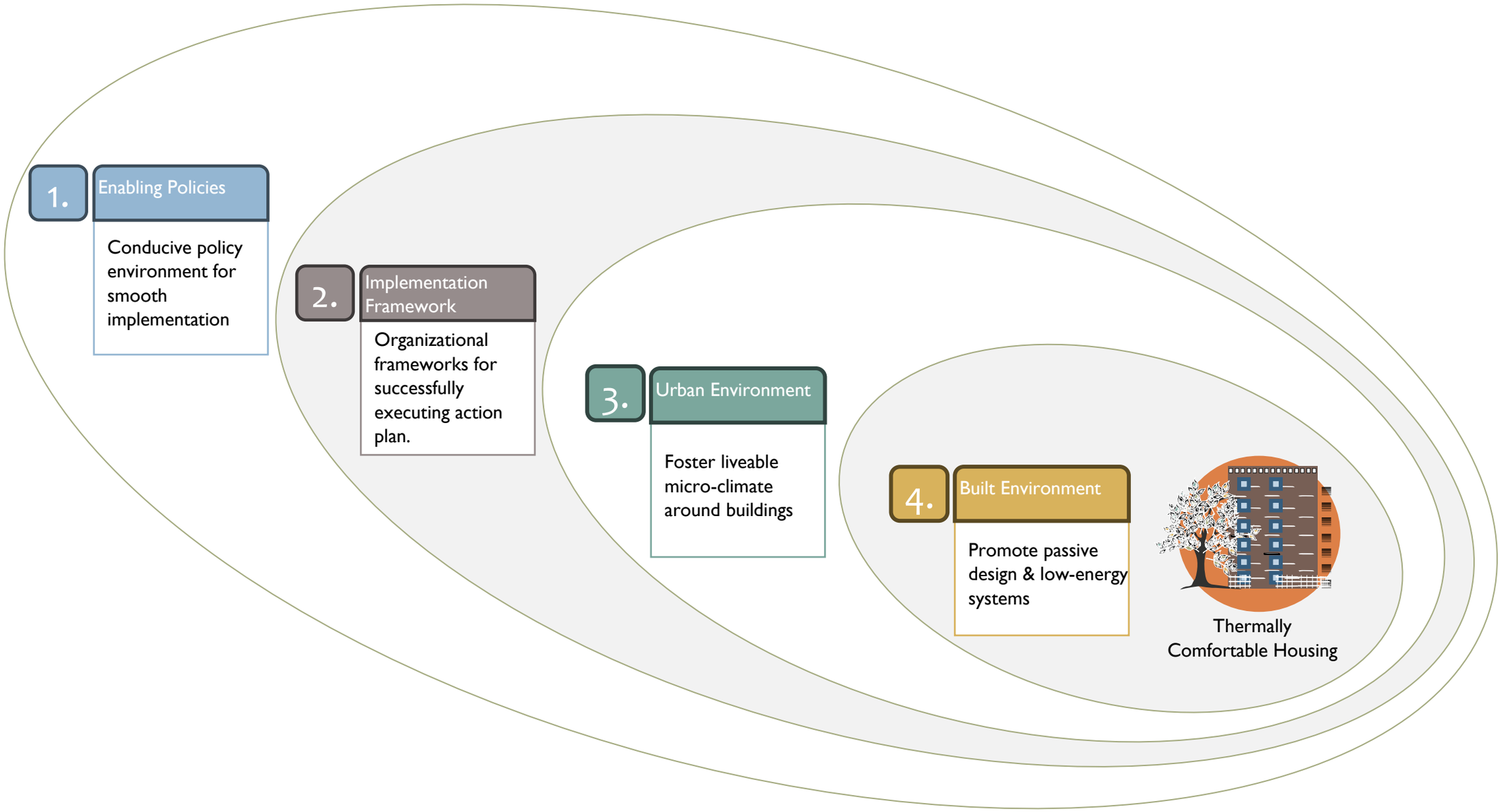


Figure 3 The Thermal Comfort Action Plan proposes an enabling policy framework which gets its teeth from a robust implementation framework. This implementation framework prioritizes on livable urban environment that ameliorates the climate impacts thereby enhancing the thermal comfort outcomes of measures adopted at building level.

3.

Enabling Policies

3 Enabling policies

Article 19 (1)(e) Indian Constitution recognizes the *right to shelter as a fundamental right*. Interpretations of Article 21 of the Indian Constitution have extended the right to housing as essential to right to life through various court rulings. The Universal Declaration of Human Rights – 1948, also ratified by India, further extends the right to housing to the right to 'adequate housing'. The United Nations, in its interpretation of the 'right to adequate housing', stresses that adequate housing is not limited to the building structure, but it also extends to sustainability, and non-discriminatory access to facilities essential for health, security, comfort and nutrition. Adding to the myriad interpretations of housing, the World Health Organization recognizes the role of housing in physical and psychological well-being among many other important factors.

> *"To have a home is more than the mere fact of having a roof above one's head. It is having a house, a place which protects privacy, contributes to physical and psychological well-being, contributes to the development and social integration of its inhabitants – a central place for human life."*
>
> *-World Health Organization*

Switching to thermal comfort, ISO 7730 defines thermal comfort as 'that condition of mind which expresses satisfaction with the thermal environment.' ASHRAE Standard 55 defines thermal comfort as 'an expression of individual's satisfaction with the thermal environment and is assessed by subjective evaluation'[6]. Consequently, thermal comfort is then a measure of physiological and psychological well-being.

Reflecting on the Constitution of India and the various definitions, Thermal Comfort is one of the basic tenets of adequate housing. Therefore, recognizing and underscoring 'Thermally Comfortable Housing for All' as a National Mission is imperative. The National Mission status will provide a top-down impetus critical for realization of the Thermal Comfort Action Plan.

An enabling policy environment paves way for a robust implementation framework

[6] Standard 55.-Thermal Environmental Conditions for Human Occupancy https://www.ashrae.org/technical-resources/bookstore

Table 1outlines the actions necessary for developing an enabling policy framework and expected outcomes that fulfil the key objectives.

Table 1 Action matrix: Enabling policies

Track	Enabling policies
Objective	To foster a conducive environment towards implementation of Thermally Comfortable housing in India
Action	Recognize and define adequate housing to formally include thermal comfort. Prioritize thermally comfortable housing at national level on a mission mode.
	Develop policies that mobilize finance, and channel research and development into thermally comfortable homes.
	Leverage synergistic policies and establish linkages for key policies to catalyse uptake and implementation of action plan. Some of the key policies are National Action Plan on Climate Change (NAPCC) National Mission on Sustainable Habitat (NMSH).
Outcome	Thermally comfortable homes will find way in key policies, infrastructure upgrades, budgetary allocations and, promote inter-ministerial collaboration and Centre-State alignment. Co-benefits would include climate resilience, alignment with SDGs, Paris Agreement and Nationally Determined Contributions.

4.

Implementation Framework

4 Implementation framework

Housing is a state subject under the jurisdiction of MoHUA. Therefore, MoHUA is envisaged as the nodal agency for the implementation of the Thermal Comfort Action Plan. Along with its key agencies, MoHUA is expected to set-up a secretariat from where it can lead the implementation of the Thermal Comfort Action Plan.

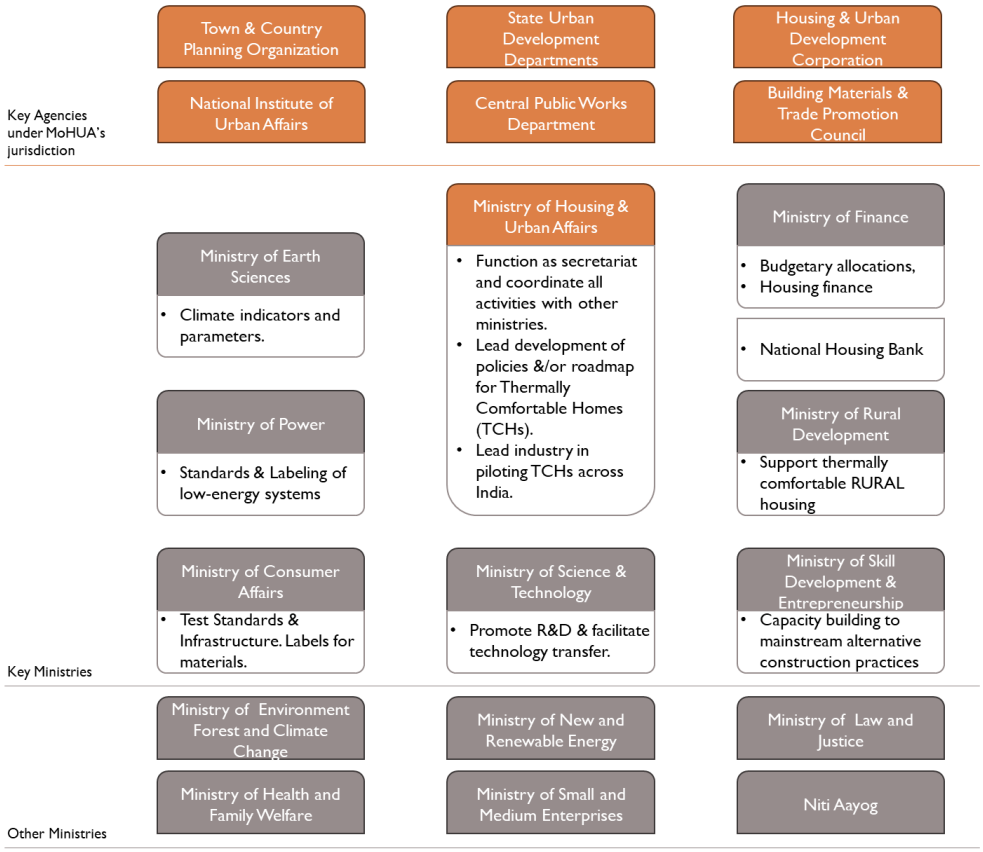


Figure 4 The implementation of the Thermal Comfort Action Plan will be led by MoHUA as the nodal ministry, and supported by other agencies (from within MoHUA) and several other ministries.

A high-level framework for the implementation of Thermal Comfort Action Plan envisages secretariats at Centre and State for planning, sanctioning and

monitoring activities, and local agencies at municipal level for on-ground execution.

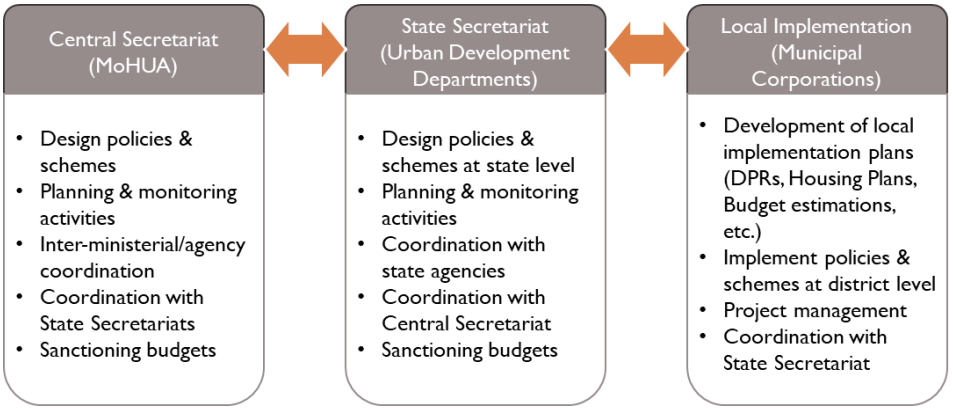


Figure 5 High-level implementation framework that spans from Central Secretariat to Municipal Corporations for seamless execution of the Thermal Comfort Action Plan

A detailed list of actions for setting up an Implementation framework and expected outcomes is presented in Table 2.

Table 2 Action matrix: Implementation framework

Track	Implementation framework
Objective	To develop a hierarchical administrative framework that ensures successful implementation of the Action Plan.
Actions	MoHUA is suited to function as the nodal agency or secretariat for implementation of the Thermal Comfort Action Plan. This secretariat will be responsible for vision setting, overall governance and inter-ministerial coordination.
	Set-up a hierarchical framework that reflects India's federal structure and ensures smooth coordination between the planning (i.e. Centre and State) and implementing (ULBs, Municipal Corporations, etc.) units.
	Set-up administrative bodies on similar lines with PMAY that has Sanctioning and monitoring committees at Centre and State level and implementation agencies at district level.
	Conduct capacity building at different levels in collaboration with academia and private sector to develop a cadre of professionals capable of executing the Action Plan.

	Complement administrative framework with IT systems that can facilitate budgeting, project tracking, training (through e-learning modules), etc.
Outcome	Administrative machinery that complements India's federal structure and is capable of on-ground implementation, monitoring and verification of the Thermal Comfort Action Plan and other allied government policies.

5.

Urban Environment

5 Urban environment

For improving the effectiveness of design interventions at the building resolution, they must be complemented with favorable microclimatic conditions. Micro-climatic conditions have the potential to enhance, mitigate, or intensify comfort conditions. Suitable interventions in urban planning and policy can reduce the stress at building level and promote the effectiveness of passive measures. These are especially critical as we move towards large scale housing developments.

5.1 Key planning aspects

This section provides an overview of key urban planning aspects that are fundamental to development of livable urban microclimates, which in turn are vital to maintaining thermal comfort in the built environment. This serves as complementary background information to the action matrix.

5.1.1 Green spaces – micro-and macro-scale vegetation

1. *Building integrated - Green Roofs and Green Walls*

   Green roofs and walls are living plant systems that are installed on the rooftops and facades of buildings. The roofs can be intensive with deeper layer of vegetation and variety of plants depending upon the thickness of the soil, whereas green walls have smaller plants/moss attached to it. It can have a range of benefits from reduced indoor overheating, improved air quality, increased energy efficiency to increased bio-diversity.

   Urban planning guidelines should introduce novel ways of integrating vertical landscaping in urbanscapes. Laying down provisions for urban farming presents a viable opportunity to integrating vertical landscapes.

2. *Vegetation around buildings*

   Vegetation cover around the built environment provides shade to buildings, surroundings and pedestrians. In addition, vegetation reflects solar radiation and evaporatively cools the surrounding due to evapotranspiration. The integration of vegetation around the built environment reduces heat accumulation in urban materials such as buildings and roads and significantly helps in reducing Urban Heat Island Effect.

   Therefore, urban planning guidelines for warm climates should specify minimum tree-canopy cover and landscape area for residential plots.

3. *Selective planting*

   The varying nature of vegetation, by season - by species, provides opportunities for thermal comfort in buildings. These may be used for

providing shade, obstructing wind flow, or vice versa. Therefore, recognizing the diversity in plantation and their application specific to climate and geography is critical.

Urban planning guidelines should outline the function of species and their placement in masterplans. Planting in delineated areas can be beneficial in mitigating climatic impacts while providing a host of co-benefits.

4. *Microclimate – Urban parks ('Cold islands'), City parks, urban farming, green corridors for transport*

Large green areas with vegetation acts as heat buffers with different effects on local climate. These are also known as cool islands. These provide better thermal perception and provide coolness to nearby areas. Whereas, city parks provide with thermal comfort in the local context (Community level).

Urban farms are a practice of producing food within urban areas. These can be done in vacant/barren lands and under-utilized urban areas. These can serve as green islands in the urban context and can protect surfaces from direct solar radiation. If practiced on a large scale then it can benefit in reducing UHI at urban level.

Transport corridors are often open spaces that can be used as ventilation paths to introduce fresh air into the urban area and/or help remove the accumulation of heat through plantation of different species of trees.

City masterplans for warm climates should accommodate macroscale urban greening in and around cities to improve thermal comfort. Macroscale greening may also be beneficial in cold climates where these forested parcels can create barriers to cold winds.

5.1.2 Blue spaces – Urban water bodies for mitigating climate impacts

1. *Preserving ponds, lakes, wetlands*

Natural water surfaces can act as a cool sink and prevent overheating of urban areas. Preserving ponds, lakes and wetlands can be beneficial as it can absorb thermal energy from solar radiation due to its heat capacity. These can lessen the accumulation of heat and thus reduce UHI.

2. *Preserving/Developing catchment areas*

A water catchment area is a land area that blends with the natural surroundings and collects rainwater. It then channels this water to other water sources. Water masses have a high heat capacity and can absorb thermal energy from solar radiation. This helps in avoiding

overheating of land surfaces, which in turn contributes to reducing the urban heat island (UHI) effect and improving outdoor thermal comfort for occupants.

5.1.3 Built form

1. *Sun, wind and sky - Protecting solar and wind access*

Sunlight and wind are necessary for well-being and comfort. Therefore, protecting sun and wind access is imperative. Inability to access sunlight will impact daylight performance and potentially thermal comfort. EN 17037 requires building occupants receive a minimum of 1.5 hours of direct sunlight exposure per day. While solar access is important its benefits must be balanced with its overheating potential.

Similarly, limited wind movement around buildings due to obstructions can lead to poor ventilation and consequently over-reliance on energy consuming mechanical means to move air. Urban planning must ensure solar and wind access for all.

Sky-view factor (measured from 0-1) is the fraction of sky visible from the point of observation. A higher sky-view factor implies not only higher potential of solar radiation incidence during sunshine hours but also higher potential of night-time radiation rejection (to the sky) or nocturnal cooling. While night-time sky cooling is effective, the primary strategy for warm climates in India should be to avoid trapping heat during sunshine hours.

Urban planning should evaluate sky exposure in existing/planned developments.

2. *Building arrangement*

A possible cause of increase in UHI is an improper building arrangement that can reduce the wind speed and thus increase the thermal capacity of the city. In warm climates, it is important that the buildings (and more importantly the openings) are perpendicular to the prevailing wind and at the same time do not block access to the surrounding buildings. Conversely, in cold climates, building arrangements must shade against cold winds. Unplanned arrangement can impact ventilation and adversely impact thermal comfort in buildings.

Geographic considerations also play key role in planning. For example, in coastal climates that experience hot-humid conditions and where ventilation is key, planning for sea breeze is an important design criterion.

3. *Building porosity*

   In warm climates, providing adequate openings or gaps in the buildings can be beneficial in maintaining the airflows and reducing wind shadow areas. This can reduce trapped heat and improve thermal comfort.


Green Transport Corridors
Acts as ventilation paths for fresh air in urban areas
Green roofs and walls
Living plant systems for low indoor overheating, increased biodiversity and air quality
Vegetation around buildings
Shades buildings, surroundings and pedestrians
Building Porosity
Adequate openings/gaps reduce wind shadow areas
Urban greens and parks
Green areas with vegetation acts as heat buffer between built spaces
Urban Water Bodies
Reduces urban heat through evaporative cooling

Table 3 outlines the actions necessary to maintain liveable urban environments.

Table 3 Action matrix: Livable environments

Track	Liveable urban environments
Objective	To foster Thermally Comfortable urban habitats that mitigate the impact of not only the existing harsh climate, but also, the impending climate change.
Action	Urban and Regional Development Plans Formulation and Implementation (URDPFI) guidelines present recognize Climate Change Mitigation and Adaptation (Section 6.2 of URDPFI vol 1), but do not provide concrete measures for town planners. Set-up Technical Committees with the powers to update URDPFI Guidelines to complement the proposed Design Standard for Thermal Comfort performance (DS(TCP)). Key recommendations from the proposed DS(TCP) that may be included in the updated URDPFI: • Vegetation integrated into built-environment and surroundings, • Reflective surfaces for roofs, walls, and roads and pavements, • Wind and solar access, and, • Building shading The guidance should provide a framework to accommodate climate and geographic diversity of India.
	In line with climate change adaptation requirements stated in URDPFI guidelines, Masterplans accommodate actions for tree cover, reflective paving, buildings (built to edge) with shades over pavements, etc. However, their translation into building bye-laws, monitoring framework for on-ground implementation and maintenance must be developed. Climate Smart Cities Assessment Framework (CSCAF) is a potential avenue to accommodate such metrics.
	Urban planning must prioritize cluster planning approach that utilizes low-rise high-density development. This is recommended in URDPFI and IS 8888 - 1(1993) – Guide for requirements of low-income housing.
	Weaving urban parks, water-bodies, urban farms in and around residential land use to improve micro-climate.

	Policy programs to advance adoption of Cool Roofs, Cool Walls, District Cooling, etc. for urban hot-spots
	An assessment framework on the lines of CSCSAF, or within CSCAF that objectively measures urban planning on indicators such as, • Number of urban hotspots (by intensity – peak temperature reached, days/hours of above a temperature threshold). • Tree cover per acre of residential land use, • Dwelling units per acre of residential land use, • Green (or soft paving) as percentage of total paving. • Reflective pavements, walls and roof-tops per acre of residential land use, • Adverse heat events, etc.
	Urban plans to mandatorily provision for, • wind and solar access for buildings, and, • tree canopy cover.
	Mainstream use of technology for acquiring data (spatial and non-spatial) such as land surveys, weather data, mapping urban hot-spots, tree cover, etc. Usher in development of digital twins and city-level models for objectively assessing strategies before implementation.
	Develop capacity (say in Institutes of eminence) to develop a new age of professionals that specializes in developing sustainable micro-climates (especially for residential land-use) mitigating climate change and its impacts
	Urban retrofit programs Priority framework
	Capacity building – Institutes of eminence
Outcome	Favourable urban micro climates that complement passively designed buildings and enhance thermal comfort. This is an outcome of, 1. Technology and data driven urban planning. 2. Alignment of bye-laws with urban planning 3. New age professionals that prioritize and balance climate change and its impacts with other urban planning concerns.

6.

Built Environment

6 Built environment

The exponents of 'Passive design', i.e. layout, building envelope and form are the primary tools to achieve comfort indoors with minimal use of mechanically operated thermal comfort systems. An efficient envelope, alone has the potential to moderate internal temperatures to reduce demand for cooling and/or heating. Prioritizing passive design as the primary intervention reduces dependence on energy systems for maintaining indoor comfort.

While a degree of indoor comfort can be achieved with passive design and adaptive comfort principles, this may not suffice and necessitate mechanical means for achieving comfortable conditions especially during periods of heat/cold stress. These systems have the potential to supplement comfort to further improve living conditions. While improving living conditions is a wholesome goal it must not come at the cost of environment. Therefore, low-energy cooling and heating systems that have low reliance on energy supply systems are key to comfort and resilience.

6.1 Key design aspects

This section provides an overview of key design aspects that are fundamental to maintaining thermal comfort in the built environment. This serves as complementary background information to the action matrix.

6.1.1 Shading

Shading such as canopies, louvres, blinds, roof overhangs etc. can be incorporated on building or around building envelope to control the amount of direct solar radiation entering the indoor space and as well as block and diffuse the reflective radiation of the envelope. The design of shadings is a function of temperature and radiation intensity. While the goal is to fully avoid unnecessary gains through shading, shading itself has its limitations. Exterior movable shading devices that can be controlled on demand have the potential of overcoming some of these limitations.

Since windows are a major source of heat gain in both warm and cold climates in India, Building bye-laws must enforce shading.

6.1.2 Thermal Mass and Insulation

Thermal mass is the ability of an object to retain heat. Building materials with high capacity to store heat, dampen the impact of external temperatures to maintain comfortable condition indoors. Thermal mass is feasible when diurnal range or difference in daily maximum and minimum temperature exceeds 6°C.

If the use of thermal mass is impractical or its effectiveness is insufficient, proper building insulation becomes an appropriate alternative. Insulation works by reducing the rate of heat transfer through the building envelope. This means that in the summer, insulation helps to keep the building cool by preventing heat from entering from the outside. In the winter, insulation helps to keep the building warm by preventing heat from escaping to the outside. The impact of insulation on thermal comfort is most significant in extreme climates. In hot climates, insulation can help to keep buildings cool and comfortable, even without air conditioning. In cold climates, insulation can help to keep buildings warm and comfortable, even with limited heating.

6.1.3 Cool surfaces

Cool surfaces (roofs, walls and pavements) are reflective and emittive in nature and therefore sustain lower surface temperatures compared to other surfaces. and surfaces that are able to reduce the surface temperature. Since the temperatures are lower the resulting heat transfer (from roofs and walls) to the indoors is lower. In warm climates this is helpful in offsetting peak temperatures and maintaining relatively comfortable conditions indoors.

Bye-laws should promote reflective or *'cool'* surfaces in warm climates and absorptive surfaces in cold climate.

6.1.4 Natural Ventilation

Natural ventilation is a way of providing fresh air into buildings by using the natural forces of wind. Natural ventilation can lower the indoor temperature and humidity in hot weather by extracting heat from the indoor air and releasing it outside. This can make the occupants feel more comfortable and reduce the need for mechanical cooling.[7]

6.1.5 Building sealing

Proper sealing and insulation of buildings can help reduce heat gain/loss, enhance comfort, and prevent moisture damage. Good airtightness can improve thermal comfort and energy-efficiency by reducing air leaks.

[7] Zaniboni, Luca & Albatici, Rossano. (2022). Natural and Mechanical Ventilation Concepts for Indoor Comfort and Well-Being with a Sustainable Design Perspective: A Systematic Review

6.1.6 Low-energy systems – Ceiling fans, Evaporative cooling, Radiant systems, Desiccant cooling, Heat Pump

Ceiling fans are devices that can improve human thermal comfort by increasing the air speed and enhancing the heat transfer from the body. Ceiling fans help improve indoor comfort as it helps in the circulation of air in the space.

Evaporative cooling systems are devices that cool the environment through the evaporation of water. Evaporative cooling dampens the positive effect on thermal comfort by eliminating heat or reducing temperature on the surface of the body's skin. In hot environments, evaporative cooling can play a role in creating a calming effect.

Radiant systems are a type of heating and cooling system that use radiation to transfer heat to or from the occupants in a building. Radiant systems can provide equal or better thermal comfort than all-air systems as creates a more uniform and stable indoor environment, and allow occupants to adjust their personal comfort level by moving closer or farther from the radiant surfaces.[8]

By using a dry substance to dehumidify the air and then cool it with evaporation or heat transfer, desiccant cooling systems can use low-quality heat sources like solar, waste heat, or district heating. They save energy and are eco-friendly, and they also avoid moisture issues and improve air quality.[9]

A heat pump is a device that transfers heat from a cold source to a hot one, using electricity. It can be used for heating or cooling buildings, depending on the season. Heat pumps can affect thermal comfort in different ways: Heat pumps produce hot water at lower temperatures than gas boilers.

[8] Caroline Karmann, Stefano Schiavon, Fred Bauman,
Thermal comfort in buildings using radiant vs. all-air systems: A critical literature review, Building and Environment, Volume 111, 2017

[9] Parmar, Haresh & Hindoliya, Dev. (2011). Desiccant Cooling System for Thermal Comfort: A Review. International Journal of Engineering Science. 3.

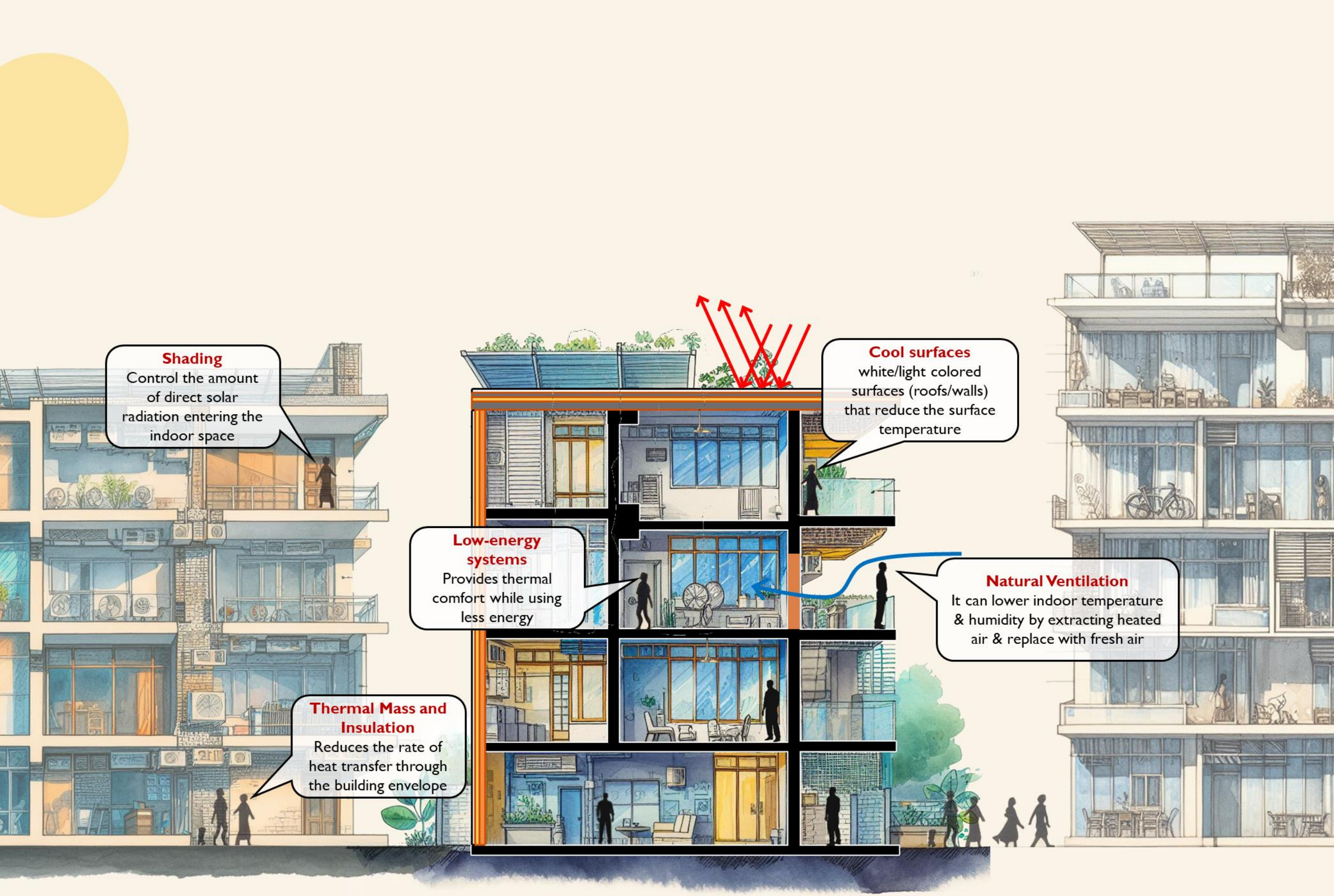

Shading
Control the amount of direct solar radiation entering the indoor space
Cool surfaces
white/light colored surfaces (roofs/walls) that reduce the surface temperature
Low-energy systems
Provides thermal comfort while using less energy
Natural Ventilation
It can lower indoor temperature & humidity by extracting heated air & replace with fresh air
Thermal Mass and Insulation
Reduces the rate of heat transfer through the building envelope

Table 4 outlines the actions necessary to maintain liveable built environment.

Table 4 Action matrix: Built environment

Track	Built environment
Objective	To mandate passive design in buildings and promote use of low-energy systems for enhancing comfort
Action	Set-up a technical committee to update the National Building Code (NBC) and Model Building Bye-laws (MBBL) to accommodate provisions from the proposed Design Standard for Thermal Comfort performance (DS(TCP)).
	Adopt and mandate DS(TCP) in all government housing schemes undertaken by the government. This would require central agencies (such as CPWD) to develop/update: 1. Standard tender documents to include requirements for compliance with DS(TCP), 2. Standard specifications for material bundles included in DS(TCP), 3. Standard Schedule of Rates for material bundles included in DS(TCP)
	The government, through its agencies can lead the implementation of DS(TCP) with Light-house/Demonstration Housing Projects. These pilot-projects will serve as living laboratories/case studies for private sector and state government agencies. This will provide a fillip to the adoption of DS(TCP) compliant buildings.
	Set-up technical committees at the State/Municipal level to adapt the proposed DS(TCP) in line with local requirements and notify for implementation. Build technical capacity among civic agencies for evolving building approval systems to include DS(TCP).
	Build technical capacity for design professionals, construction agencies, central/state government agencies in design and construction of DS(TCP) compliant buildings. Build technical capacity among civic agencies for evaluation, verification, and inspection of building permit applications.
	Develop framework for accreditation of construction professionals. State Urban Development department to provide training, testing and accreditation of professionals. Online systems to host electronic training content,

administer tests and maintain registry of accredited professionals.

Develop online compliance evaluation frameworks for facilitating compliance application process.

Develop schemes that promote DS(TCP) compliant homes. Schemes may provide operational, financial or other incentives.

Operational incentives may include fast-tracking land availability, single-window clearances, etc.

Financial incentives may include, subsidies, tax breaks, production linked incentives, etc.

Conduct outreach and awareness campaigns targeting end-users, private developers and other stakeholders. These awareness programs shall outline the benefits of DS(TCP) compliant homes, and in turn drive up the demand.

Build infrastructure to develop,

- new-age materials (phase change, nano particles, etc.),
- construction techniques and technologies, and,
- alternate materials and construction practices that are empirically known to promote thermal comfort,
- advanced cooling and heating technologies and equipment,
- dynamic building controls (for kinetic facades, building shades, dynamic insulation, etc.)

Infrastructure will include laboratories for research in the fields of Building Physics, Building Materials and Construction Techniques and Technologies.

This research ecosystem requires partnerships between the academia, industry and government.

Mobilizing finance for developing infrastructure for research and conducting research in new materials, construction technologies, cooling/heating systems require financing.

Finance can be mobilized as technology grants, competitions, industry partnerships etc. with support from government, private sector and bi/multi-lateral agencies.

Develop ecosystem for piloting, scaling and marketing new technologies. This ecosystem will

Global Housing Technology Challenge (GHTC) and Global Cooling Prize are examples of efforts to incubate technologies. Other technology incubation efforts could

	come through enabling start-up ecosystem in construction that channels venture capital.
	Develop an ecosystem for labelling construction assemblies for thermal comfort performance. This ecosystem will require setting up an agency that is responsible for issuing label, market surveillance and maintaining product registry. To complement this framework, develop standards (for testing and thermal comfort performance) and testing infrastructure across the country.
	Develop a national material database of thermal properties of commonly used products that accounts for variation in performance due to diverse characteristics of raw material and manufacturing practices. This database will facilitate ULBs to adapt construction bundles in DS(TCP) to the regional context.
	Establish skill development centres that enable adoption of new construction techniques and technologies. Ability to successfully execute thermally comfortable homes tat are durable as well is important for credibility and consumer confidence.
	Develop a roadmap for achieving thermal comfort in rural housing as well. Focus on, 1. traditional techniques and technology, 2. skill development within the community and emphasis on community-built homes to maintain affordability*, 3. developing agri-waste construction products to develop low-carbon and low-cost building materials aimed towards local use. *Rural economy focuses on agriculture that implies availability of labour in off-season. Incentivising community-built homes through rural employment schemes (such as MGNREGA) will not only skill agricultural labour, but also provide a secondary income stream. Utilizing agri-waste can further improve affordability.
	Extend BEE Star labelling to Evaporative Coolers and other low-energy systems.
Outcomes	Passively designed homes that utilize low-energy systems to meet higher standards of adaptive thermal comfort in both urban and rural context.

- Demand and awareness of thermal comfort, thermally comfortable homes (and performance levels).
- Adoption of DS(TCP) in national and municipal frameworks.
- Government led implementation of DS(TCP) pan India.
- Empowered professionals, construction and civic agencies that design, construct and certify thermally comfortable homes. Streamlined compliance documentation process add to the experience.
- Developed and mature construction market for products suitable towards advancing thermal comfort. Mature construction market entails,
    - Awareness for products that promote thermal comfort.
    - Reliable products (labelled after due testing) that meet thermal performance.
    - Reliable supply chains and delivery mechanisms,
    - Mechanisms for accelerated technology transfer to market.
    - Readily available capital/finance incubate and scale revolutionary technologies/products
- Low-carbon, thermally comfortable, affordable and community built rural homes.

7.

Impact of Action Plan

7 Impact of Action Plan

The strategies outlined in the action plan have the potential to improve comfortable conditions indoors by up to 25% (considering degree discomfort hours as a comfort metric). Central to comfort improvement are improvement in health, well-being and productivity. But these impacts are not limited to only comfort. Built on the foundations of passive design, these thermally comfortable homes have the potential to improve energy efficiency in the housing stock and reduce dependence on fossil fuels. This section outlines the technical potential for energy savings, emissions and demand abatement, and cost savings envisaged from the implementation of the Thermal Comfort Action Plan

For a background to the analysis, the thermal comfort performance levels are introduced. The performance is outlined in the Design Standard for Thermal Comfort performance and has been outlined here. The Design Standard for Thermal Comfort Performance outlines three levels of Thermal Comfort Performance:

1. Level A implies minimum thermal comfort achieved by passive design means only. These means are reflective of no cost improvements over a business-as-usual case.
2. Level A+ implies enhanced thermal comfort performance that includes additional cost measures such as thermal insulation in envelope assemblies and improved glazing products.
3. Level A++ implies high level of thermal comfort performance with further improved envelope assemblies (i.e. better insulation and double glazed window assemblies). While, the standard mandates only low-energy systems for level to supplement comfort requirements for Level A++, it has been ignored for impact assessment. The omission will only lead to more conservative outcomes.

In contrast, business-as-usual case represents poor thermal comfort performance resulting from current construction practices. For the purpose of analysis, the impact evaluates the potential of energy saving, demand abatement and cost avoidance considering all cases are air-conditioned.

For the impact assessment, 2 cases have been modeled;

1. business-as-usual case that assumes no change in prevalent construction practices, and,

2. a progressively improving building stock. The progressive improvements in building stock refer to the improvements in Thermal Comfort Performance.

The progressive improvements are expected outcome of implementation of Thermal Comfort Action Plan. This progressively improving stock model is or PrISM. PrISM has been presented in Figure 6.

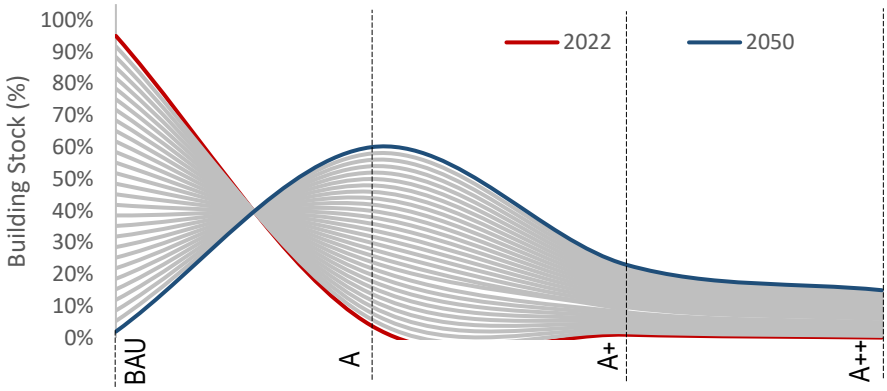


Figure 6 The distribution of stock changing from 2022 – 50 across different levels of thermal comfort performance has been modeled. It is assumed that the Thermal Comfort Action Plan will have been successfully implemented and in 2050 the BAU (i.e. thermally uncomfortable) stock will be completely replaced.

The PrISM assumes, in 2050, implementation of the action plan will result in around 60% of the building stock achieving Level A performance, while over 20% and 15% stock will comply with Level A+ and A++ thermal comfort performance respectively. It is expected that interventions across the different objectives outlined in the action plan will result in significant improvement in the level of thermal comfort in residential dwellings, thereby meeting higher thermal comfort standards. The performance benchmarks of Energy Use Intensity (EUI) in kWh/m^2-yr, cooling and heating demand in kW/m^2 and financial impact of savings in energy use and demand abatement have been analyzed.

Energy Use and Demand: Potential Savings

The energy use savings over business as usual (BAU) case have been presented in Figure 2. A major portion of the country is spread across Composite and Warm-Humid climate. The technical potential of the action plan across different climate zones shows that maximum potential for energy use savings is possible in Warm-Humid climate followed by Composite climate, up to 13 billion GW and over 10 billion GW respectively, by 2050. Cold climate shows lowest potential of energy use savings due to lower EPI and significantly low residential stock.

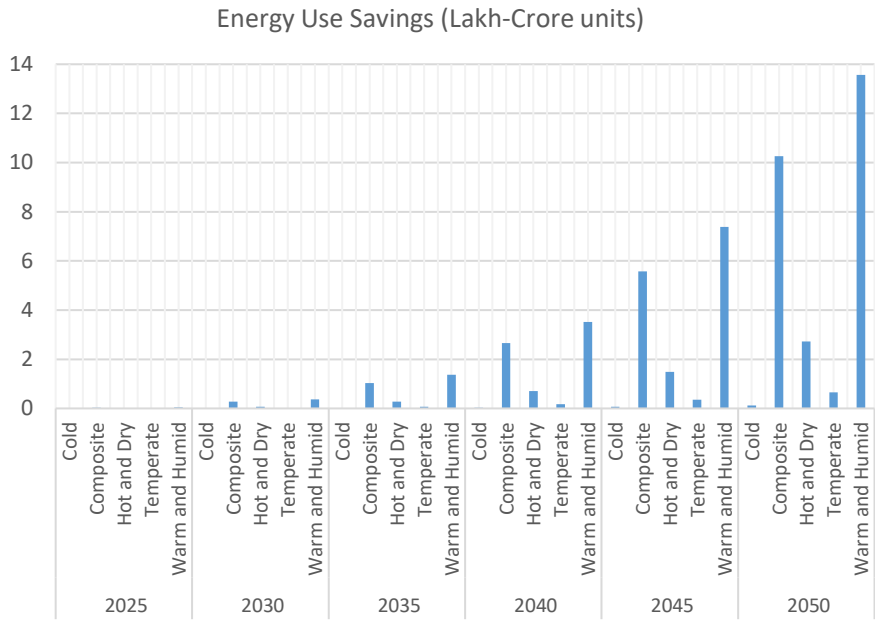


Figure 7 Energy use savings potential in different climates

The action plan is further expected to provide both cooling and heating demand potential upon aggressive implementation and uptake. Similar to energy use savings, highest demand abatement potential is expected across Composite and Warn-Humid climate zones, of up to 22 TW and 29TW respectively up to 2050.

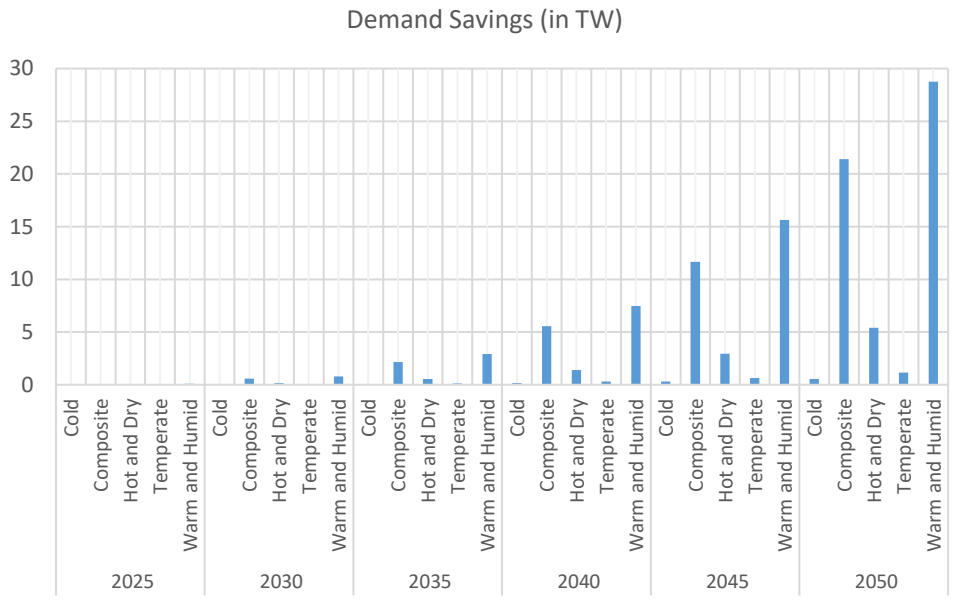


Figure 8 Demand savings potential across different climate zones

The potential savings in energy demand is expected due to use of strategies such as alternate building materials for construction, use of low-energy comfort systems and passive design strategies to improve comfort conditions. These strategies allow for enhanced comfort of occupants while making sure that comfort is not achieved at the expense of higher energy consumption.

Financial Impact of Action Plan: Energy Use Cost Savings

While an aggressive push for alternate strategies to improve comfort clearly indicate potential to realize savings in energy use and energy demand, it should be ensured that this does not financially impact the end-user. The savings potential of energy use cost has been explored and presented in Figure 4.

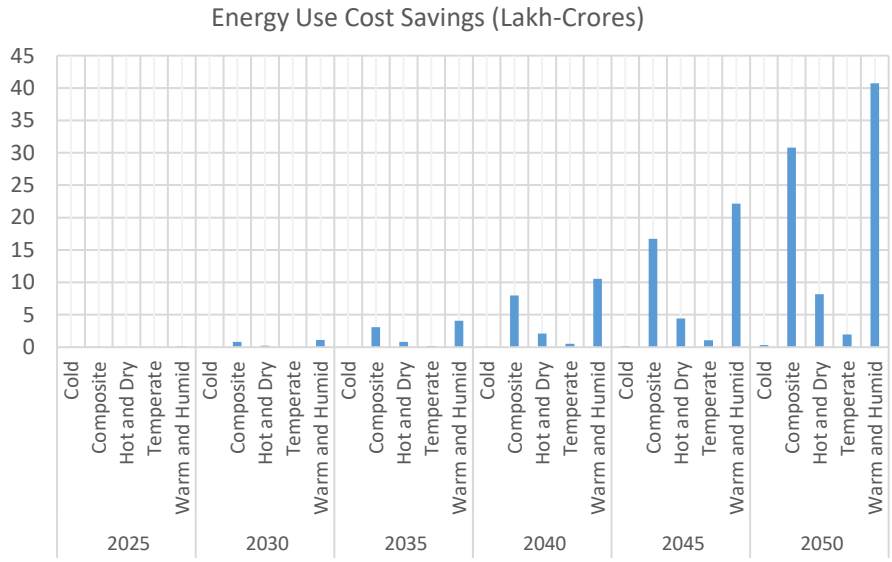


Figure 9 Energy use cost savings potential across different climate zones

As per the projections, aggressive uptake of the action plan is expected to potentially lead to savings up to 40 lakh crores, in Warm-Humid climate, followed by up to 20 lakh crores in Composite climate by 2050. These potential savings are a result of savings in energy use. It should be noted that use of traditional construction practices further has the potential to reduce the cost of construction of thermally comfortable homes across India. Furthermore, passive design strategies have the potential to reduce the costs due to reduction in requirements of active cooling and heating required to achieve comfort.

The impact assessment study has provided quantitative benefits of energy and cost savings, and, emission and demand reduction. There are however other intangible benefits to rolling out the action plan.

The Thermal Comfort Action Plan is envisaged to generate demand for thermally comfortable housing and sustainable townships and in turn provide a fillip to the construction industry. It is expected to open up the industry to research and innovation in new materials, construction practices and techniques. It is also

expected to revive existing tradition materials, construction practices and techniques that are empirically known to promote thermal comfort. The sheer volume of shortage is expected to bring economies of scale, combining the unlikely pair of comfort and affordability. This extends to second-order benefits of improved living conditions and long-term economic development.

8.

Key Takeaways

8 Key Takeaways

1. The Thermal Comfort Action Plan sets out with a progressive vision for ensuring Thermally Comfortable Housing for all. As equity demands, this vision applies to all residential development.
2. Combining the telling effects of climate change, rampant urbanization and climate unfriendly construction practices, heat stress is no longer limited to the outdoor environment. Given the context, right to shelter enshrined in the Indian constitution is inadequate. Therefore, for safeguarding lives, Thermal Comfort, among other things, must be recognized as one of the basic tenets of adequate housing.
3. Distinguishing 'Thermally Comfortable Housing for All' as a National Mission will provide a top-down impetus critical for implementation of the Thermal Comfort Action Plan.
4. The Thermal Comfort Action Plan has progressive objectives that focus on
    a. Developing a conducive policy environment for implementation of Thermal Comfort Action Plan,
    b. Building on the foundation of policy environment, the Thermal Comfort Action Plan proposes developing an administrative framework for ensuring coordinated and smooth implementation,
    c. With an implementation framework in place the, Thermal Comfort Action Plan proposes prioritizes interventions at urban scale based on sustainable planning principles,
    d. Finally, urban environments planned on sustainable principles leverage the benefits of passive design to meet thermal comfort goals

Figure 10 Progressive objectives, each building on previous to reinforce implementation of TCAP and realise the vision of Thermally Comfortable Home for All

5. MoHUA is suited to assume the role of nodal agency, bringing together state agencies, other ministries at the centre and stitching international cooperations.
6. The implementation of the Thermal Comfort Action Plan shall require a dedicated secretariat at the Centre helmed by the nodal agency. The Central Secretariat will require representation at the state level for close coordination. The representation at state, i.e. the State Secretariat is expected to work closely with municipal corporations for implementation. The structure of this hierarchy, roles and responsibilities of members is critical to the successful implementation of the Thermal Comfort Action Plan.
7. It is essential to involve urban planning agencies in developing city master plans that promote thermally comfortable urban habitats in the city. Creating a conducive urban microclimate is the first line of defence against harsh climate, as even the most climate conscious buildings have limited potential of achieving thermal comfort in detrimental microclimates. A microclimate that moderates the extreme impacts of climate can lead to better thermal comfort outcomes indoors. Some of the key measures that may be adopted are
    a. A revision of Urban and Regional Development Plans Formulation and Implementation (URDPFI) guidelines to accommodate concrete measures for town planners (See Section 5.1 - Key planning aspects, outlining the planning measures that should be accommodated in URDPFI)
    b. Develop key metrics for evaluating climate resilience in urban planning. Frameworks such as Climate Smart Cities Assessment Framework (CSCAF) may accommodate these metrics for ranking cities.
    c. Adopt cluster planning approach to avoid high rise-high density residential developments.
    d. Scale cool roofs, district cooling and other startegies through city-wide policy action. A million cool roofs program may serve as an example.
    e. Mainstream use of technology for informed planning decisions. For example, developing digital twins of cities for mooting evidence-based strategies.
    f. Develop capacity to train new-age professionals in specialised as well as interdisciplinary fields to address climate change in planning cities and neighborhoods.

8. A favourable microclimate complemented with climate conscious buildings based on passive design principles improves indoor thermal comfort. Coupled with low-energy systems, thermal comfort can be further enhanced.
    a. Adapt bye-laws to include recommendations proposed in Design Standard for Thermal Comfort Performance (DS(TCP)) (See Section 6.1 - Key design aspects outlining the design aspects that building bye-laws should accommodate). Simultaneously, develop digital tools like online compliance frameworks to ease the onerous compliance processes.
    b. Government to take initiative and develop pilots for demonstration as light-house projects. The government may take up the role to create specification documents, schedule of rates and other construction documents such as tenders to encourage participation by private developers.
    c. Conduct capacity building for various audience groups – Design Professionals, Developers, Construction Agencies, Urban Local Bodies for development of Thermally Comfortable Homes.
    d. Develop accreditation programs for professionals involved in the compliance verification process for credibility in compliance processes.
    e. Outreach and awareness programs among end-users to generate demand for Thermally Comfortable Housing.
    f. Mobilize finance for thermally comfortable homes. Schemes for end-users, developers, manufacturers, and other stakeholders can provide a boost to the Thermally Comfortable Homes market.
    g. Set-up ecosystem for research and development in the domains of materials, construction technology and construction techniques. A network of accredited test facilities is also critical to the success of the research and development initiatives.
    h. Expand the scope of the DS(TCP) to include rural housing as well. Rural housing focuses on traditional construction techniques and is extremely cost-sensitive. Community built homes have the potential to offset the labour cost and/or provide secondary source of income for rural

communities. This must be supported by workshops on building techniques for rural communities.

i. It must be recognized, that across the board, self-constructed houses form a dominant proportion of the housing stock in low-income groups. Therefore, it becomes necessary to disseminate information to these groups on building typologies, material choices, design strategies for thermal comfort of the occupants. Privately constructed houses form the largest segment of PMAY houses but at the same time, the homeowners lack awareness of technical knowledge and infrastructural support in terms of comfort and sustainability. To improve this, formation of a communication network encompassing government bodies, designers, developers and homeowners is crucial.

9. The impact of implementing the Thermal Comfort Action Plan suggests a technical potential of 25 lakh crore units of electricity in 2050. In terms of electricity demand, a technical potential exceeding 55 TW exists.

The Thermal Comfort Action Plan aims to stimulate demand for thermally comfortable housing and sustainable townships, which could boost the construction industry. This plan could lead to research and innovation in new materials and construction practices, as well as the revival of traditional materials and techniques known for promoting thermal comfort. The high demand could result in economies of scale, making comfort and affordability possible. Improved living conditions and long-term economic development are potential secondary benefits.

While the plan suggests multiple strategies, a key aspect of this plan is to ensure thermal comfort without compromising the affordability for marginalized low-income groups, who are most vulnerable to climate change.

9.

Appendix

9 Appendix

9.1 Actions and timelines

	2025-30	2030-35	2035-40	2040-45	2045-50
Policy Development and Implementation	Setup Committee for Review	ULBs in Tier 1 cities amend bye-laws	ULBs in Tier 2 amend bye-laws	ULBs in Tier 3 cities amend bye-laws	Update mandatory performance levels to A++ in Tier 3 cities
Adopting TC Standard	Review MBBL for update	Implement Standard in Tier 1 cities	Implement Standard in Tier 2 Cities	Implement standard in Tier 3 cities	
			Update mandatory performance level to A++ in Tier 1 cities	Update mandatory performance level to A++ in Tier 2 cities	
Development of Rural TC Standard	Develop TC standard for rural housing	Setup committee for review	Implement standard in Panchayat jurisdiction	Update mandatory performance levels to A++	
		Review local DCRs			
Implement TC standard in state sponsored housing	Develop schedule of rates and specification of construction assemblies Develop standard contract documents	Pilot TCAH in all states	Mainstream standard in state sponsored housing		
Revise guidelines for adoption of passive design strategies	Setup Technical committee for review	States amend guidelines according to state requirements	ULBs enforce guidelines in Tier 1 cities	ULBs enforce guidelines in Tier 2 cities	ULBs enforce guidelines in Tier 3 cities

	Review local DCRs and adopt TC guidelines	Notify in gazette		
Include TCAP in Climate Action Plans	Setup committee for review	ULBs adopt TCAP into city climate action plans		
	Review SCAPs			
	Adopt TCAP into SCAPs			
Urban Planning	Identify key vulnerable urban centers	ULBs accommodate updated masterplans for implementation	Roll out plan in remaining urban centers based on feedback	
	Review urban planning guidelines	Conduct tree plantation drives	ULBs to conduct dedicated planting and maintenance of trees	
	Conduct tree census and identify hotspots	Setup local monitoring stations for post implementation assessments		Update stringency
	Review DCRs for update with minimum green cover requirements Update plans to include cool roads and pavements			
S&L programs	Identify materials for labelling	Develop standard for labelling	Mandate thermal performance values for star labelling	Mainstream star labelled products in Tier 2 and Tier 3 cities

	Identify low-energy comfort systems for labelling		Ensure market penetration of star labeled products in Tier I cities
Infrastructure Development	Draft policy for establishing TCASs	State TCASs established and notified	
Setup Thermal Comfort Action Secretariat (TCAS)	Notify in gazette	District level implementation bodies established and notified	
	Setup TCAS at Centre		