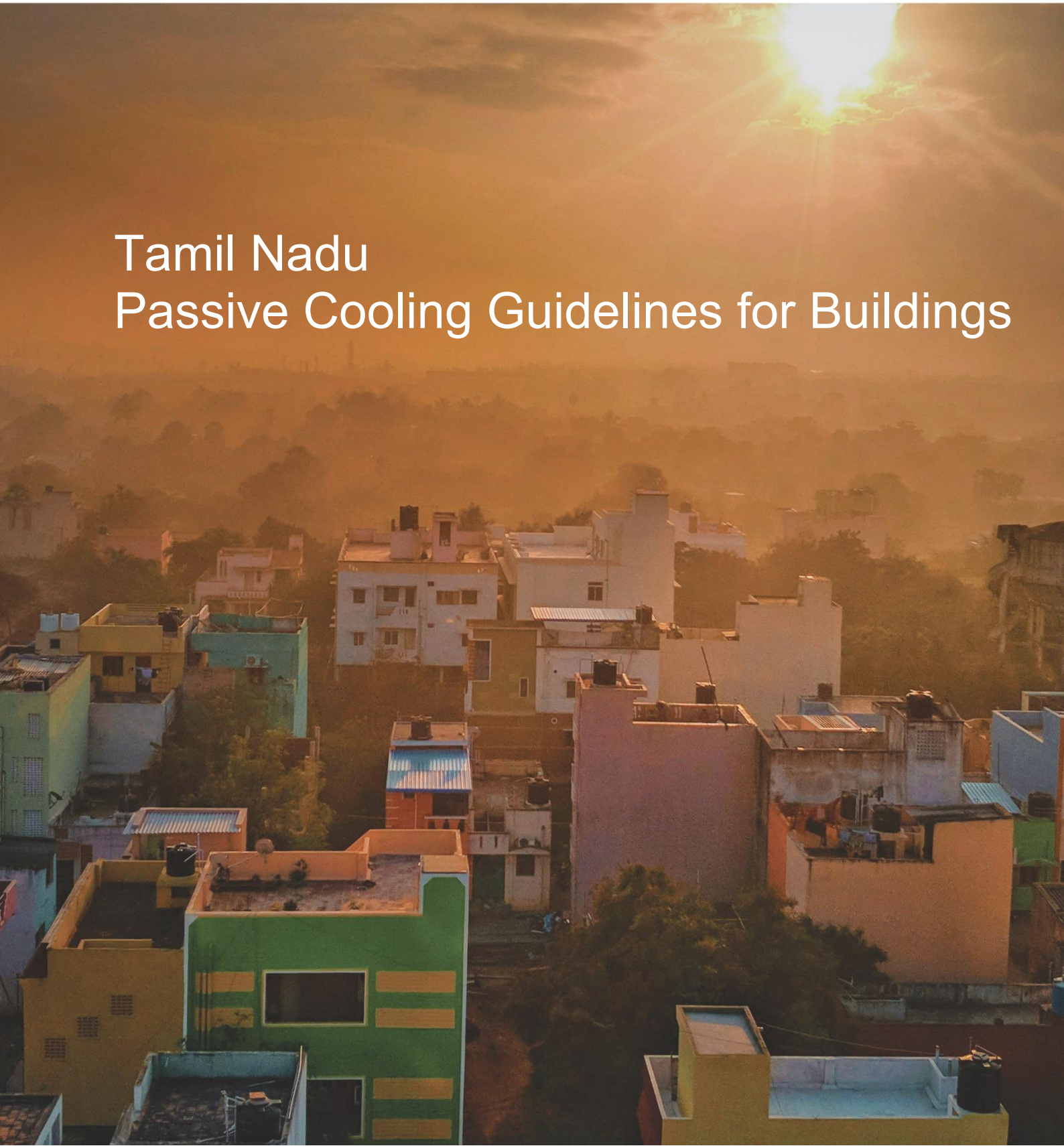
Tamil Nadu
Passive Cooling Guidelines for Buildings



Under the Framework of

Cool Coalition
a UNEP-convened initiative

Supported by

Schweizerische Eidgenossenschaft
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Embassy of Switzerland in India and Bhutan

Environment, Climate Change and Forest Department
Government of Tamil Nadu

TNGCC
Tamil Nadu Green Climate Company

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Tamil Nadu Green Climate Company

Acknowledgement

The Guidelines are prepared by the United Nations Environment Program (UNEP) for the Environment Climate Change and Forest Department (ECCFD), State Government of Tamil Nadu, to guide the building sector in Tamil Nadu towards design and construction practices that provide cost effective, climate friendly cooling and that protect against rising extreme heat. The guidelines have been developed as part of the BeCool project in India supported by the Swiss Agency for Development and Cooperation (SDC) India and under the framework of the Cool Coalition.

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The authors would like to acknowledge the leadership and guidance of the Environment Climate Change and Forest Department, Tamil Nadu and the Tamil Nadu Green Climate Company (TNGCC) in the development of these guidelines.

The authors would like to acknowledge the contributions and review from departments and officials of the State Government of Tamil Nadu including from Environment Forest and Climate Change Department, Tamil Nadu Green Climate Company, Housing and Urban Development Department, Public Works Department, Tamil Nadu Urban Habitat Development Board, Chennai Metropolitan Development Authority, Municipal Administration and Water Supply Department, Directorate of Town and Country Planning, Tamil Nadu Police Housing Corporation Limited.

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Thiru C Joseph Vijay
Hon'ble Chief Minister
Government of Tamil Nadu



Message

Tamil Nadu has consistently demonstrated leadership in addressing the impacts of climate change through proactive policies and people-centric initiatives. In 2024, our Government declared heatwaves as a State-specific disaster, recognizing the increasing severity of extreme heat and its implications for the health, livelihoods, and well-being of millions of our citizens. Protecting people, particularly vulnerable communities, from the adverse effects of rising temperatures and ensuring equitable access to sustainable cooling and heat resilience solutions remain key priorities of our Government.

We are implementing a range of initiatives to strengthen the State's preparedness against rising heat. These include scientifically assessing the vulnerability of our districts to extreme heat, strengthening the capacity of government departments to safeguard people, infrastructure, and natural resources, and formulating policies that will enable Tamil Nadu's transition towards a climate-resilient future. These efforts reflect our commitment to building a safer, healthier, and more resilient State.

The Tamil Nadu Building Passive Cooling Guidelines provide a comprehensive framework for integrating passive cooling into building design and construction. By combining traditional architectural wisdom with modern technologies, the Guidelines promote thermally comfortable, energy-efficient, and climate-responsive buildings. They also offer practical solutions for retrofitting existing buildings, making passive cooling accessible to communities that cannot afford energy-intensive mechanical cooling.

The Guidelines will play an important role in advancing Tamil Nadu's climate adaptation and mitigation goals. I urge government agencies, urban local bodies, architects, planners, engineers, developers, and the private sector to adopt these recommendations and work together towards creating heat-resilient buildings across the State. The Government of Tamil Nadu will continue to support and promote the widespread adoption of passive cooling practices.

I commend the Department of Environment, Climate Change and Forests, the Tamil Nadu Green Climate Company, the United Nations Environment Programme, and all partner departments and technical experts for their dedication and collaboration in developing these Guidelines. These Guidelines mark an important step towards building a cooler, healthier, and more climate-resilient Tamil Nadu.

Dr. V. Rajeev
Hon'ble Minister Environment and Climate Change,
Government of Tamil Nadu



Message

Tamil Nadu is one of India's leading economic and socially progressive States. Sustaining this progress requires building resilience to the growing impacts of climate change, particularly the increasing frequency and intensity of extreme heat. Without timely adaptation, rising temperatures will place significant pressure on public health, livelihoods, productivity, and energy systems, while increasing the financial burden on both citizens and the Government through higher cooling costs and growing electricity demand.

The social cost of inaction is even greater. Heat stress affects the health and well-being of our people, particularly vulnerable communities. Schools, healthcare facilities, housing, and other public buildings must be designed to provide safe and comfortable indoor environments that can withstand future climatic conditions. Improving thermal comfort is therefore not only an environmental imperative but also a social and economic necessity.

The Building Passive Cooling Guidelines provide practical and scientifically informed guidance for designing and retrofitting buildings that remain thermally comfortable with minimal dependence on energy-intensive cooling systems. By combining climate-responsive design, traditional architectural practices, and modern technologies, the Guidelines promote cost-effective, energy-efficient, and climate-friendly solutions. Their alignment with national building energy codes further supports Tamil Nadu's commitment to climate adaptation, sustainable development, and responsible resource use.

We cannot allow the impacts of climate change to undermine the remarkable progress achieved by our State and its people. I commend the Department of Environment, Climate Change and Forests, the Tamil Nadu Green Climate Company, the United Nations Environment Programme, and all partner institutions for developing these Guidelines. Their successful implementation will be an important step towards creating cooler, healthier, and more resilient communities across Tamil Nadu.

Tmt. Supriya Sahu, I.A.S,

Additional Chief Secretary, Department of Environment, Climate Change & Forests



Passive cooling can reduce indoor temperatures by 3–4°C while lowering cooling energy demand by up to 30% with little or no electricity use. It provides a sustainable pathway to create heat-resilient buildings, particularly for economically vulnerable communities. The Building Passive Cooling Guidelines offer a practical framework for integrating energy-efficient and climate-responsive design into buildings and can be incorporated within existing regulations, including the Tamil Nadu Combined Development and Building Rules (TNCDBR).

Tamil Nadu has begun implementing these Guidelines through the 'Pasumai Palli' (Green School) Programme, retrofitting 300 government schools with passive cooling solutions. I commend the Environment, Forest and Climate Change Department, Tamil Nadu Green Climate Company, UNEP, and partner departments for their support, and look forward to scaling these Guidelines across the State.

Dr. Balakrishna Pisupati,

Country Head, India, United Nations Environment Programme



The United Nations Environment Programme (UNEP) is pleased to support the development of the Building Passive Cooling Guidelines through the UNEP–SDC BeCool Programme under the Cool Coalition.

As extreme heat increasingly impacts public health, energy demand, and economic development, the UN Secretary-General's Call to Action on Extreme Heat highlights the need for scientific, climate-friendly cooling solutions that prioritize vulnerable communities. These Guidelines respond by strengthening the capacity of the building sector to adopt long-term, cost-effective passive cooling measures.UNEP remains committed to supporting state and city governments in advancing sustainable cooling across India. We commend the leadership of the Department of Environment, Climate Change and Forests, Tamil Nadu Green Climate Company, and all technical experts, and look forward to continued collaboration in promoting the widespread adoption of these Guidelines.

Mr. Philippe Sas,

Head of Cooperation, Counsellor Embassy of Switzerland in India and Bhutan



The Tamil Nadu Passive Cooling Guidelines for Buildings equip architects, engineers, and students with practical knowledge to design buildings that are thermally comfortable, energy-efficient, and resilient to rising heat stress. By promoting passive cooling measures, they offer practical solutions that can improve indoor comfort while reducing energy demand, particularly for vulnerable communities.

For over four decades, Switzerland has championed energy-efficient buildings and sustainable construction. Building on this experience, we work closely with Indian partners to co-develop and adapt global knowledge to local climatic conditions and policy priorities. We commend the Department of Environment, Climate Change and Forests, Government of Tamil Nadu, for its leadership in advancing sustainable cooling and climate resilience. The International Cooperation Office at the Embassy of Switzerland in India is pleased to support the development of these Guidelines through technical assistance under the UNEP-led BeCool Programme, in partnership with Tamil Nadu.

Tmt Asha Ajith, I.A.S,

Managing Director, Tamil Nadu Green Climate Company, Department of Environment, Climate Change



The Building Passive Cooling Guidelines promote low-emission passive cooling as a practical solution to address extreme heat and improve indoor thermal comfort. Based on climate data, energy modelling, and thermal performance assessments, they provide evidence-based recommendations for climate-responsive building design.

The Guidelines advocate thermally insulated walls and roofs, effective shading, and natural ventilation, with strategies tailored to different climatic zones and building types. They also include retrofit measures for existing buildings, considering future temperature rise and urban heat island effects to strengthen long-term heat resilience. I appreciate UNEP and the participating State departments for their technical and institutional collaboration in developing this important resource.

Thiru. Bakan Jagdish Sudhakar, I.F.S,

Chief Executive Officer (CEO), Tamil Nadu Green Climate Company, Department of Environment, Climate Change



The Building Passive Cooling Guidelines represent a significant milestone in advancing climate-resilient and energy-efficient buildings in Tamil Nadu. By promoting practical passive cooling strategies, the Guidelines support improved thermal comfort, reduced energy demand, and enhanced resilience to rising temperatures.

The Tamil Nadu Green Climate Company is committed to facilitating their adoption through policies, programmes, and partnerships across the State. Initiatives such as the 'Pasumai Palli' (Green School) Programme demonstrate the potential of passive cooling in both new and existing buildings. I appreciate the technical support of UNEP and the contributions of all partner departments and experts in developing this important resource for Tamil Nadu.

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List of Abbreviations

AAC – Autoclaved Aerated Concrete

ACH - Air Changes Per Hour

CFM – Cubic Feet Per Minute

CMDA - Chennai Metropolitan Development Authority

ECSBC– Energy Conservation and Sustainability Building Code

ECSBC-R – Energy Conservation and Sustainability Building Code - Residential

ECBC – Energy Conservation Building Code

ENS – Eco Niwas Samhita

ESCO – Energy Services Company

IMAC – Indian Model for Adaptive Comfort

kJ/m²K – Kilojoules per square metre Kelvin

NBC – National Building Code

NOC – No Objection Certificate

PCS – Passive Cooling Strategies

PF – Projection Factor

PWD - Public Works Department

RCC – Reinforced Cement Concrete

RH – Relative Humidity

SDC – Swiss Agency for Development and Cooperation

SHGC – Solar Heat Gain Coefficient

SoR – Schedule of Rates

SRI – Solar Reflectance Index

RETV - Residential Envelope Heat Transmittance

TANGEDCO - Tamil Nadu Generation and Distribution Corporation

TNCDBR – Tamil Nadu Combined Development and Buildings Rules

TNGCC - Tamil Nadu Green Climate Company

TNUHDB - Tamil Nadu Urban Habitat Development Board

UDD – Urban Development Department

UHI – Urban Heat Island

UHIE – Urban Heat Island Effect

ULBs – Urban Local Bodies

UNEP – United Nations Environment Programme

WBGT – Wet Bulb Globe Temperature

WOA – Window Openable Area

W/m². K – Watts per square metre Kelvin

WWR – Window-to-Wall Ratio

Glossary

Capacitive Insulation – Insulating material that stores heat and releases it slowly over time, helping to stabilise indoor temperatures.

Climate Change – The Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.'

Cross Ventilation - natural ventilation strategy that uses wind to induce fresh air movement through a space by positioning of windows or openings in opposite or adjacent walls.

Emittance or Thermal Emittance: the ratio of the energy radiated from a material's surface to that radiated from a blackbody (perfect emitter), at the same temperature and wavelength and under the same conditions. It is a dimensionless number between 0 (a perfect reflector) and 1 (a perfect emitter).

Equivalent Solar Heat Gain Coefficient (SHGC_eq): modified SHGC for a fenestration with permanent. It accounts for the impact of shading in reducing incident solar radiation. It is derived by dividing the glass SHGC by the Shading Equivalent Factor (SEF), calculated for the Projection Factor (PF), as per ECBC 2017, Section 4.33, Equation 4.1.

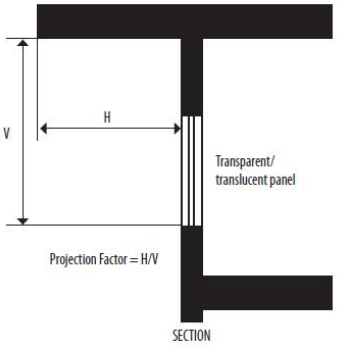
Heat Stress – A condition caused by exposure to high temperatures and humidity, potentially leading to heat-related illnesses in humans.

Heat Waves – Extended periods of excessively high temperatures, often with high humidity, posing health and infrastructure risks.

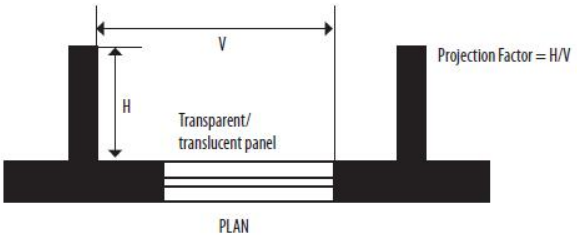
Indian Model for Adaptive Comfort (IMAC) – A thermal comfort model developed for Indian climates that defines acceptable indoor temperature ranges based on outdoor conditions and adaptation.

Insulation– Materials used to reduce heat flow between inside and outside environments, improving energy efficiency and comfort.

Projection Factor (PF)_overhang- determines the percentage of window area shaded. It is derived as the ratio of the horizontal depth of the external shading projection to the sum of the height of the fenestration and the distance from the top of the fenestration to the bottom of the farthest point of the external shading projection, in consistent units.



Projection Factor (PF)_side fin- the ratio of the horizontal depth of the external shading projection to the distance from the window jamb to the farthest point of the external shading projection, in consistent units. For windows having both overhangs and side fins, projection factor is average of ratio projection factor for overhang only and projection factor of side fin only.



Residential Envelope Heat Transmittance (RETV) - RETV is the net heat gain rate (over the cooling period) through the building envelope of dwelling units (excluding roof) divided by the area of the building envelope (excluding roof) of dwelling units. Its unit is W/m2.

Resilience – The ability of systems—social, economic, or environmental—to absorb, adapt, and recover from climate-related shocks and stresses while maintaining function. In the context of climate change, resilience can be defined as the ability to prepare for, respond to, and manage the effects of climate change

.

Resistive Insulation – Material that slows down heat transfer by offering resistance to heat flow, commonly used in building envelopes.

Relative Humidity (RH) – The percentage of moisture in the air relative to the maximum amount the air can hold at that temperature.

Shading Projection Factor (PF) – The ratio of the depth of a shading device to the height of the window it protects; higher PF means better shading.

Shading Equivalent Factor (SEF) - coefficient for calculating effective SHGC of fenestrations shaded by overhangs or side fins, provided in Equation 4.1 in Section 4.3.3 of ECBC 2020 or Section 5.3.3 of ECSBC 2024.

Solar Heat Gain Coefficient (SHGC) - ratio or fraction of incident solar radiation entering a space through the glass part of fenestration causing heating. Solar heat gain includes directly transmitted solar heat (as longwave infrared radiation) and absorbed solar radiation, which is then reradiated, conducted, or convected into the space.

Solar Reflective Index - The Solar Reflectance Index (SRI) is an indicator of the ability of a roof surface to return solar energy to the atmosphere. An SRI value is calculated using the roof surface's Solar Reflectance (SR) and Thermal Emittance (TE).[1] It is a measure of a surface's ability to reflect solar heat Higher SRI values indicate better heat reflection and lower heat absorption and surface temperatures.

Solar Reflectance- the fraction of solar radiation or energy (mostly infrared radiation) that is reflected by a surface, to the solar radiation incident upon it.

Specific Heat – The amount of heat required to raise the temperature of a unit mass of a substance by one degree Celsius (or Kelvin).

[1] CRRC-SRI-Document_2024-04-17.pdf

Thermal comfort - state of human mind (in buildings, occupants of a space) that reflects satisfaction with the thermal environment and is evaluated through subjective assessment. Environmental conditions that influence thermal comfort are air and radiant temperature, relative humidity, air speed. Clothing and metabolic rate also influence thermal comfort.

Thermal Mass – The ability of a material to absorb and store heat energy; materials with high thermal mass help regulate indoor temperature fluctuations.

U-Value – heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on each side. Unit of U value is W/m2. K. It is a measure of how well a building element (e.g., walls, windows) conducts heat; lower U-values indicate better insulation and reduced heat transfer.

Urban heat island effect – The intensification of heat in urban areas caused by dense construction, limited vegetation, and heat-absorbing materials. UHIE occurs in urban areas where the air temperature is significantly higher than in suburban areas due to heat retention by buildings, roads, and other hard paved surfaces. The UHI effect mainly results from high-density infrastructures, which not only limit air flow but also retain and emit heat.

Ventilation: the process of supplying or removing air by natural or mechanical means to or from any space. Such air is not required to have been conditioned.

Vertical fenestration - all areas (including frames) in a wall, at a slope of 60 degrees or greater from horizontal, that let in light, including windows, glass walls, clerestories, doors. Trombe wall assemblies, where glazing is installed within 300 mm of a mass wall, are considered walls, not fenestration.

Visual Light Transmittance (VLT) - It is the ratio of the total transmitted light to the total incident light. It is a measure of the transmitted light in the visible portion of the spectrum through a material.

Wall - that portion of the building envelope, including opaque area and fenestration, that is vertical or tilted at an angle of 60° from horizontal or greater. This includes above and below-grade walls, between floor spandrels, peripheral edges of floors, and foundation walls.

a. Wall, above grade: a wall that is not below grade
b. Wall, below grade: that portion of a wall in the building envelope that is entirely below the finish grade and in contact with the ground

Wet Bulb Globe Temperature (WBGT) – A composite temperature that accounts for heat, humidity, wind, and solar radiation, used to estimate heat stress on humans.

Window to wall ratio (WWR): the ratio of the non-opaque (glazed) building envelope components area to the building envelope area (excluding roof).

$$WWR = \frac{Total\ Area\ of\ Windows\ (Glazed\ Area)}{Total\ Area\ of\ External\ Wall\ (including\ windows)}$$

Window Openable Area – The percentage of operable panels (glazed or opaque/louvered shutters) within external windows that are openable and can provide natural ventilation.

Solar Heat Gain Coefficient (SHGC) – A measure of how much solar radiation is transmitted through glazing, contributing to indoor heat gain.

Window U-Value – The rate of conductive heat transfer through the entire window assembly, including both glazing and frame, expressed in W/m²K.

1 Introduction

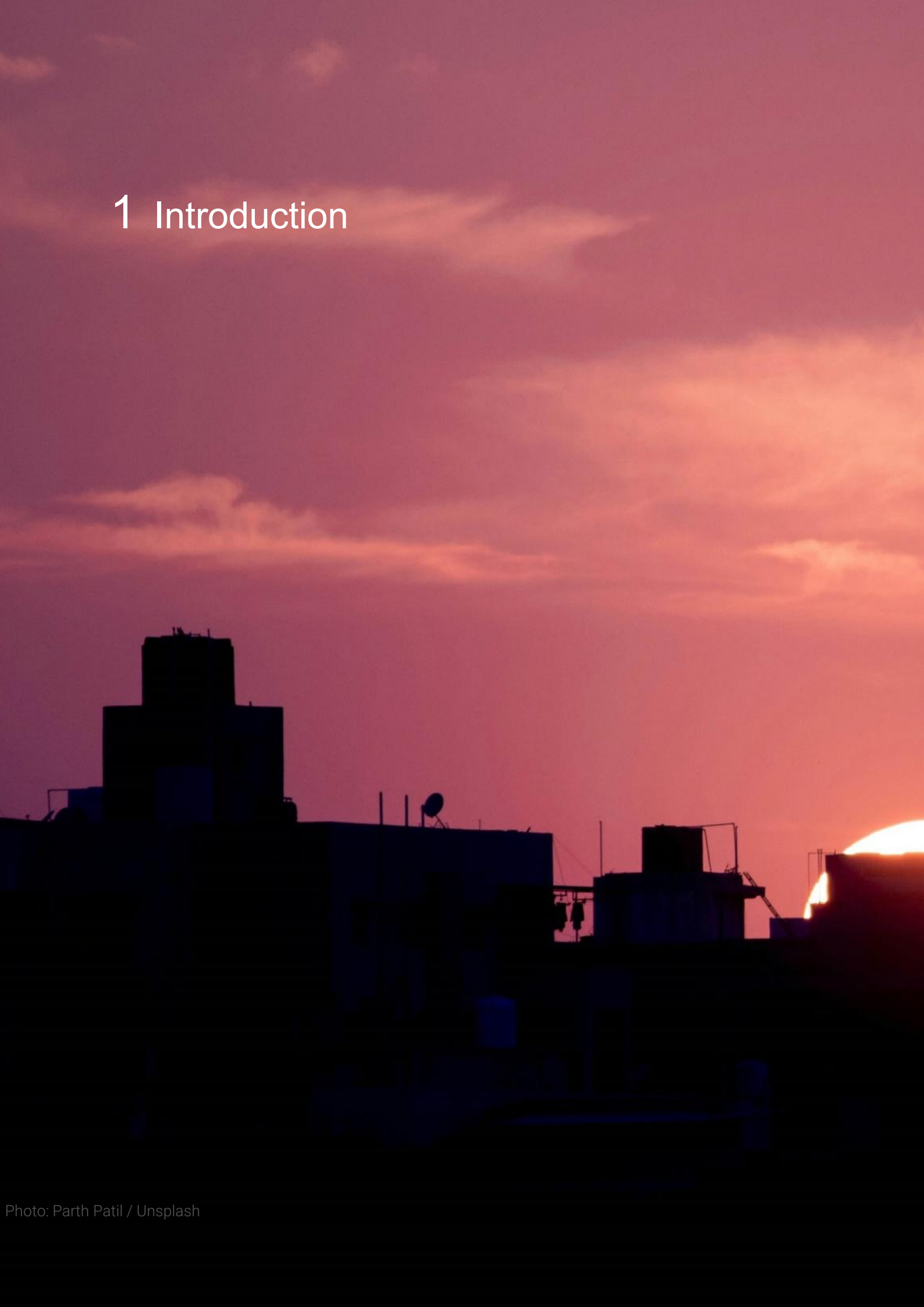
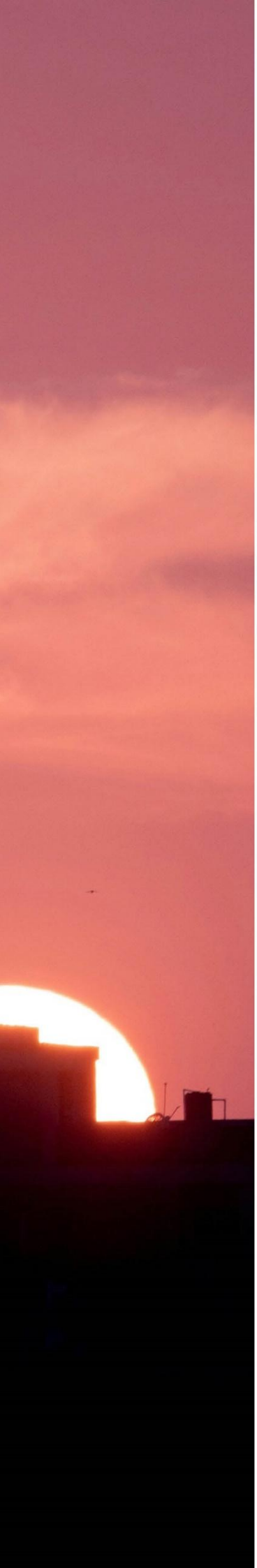


Photo: Parth Patil / Unsplash



1.1. Climate change and heat emergency

The Government of Tamil Nadu has declared heatwaves as a State-specific Disaster. A government order issued in 2024 stated that the phenomenon of Urban Heat Islands (UHI) aggravated the risk of heat stress in cities. Regions in Tamil Nadu where outdoor air temperatures exceed 40°C during peak summer are most vulnerable, posing a threat to public health. Populations at greatest risk include the elderly, children, individuals with pre-existing health conditions and marginalized communities.

The harmful effects on health and well-being arise when high temperatures persist over several days or even an entire season. In Tamil Nadu, rising humidity levels compound this risk. When humidity is high, the human body is unable to lose heat effectively through the evaporation of sweat. The Wet Bulb Globe Temperature (WBGT)—which accounts for air temperature, relative humidity, and radiation from surrounding surfaces in shaded locations—is the key indicator of heat stress. Heat Index Charts show that, in general, a WBGT of 36°C at 70% relative humidity marks the threshold of heat stress. When WBGT levels at night remain above 32°C for prolonged periods, people experience sleep deprivation, leading to exhaustion and reduced productivity.

1.2. Urban context of extreme heat

Multiple studies are pointing towards the growing trend of urban heat island effect (UHIE) in major towns of Tamil Nadu. UHIE is caused by the absorption and retention of heat during the daytime by hard and dark surfaces, the mass of buildings in dense built-up areas, and heat released from motor vehicles and air conditioning systems. The UHI effect elevates evening and night temperatures by 4 to 6 °C.

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The United Nations Environment Programme, in partnership with the CEPT Research and Development Foundation, conducted a yearlong study of urban heat island effects in the Chennai Metropolitan Area. UHIE hotspots in the city experience 4 to 6 °C rise in daytime temperatures.

With a projected global temperature rise of at least 2°C, the conditions of heat in cities would be further exacerbated unless ameliorative actions are taken. UHIE is already aggravating impact of heat stress for majority of the urban population. For those who can afford the cost, UHIE results in extensive dependence on air-conditioning, setting up a vicious cycle where cooling systems expel heat outdoors, further increasing ambient temperatures. Others, often economically under privileged populations, who are unable to access cooling solutions, the risks to health and livelihoods are multiplied manifold.

UHIE mitigation and adaption requires neighbourhood and city-level measures of reducing concrete surfaces and increasing green-blue infrastructure. At the building level, strategies that deliver enhanced cooling but also that reduce heat emissions from cooling devices or other systems are required.

1.3. Passive cooling - protective building practices for all citizens

Poorly designed buildings exacerbate heat stress by trapping heat during the day due to direct solar radiation through unshaded glazing, and by retaining heat at night because of inadequate ventilation. These effects are further intensified by the UHI phenomenon. It is therefore imperative that all new buildings be designed to protect citizens from heat stress and to minimise the demand for cooling using air-conditioning.

Passive cooling is a environmentally sustainable strategy that reduces temperatures inside buildings with minimal to zero use of mechanical energy such as employed in air conditioners or other electricity-based cooling devices. PCS, in this context, refers to the

design of roofs, walls, windows, shading devices, and ventilation arrangements of a building or the **'building envelope'** to minimise the impact of extreme outdoor temperatures on indoor habitable spaces, while also taking advantage of natural cool breezes during pleasant periods. Passive cooling of buildings should be part of a comprehensive plan for protection against heat stress, complemented by measures taken at the neighbourhood and city levels, to minimise the UHI effect.

1.3.1. Climate responsiveness

The task of passive cooling strategies is to respond optimally to the climatic parameters of a particular region. This approach allows natural cooling of the building and minimizing use of electricity for maintaining comfortable interiors. Climate sub-classification was conducted to account for variations in climate and their effect on designing passive cooling strategies. All 38 administrative districts of Tamil Nadu were analysed with respect to the closest available weather station data. Recommendations have been formulated based on this climate classification, ensuring that regulatory measures align with localised climatic conditions. The PCS standards and prescriptions are tailored for each of these climatic zones. This helps in optimising the construction of walling and roofing materials and techniques.

1.3.2. Future proofing of heat adaptation

The temperature rise is likely to continue. This is now being factored into the revisions to the NBC, the ECSBC, and the ENS. Similarly, these Guidelines take the likely temperature rise into account. In addition, the Guidelines make allowance for conditions of UHI and restricted natural ventilation in densely developed urban areas.

1.3.3. Alignment with national codes

The objective of these Guidelines is to enable integration of passive cooling strategies (PCS) in building design and construction across all typologies—residential, commercial, and institutional—to protect all citizens from heat stress. The provisions in the Guideline align with both the National building Code (NBC), and the Energy Conservation and Sustainability Building Code (ECSBC) 2024 – commercial and residential.

The ECSBC for commercial and residential buildings, developed by the Bureau of Energy Efficiency recommend solutions for both passive and active cooling to improve energy efficiency and climate adaptation. Tamil Nadu has already notified ECSBC 2024 – Commercial. However, these codes apply only to large-scale commercial and residential projects and do not cover smaller buildings. Eligibility for ECSBC is:

1. Non-residential buildings with greater than 100 kW connected load or 120 kVA contract demand
2. Residential buildings in greater than 500 square meter plot area

This creates ambiguity, particularly for naturally ventilated and mixed-mode buildings, which often have lower power demands and may not clearly fall under the code's scope. Approximately 50% of total built up area in towns and cities that needs protection from heat stress and discomfort is not under the ambit of the ECSBC. The codes also allow alternate compliance paths where passive cooling (or building envelope optimization) can be relaxed by increasing performance of other building systems such as air conditioning and lighting.

Given that most buildings constructed in Tamil Nadu's are relatively small projects, a pathway for sustainable cooling to all types and sizes of buildings—residential, institutional, and commercial—excluding industrial buildings, is called for.

1.3.4. Applying the Passive Cooling Guidelines

1. **Choose the building type and category**: The Guidelines has defined building categories based on extent of air conditioning used. Buildings that rely mostly on natural ventilation are awarded relaxation in stringency of passive cooling measures.
2. **Identify sub-climate classification:** climate zone of all districts of Tamil Nadu has been identified as PCS is acutely climate sensitive.
3. **Select the passive cooling strategies:** Based on the on-building category (type and air-conditioned area) and climate classification of the project, PCS should be selected from amongst the recommended ones.
4. **Select construction materials and technologies:** To facilitate execution of recommended passive cooling strategies, the Guidelines provide solution set of prescribed thermal properties in the form of construction details, along with costs to guide procurement and budget estimation.

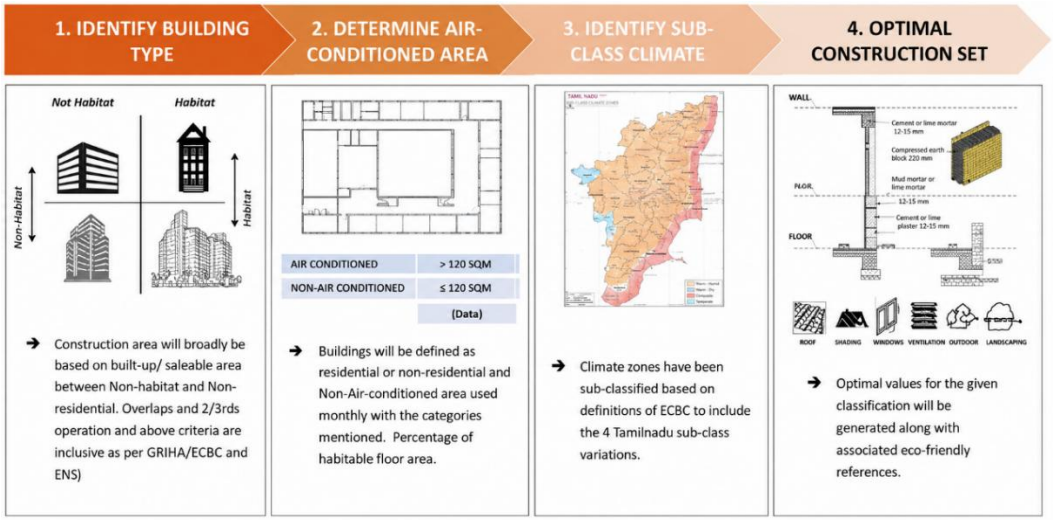


Figure 1 Implementation framework for Passive Cooling Guidelines and selecting optimum thermal properties for building envelope (Source: Authors)

1.3.5. Integrating passive cooling in building regulations

The strategies recommended in the Building Passive Cooling Guidelines are designed for integration into building bylaws and development control regulations of Tamil Nadu. Building construction in towns and cities is regulated by building bylaws enforced by urban local bodies (ULBs). These bylaws are mandatory and work in conjunction with Town Planning and Development Control Regulations, which govern the type and extent of development permitted on a given land parcel. The Building Byelaws are generally consistent with the relevant provisions of the National Building Code (NBC). In Tamil Nadu, the Tamil Nadu Combined Development and Building Rules (TNCDBR) frames the design and construction requirements for buildings, though ULBs may modify them to suit local priorities and needs. Please see Annexure 2 for approach.

.

2 Climate Sub-Classification



Photo: Aamir Dukanwala/Pexels

The task of passive cooling strategies is to respond optimally to the climatic parameters of a particular region. Priority is given to the periods of extreme weather conditions. The range of diurnal temperature variation, relative humidity, and direct as well as diffuse solar radiation are key determinants.

The Energy Conservation and Sustainability Building Code classifies bulk of Tamil Nadu in the warm-humid climate zone with some areas, primarily around Kodaikanal and Coonoor, in the cold climate zone. Warm-humid climate zones are characterized by high temperatures (mean monthly maximum temperatures between 30 °C to 38 °C), high humidity (60-80 percent), and high rainfall.

From the perspective of applying advanced passive cooling methods, the state experiences more variations than capsulated in the definition of warm-humid climate conditions. These impact optimal potential for applying PCS such as thermal mass and natural ventilation.

The parameters of climate data that are relevant for the specification of PCS performance standards are

i. temperatures during the peak hot season,
ii. relative humidity,
iii. the diurnal variation during the peak hot season

The combination of the three has a bearing on the appropriate thermal mass of the enclosing walls and the roof construction. Greater humidity requires greater natural ventilation but with enhanced shading.

2.1. Sub climate classification of Tamil Nadu

An analysis of weather data from all weather stations of Tamil Nadu reveals three climate sub-zones: Hot-humid, Warm-humid, and Cool-temperate. This sub-classification is now being recognised in the revised NBC's section on *Approach to Sustainability*. Three climate sub-classifications, with summer diurnal variation and average peak summer maximum temperature ranges outlined in Table 1 should be followed while designing passively cooled buildings in Tamil Nadu.

Table 1 Climate zone characteristics. (Source: Authors)

Climate Zone	Average peak summer (March to June) Diurnal Variation (℃)	Average peak summer Maximum temperature (℃)
Cold	5.5	25.7
Warm-Humid	3.3	31.6
Hot-Humid	8	37.4

Note – Peak summer months are considered from March to June. Based on the district-wise sub-classification of Tamil Nadu's climate, PCS standards and prescriptions will be tailored to ensure an optimal response for each climatic zone.

In Figure 2, the average daily temperature variation for each month from the weather data of all the weather stations located in different zones of Tamil Nadu can be seen.

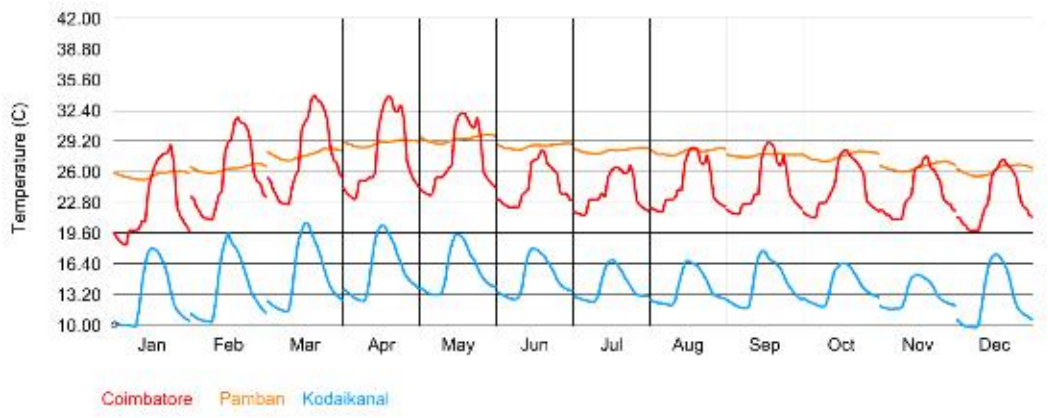


Figure 2 Average daily air temperatures for Coimbatore, Pamban and Kodaikanal, representing the three climate sub-classifications: Hot-humid, warm-humid and cold, respectively. (Source: Authors)

2.1.1 Hot-Humid Climate

Locations where the maximum temperature during the hottest month's ranges between 35°C and 39°C, and a significant diurnal variation in temperature is observed, ranging between 7°C and 10.5°C are to be classified as **hot-humid**. Basically, diurnal temperature swing is significant. Maximum summer temperatures typically reach 40°C in the afternoon, while minimum temperatures drop to 29°C at dawn. The summer season experiences a high diurnal temperature variation of 7°C to 10.5°C. It is during this hot period that heat waves occur, with temperatures further elevated in urban hot spots due to the Urban Heat Island (UHI) effect. Therefore, protection against direct solar radiation and high ambient air temperatures is essential. Passive measures called for in this climate:

- Good roof insulation and high-reflectance roof surfaces (top finish).
- Externally shaded windows to reduce heat gain from solar radiation while providing adequate daylighting for interior spaces. High-performance glass in windows, where affordable, can be a technical option to external shading.
- Good night ventilation to take advantage of lower night time temperatures.
- Some thermal mass in walls, combined with insulation.
- Insulation of walls and roof, along with air-tight windows where air-conditioning is installed.

Implementing these measures will significantly reduce summer discomfort in naturally ventilated spaces and lower cooling demand in air-conditioned spaces. During the monsoon and cooler seasons, minimum temperatures can drop to 24°C. Incorporating the above measures will maintain indoor comfort during these seasons as well. On the other hand, a lack of protection of windows from solar radiation and a heat-conductive roof can result in discomfort indoors during these seasons.

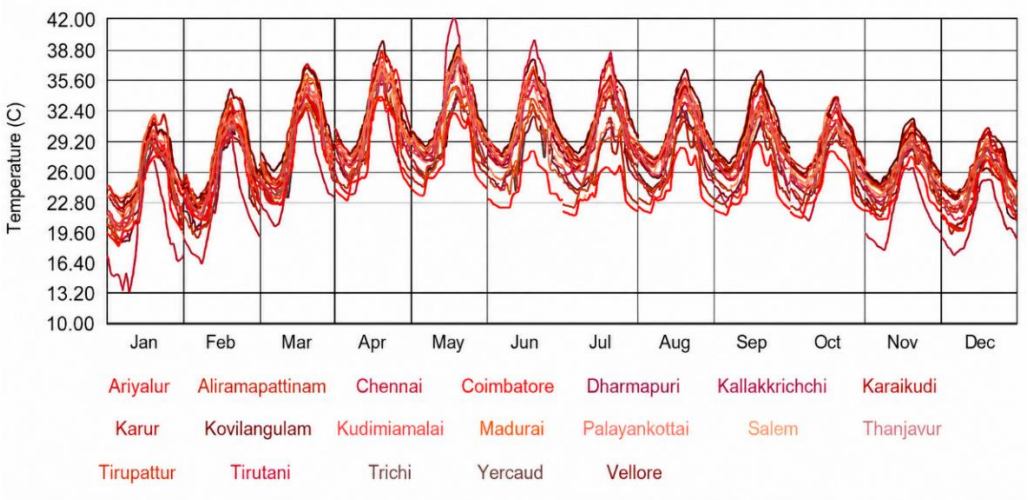


Figure 3 Average daily air temperatures for Hot-Humid climate. (Source: Authors)

2.1.2 District-wise Climate Sub-classification

Locations where the maximum temperature during the hottest month's ranges between 28°C and 29°C, the diurnal temperature variation ranges between 3°C and 5°C are to be classified as Warm-Humid climate zones. Maximum summer temperatures reach 28°C during the day, while minimum temperatures drop to 27°C at dawn. The diurnal temperature variation does not exceed 5°C. During the monsoon and cooler seasons, minimum temperatures can drop to 24°C.
Appropriate passive measures here can limit the need for air conditioning to the daytime in the warmest season:

- Insulated roof with high-reflectance roof finishes.
- Large openings for copious ventilation, with opaque ventilation shutters.
- Externally shaded windows to protect against direct and diffuse radiation.
- Walls of low mass and light construction with insulation.
- Insulation of walls and roof, along with air-tight windows where air-conditioning is installed.

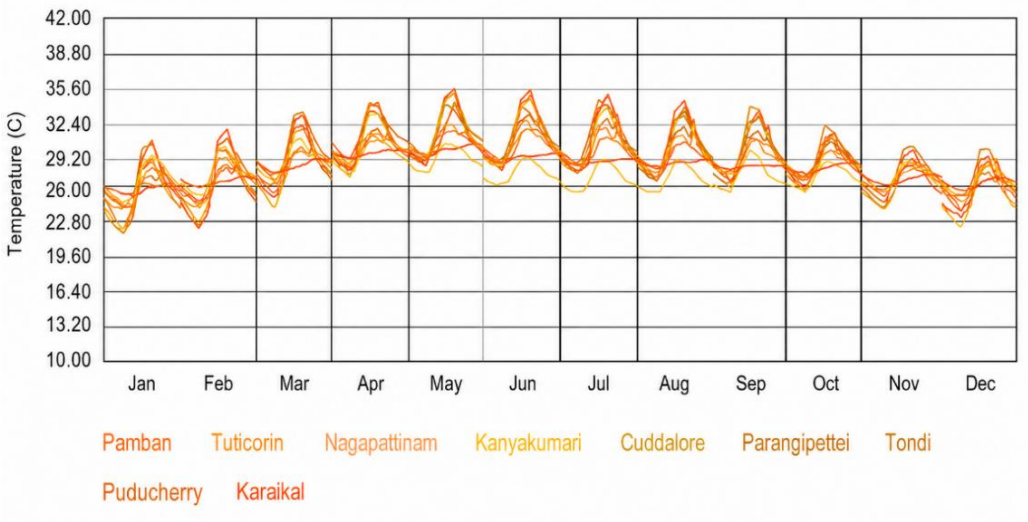


Figure 4 Average daily air temperatures for Warm-Humid climate. (Source: Authors)

2.1.3 Cold Climate

In the hills, temperatures are much cooler. The maximum temperature rises to 20°C, while the minimum temperature drops to 10°C. Diurnal temperature variation is significant, ranging between 6°C and 8°C. The hill regions of Tamil Nadu experience a cool-temperate climate, with comfortable temperatures for most of the year and should be classified in the cold climate zone. During peak summer, the maximum temperature rises to 24°C, while in winter, the minimum temperature drops to 17°C. The region receives strong solar radiation. Passive measures called for in this climate:

- Insulated roof
- Windows adequately sized for daylighting interior spaces.
- Adjustable external shades over windows to provide shade during summer and admit morning and afternoon sunlight during winter.
- Moderate thermal mass in walls.
- Air-tight windows for winter.

No air conditioning would be required if overheating due to large unshaded windows is avoided.

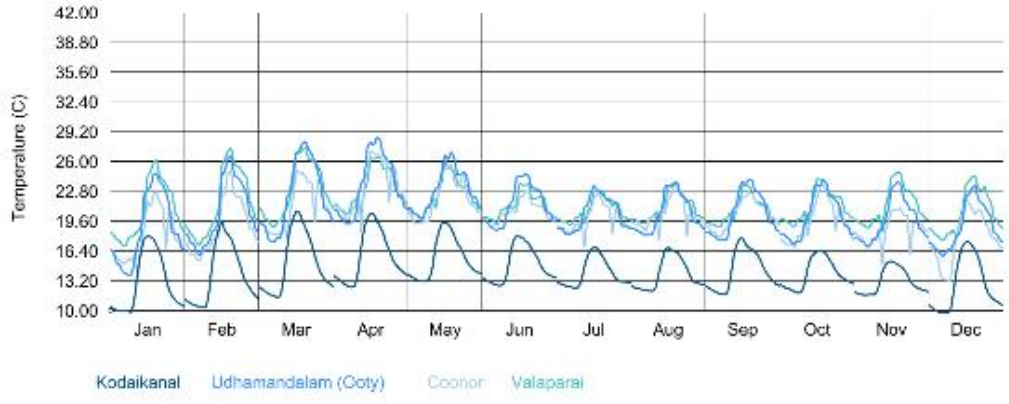


Figure 5 Average daily air temperatures for Cool-temperate climate. (Source: Authors)

2.2. District-wise climate sub-classification

Climate characteristics are agnostic to administrative boundaries; there is no fine boundary line between separating the three climatic sub-classifications as climate shifts along with geographic conditions. However, some extent of classification is required for the ease of applying this Guideline and in the future, checking compliance by urban local bodies and administrations. For administrative convenience and ease of implementation, each district of Tamil Nadu can be ascribed a climate sub-classification (Table 1). The following method was adopted to arrive at a district level climate classification.

1. **Climate Sub-Classification:** A distinction is made between Hot-Humid and Warm-Humid climates based on Peak Dry Bulb Temperature and Average Peak Summer Diurnal Variation.
2. **Analysis of Administrative Districts:** All 38 administrative districts were analysed with respect to the closest available weather station data.
3. **Consistency with Administrative Boundaries:** For ease of implementation, climate zones are aligned with district boundaries.

Table 2 Climate zone by District - Cold and Warm-Humid climate. (Source: Authors)

Climate	District	
Cold Climate	Dindigul (Palani, Oddanchatram, Kodaikanal)	Nilgiris (Udhagamandalam, Coonoor, Gudalur)
	Coimbatore (Valparai)	Erode (Bhavanisagar)
Warm and Humid	Thiruvarur(Mannargudi, Thiruthuraipoondi, Thiruvarur) Nagapattinam(Kilvelur, Vedaranyam,Nagapattinam) Mayiladurai(Poompuhar,Mayiladurai, Sirkazhi)	Thoothukudi (Ottapidaram,, Srivaikuntam, Thoothukkudi, Tiruchendur, Vilathikulam)
	Kanniyakumari (Padmanabhapuram, Vilavancode)	Tirunelveli (Radhapuram)
	Ramanathapuram(Mudukulathur, Paramakudi,Tiruvadanai)	
	Thanjavur (Aranthangi, Pattukkottai, Peravurani)	
	Cuddalore (Bhuvanagiri, Chidambaram)	
Hot and Humid	Ariyalur	Cuddalore (Entire district except Bhuvanagiri, Chidambaram)
	Chengalpattu	Dindigul (Entire district except Palani, Oddanchatram,Kodaikanal)
	Chennai	Kallakurichi
	Coimbatore	Kanchipuram
	Krishnagiri	Salem
	Madurai	Sivaganga
	Namakkal	Tenkasi
	Nilgiris (Mettupalayam)	Thanjavur (Entire district except Aranthangi,Pattukottai, Peravurani)
	Perambalur	Theni
	Thiruvallur	Thoothukudi (Entire district except Ottapidaram, Srivaikuntam, Thoothukkudi, Tiruchendur,Vilathikulam)

	Thiruvarur (Entire district except Mannargudi,, Thiruthuraipoondi, Thiruvarur)	Tiruchirapalli
	Tiruppur	Tirunelveli (Entire district except Radhapuram)
	Tiruvannamalai	Villupuram
	Vellore	Virudhunagar

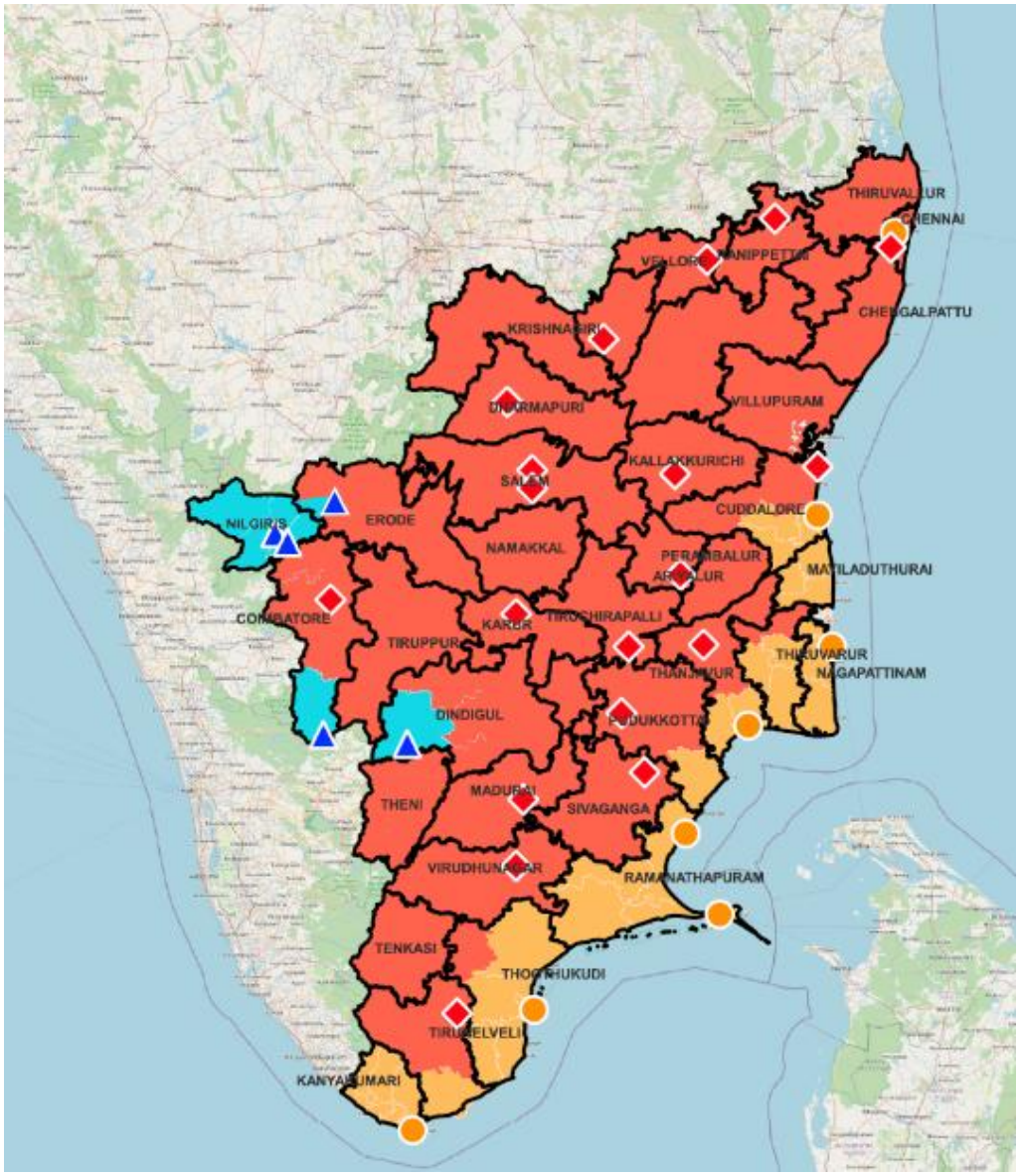


Figure 6 District map of Tamil Nadu showing the sub-classification of climate zones. (Source: Authors)

3 Passive Cooling Strategies Sub-Classification

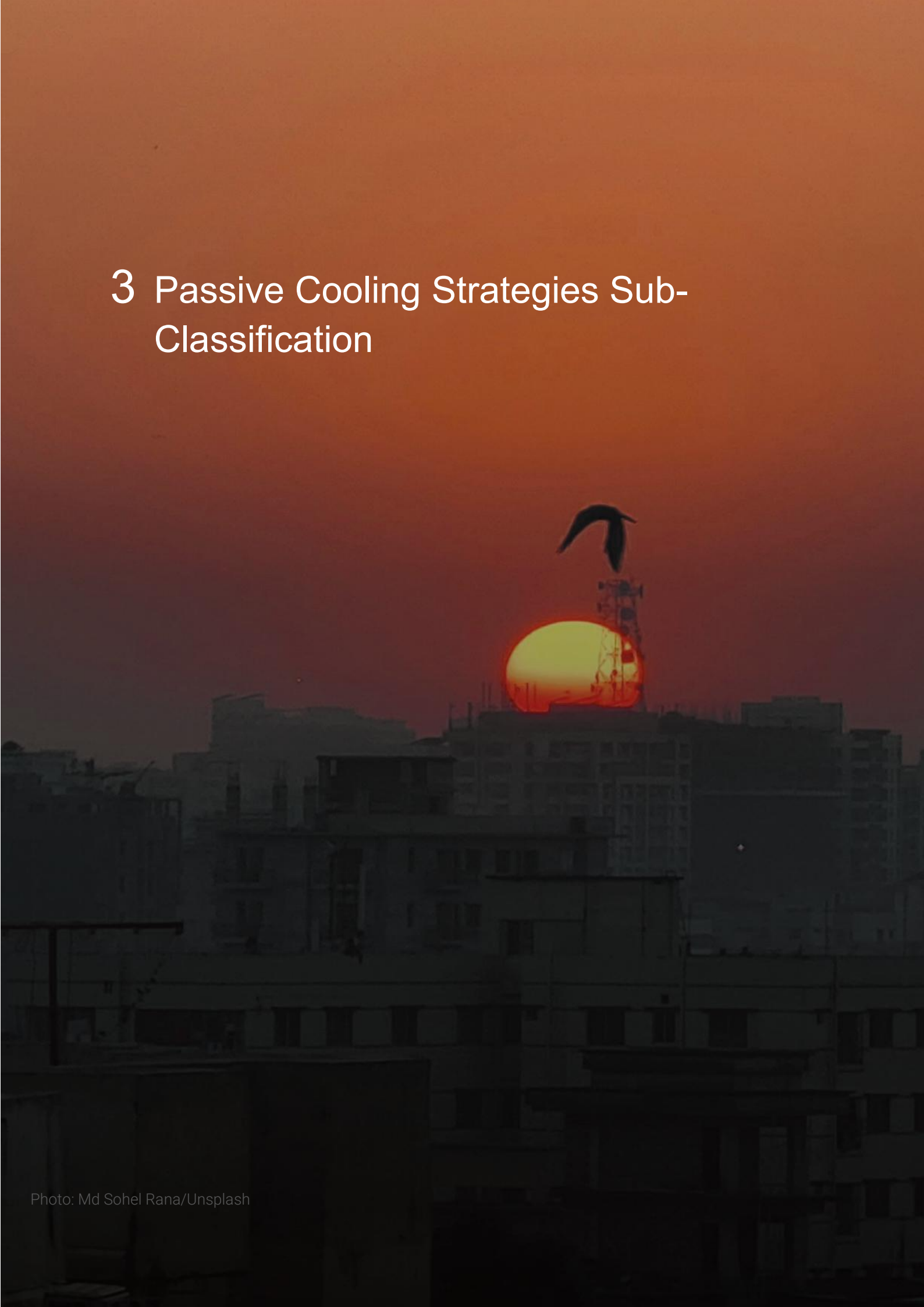


Photo: Md Sohel Rana/Unsplash

Human body has a limit for the intensity of heat (a function of temperature, relative humidity, wind speed and other environmental factors) it can bear. Exposure to heat beyond this threshold can endanger health. Buildings are meant to shield from such exposure by limiting heat transfer from outside. Passively cooled buildings employ the inherent thermal resistance of certain construction materials.

3.1 Heat stress

Heat stress is a physiological condition caused when the body is unable to maintain its core temperature by losing heat to its surrounding environment. For those who cannot afford air-conditioning, the risk of heat stress is greater during the hot season and during heat waves. This risk increases further when the Urban Heat Island (UHI) effect causes a rise in peak local temperatures, and when high temperatures persist into the evening and night. Heat stress becomes a progressive condition with the global temperature rise due to climate change. Climate change is expected to result in higher air temperatures as well as increased relative humidity (RH). The combined effect of dry bulb air temperature (DBT), RH, and radiant heat from surrounding surfaces is measured as Wet Bulb Globe Temperature (WBGT).

3.1.1 Heat Stress Index

Medical science has developed Heat Stress Indices that indicate rising degrees of heat stress risk as WBGT increases. These indices guide Heat Action Plans by defining protective, precautionary, and palliative measures necessary for citizens' health and well-being. The following Heat Index Chart helps establish acceptable limits for indoor conditions in residential, institutional, and commercial buildings.

Relative Humidity %	Temperature °C																
	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
40	27	28	29	30	31	32	34	35	37	39	41	43	46	48	51	54	57
45	27	28	29	30	32	33	35	37	39	41	43	46	49	51	54	57	
50	27	28	30	31	33	35	36	38	41	43	46	49	52	55	58		
55	28	29	30	32	34	36	38	40	43	46	48	52	54	58			
60	28	29	31	33	35	37	40	42	45	48	51	55	59				
65	28	30	32	34	36	39	41	44	48	51	55	59					
70	29	31	33	35	38	40	43	47	50	54	58						
75	29	31	34	36	39	42	46	49	53	58							
80	30	32	35	38	41	44	48	52	57								
85	30	33	36	39	43	47	51	55									
90	31	34	37	41	45	49	54										
95	31	35	38	42	47	51	57										
100	32	36	40	44	49	56											

Caution | Extreme Caution | Danger | Extreme Danger

Figure 7 Heat Index Chart - limits for indoor conditions in residential, institutional and commercial buildings. (Source: Kim Knowlton, Natural Resources Defence Council SAHHS, Pune, India | 14 February 2020)

The index highlights the absolute necessity of ensuring that the Heat Index inside buildings does not exceed the threshold of high stress. The numbers in the boxes represent the Heat Index:

- Below 33: You may be uncomfortable but are physiologically safe.
- Between 33 and 39: Protective action is necessary.
- Above 40: There is a risk of physiological distress.

In the humid climate across Tamil Nadu (except in the hill areas), at 60% RH, temperatures above 33°C cause high stress. At 70% RH, high stress can set in at just 29°C. This condition is worsened when the surface temperature of walls or ceilings is higher than the air temperature, as is often the case under lightweight metal roofs and thin concrete walls exposed to direct solar radiation. When night-time temperatures

persist above 30°C with RH above 60%, it leads to sleep deprivation, resulting in reduced resilience and stamina.

3.2 Building envelope and Heat Gain

The envelope of a building modifies the flow of heat from the outside to the inside, and also from the inside to the outside. Outdoor air temperature varies through the day and night, and the impact of direct solar radiation on the roof, walls, and windows also changes accordingly. Heat gain into the building occurs when the air temperature, combined with incident solar radiation, makes the outer surfaces hotter than the indoor surfaces. Conversely, heat will flow outwards during the night when the outside is cooler than the inside.

The properties of the different elements of the building envelope and their exposure to solar radiation and outdoor air temperature determine the rate and quantum heat transfer across the building envelope. The heat transfer across the building's roof, its walls and windows can be measured separately for each element by simulation software.

- The roof receives the highest intensity of solar radiation, followed by the western and eastern facades. The northern and southern faces receive much less solar radiation.
- The roof and walls can resist the flow of heat to the inside by virtue of their thermal insulation and thermal mass. Unshaded windows (glazed openings) are most vulnerable.
- The top floor (directly under the roof) is worst affected.
- Walls and windows for all lower floors are critical

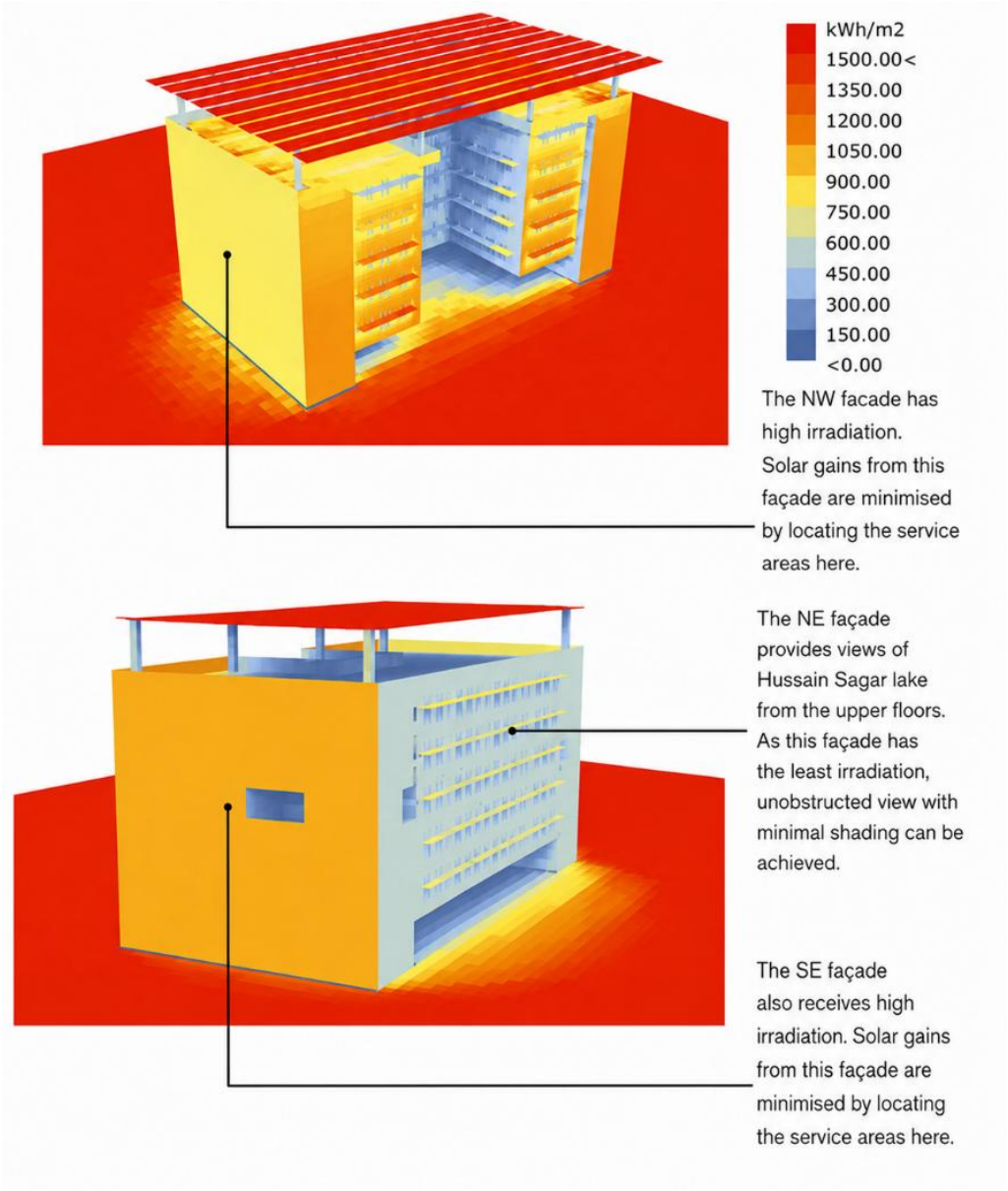


Figure 8 Heat gain from the different elements of the building envelope. (Source: Ashok B Lall Architects)

Top floors gain more heat from roofs. The graph below shows simulated results for rooms on the top floor of a typical residential building but with different orientations with respect to the Sun. The building envelope details are as follow:

- Reinforced concrete cement roof without any layer of insulating material in the roof construction and grey cement finish.
- Windows with single glazing and a standard 500 mm wide shade overhang at the lintel level.
- 230 mm thick brick walls with painted plaster on both faces.

The simulation results show that orientation with respect to the sun matters. Eastwards and westwards exposure of walls and windows calls for additional protection:

- Most heat is transferred through the roof.
- In the case of the room with a large west-facing unshaded window, more heat is received from the window than from the roof.

- In the case of the room with a wall facing west, a considerable amount of heat is received from the walls.
- Rooms with external walls and windows facing north or south receive considerably less heat from windows and walls.

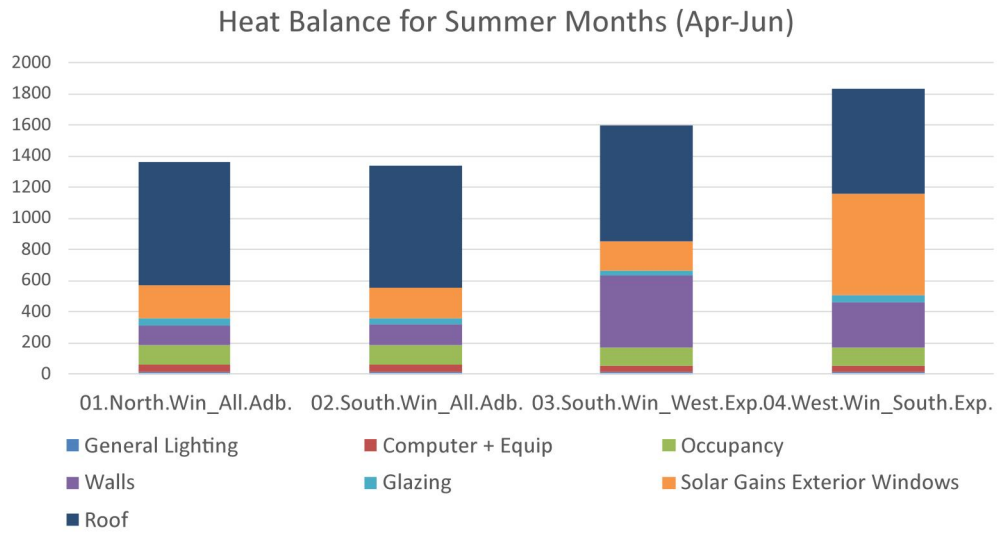


Figure 9 Heat balance for summer months for the top floor. (Source: BEEP, 2015)

The next graph shows simulated results for rooms on an intermediate floor of a typical residential building but with different orientation with respect to the Sun. The results show that:

- Most heat is transferred through the windows
- West-facing unshaded large window receives excessive heat
- Room with wall facing West receives considerably more heat from the walls
- Rooms with external walls and windows facing North or South receive considerably less heat from windows and walls.

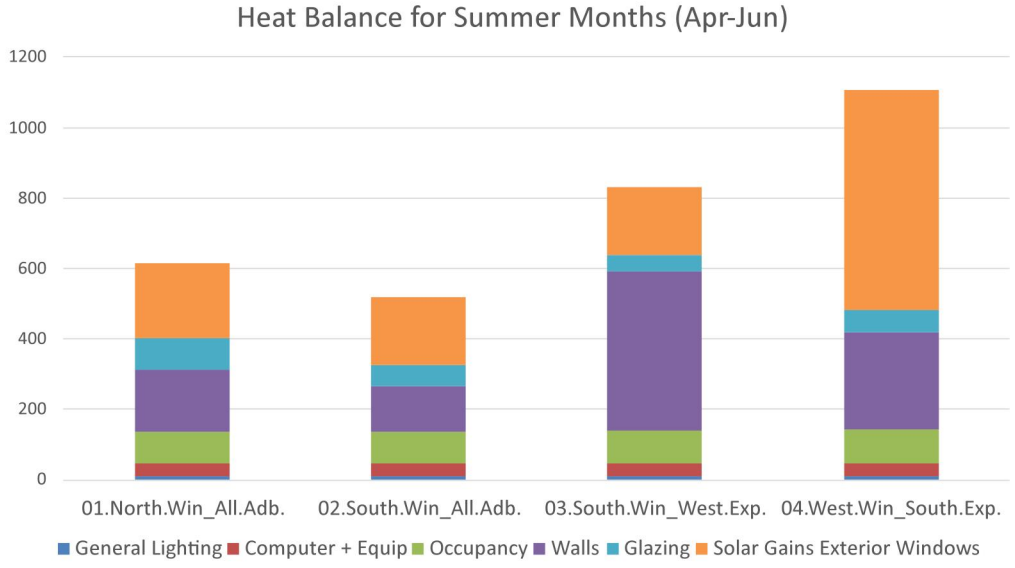


Figure 10 Heat balance for summer months for the intermediate floor. (Source: BEEP, 2015)

3.3 Thermal discomfort and heat stress

The experience of comfort is somewhat subjective. In air-conditioned spaces, occupants tend to expect lower temperatures. In non-air-conditioned spaces,

occupants remain comfortable at higher temperatures. Research based on statistical surveys across the various climatic zones of India has established the range of temperatures within which occupants of buildings feel reasonably comfortable. This comfort range varies with the month-to-month changes in outdoor temperatures, as experienced by people living in a particular climate zone. People adapt to warmer temperatures during the hot season and prefer cooler temperatures during the cool season. This has now been codified as the Indian Adaptive Comfort Model (IMAC) in the National Building Code 2016.
IMAC assumes the use of ceiling fans in spaces that are either occasionally air-conditioned or not air-conditioned at all. It is observed that in naturally ventilated buildings, occupants adapt to somewhat higher temperatures and still feel comfortable. However, the upper range of temperature for adaptive comfort is reduced when occupants experience air-conditioned comfort periodically. The comfort range shrinks considerably when occupants become accustomed to air-conditioned environments, as in fully air-conditioned buildings. As an example, the adaptive comfort band for a hot-humid climate in Coimbatore district over the course of one year—calculated from seasonal weather data—is shown below for three scenarios:

i. naturally ventilated building with no air conditioning,
ii. partially air-conditioned building,
iii. fully air-conditioned building.

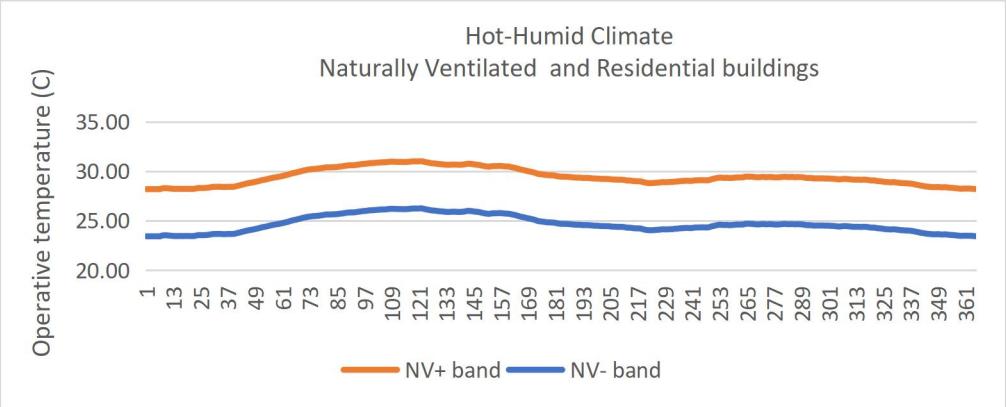


Figure 11 The adaptive comfort band for a naturally ventilated residential building in a hot-humid climate zone. (Source: Authors)

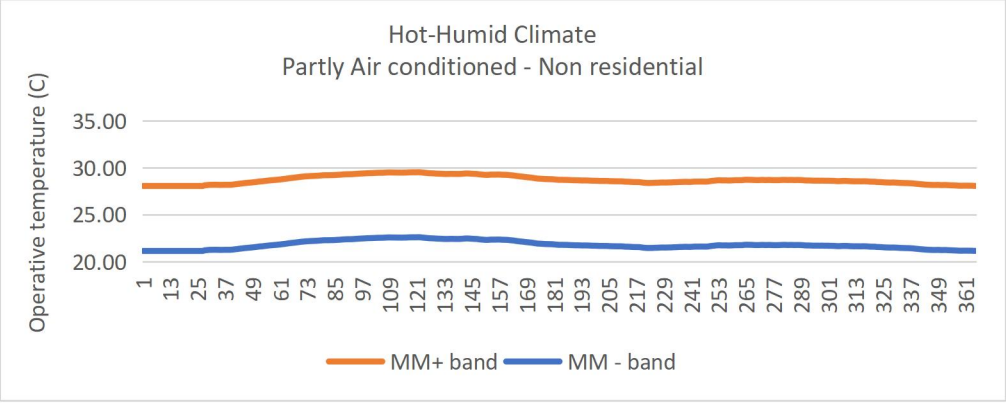


Figure 12 The adaptive comfort band for a partially air-conditioned non-residential building in a hot-humid climate zone. (Source: Authors)

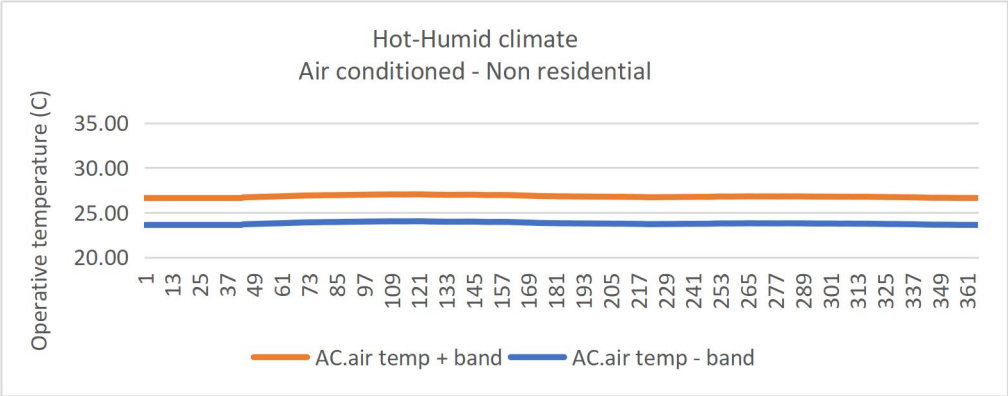


Figure 13 The adaptive comfort band for an air-conditioned, non-residential building in a hot-humid climate zone. (Source: Authors)

Considering our concern to protect occupants of buildings from heat stress, indoor temperatures, ideally, should not exceed the upper limits of the Adaptive Comfort range. Discomfort is experienced when this limit is crossed. The degree or intensity of discomfort increases with rising temperature and humidity. At a certain threshold of discomfort, occupants may resort to air-conditioning—if it is affordable. The effectiveness of PCS is to be evaluated in relation to IMAC and the heat stress index. The ASHRAE 55 standard, which is an American national standard for indoor comfort, is not applicable in this context.

3.4 Passive cooling strategies and effectiveness

Passive cooling strategies are approaches that utilize natural resources like sun, wind, soil, and water in building design to maintain indoor thermal comfort with reduced heat ingress and minimal energy consumption. Passive cooling is commonly understood as a set of natural processes and techniques to reduce indoor temperatures, in contrast to the use of 'active' mechanical equipment (Givoni,1994).

In the application of Passive Cooling Strategies (PCS) for these guidelines, we refer to methods of designing and constructing a building's fabric to protect indoor spaces from external heat sources and to remove accumulated heat indoors without relying on air conditioning. The effectiveness of PCS can be further enhanced by increasing air movement through electric circulating fans and exhaust systems to relieve discomfort. The main elements of PCS include the external envelope of the building—walls, windows, and roof. With proper design and construction, these elements can significantly improve indoor thermal comfort. Conversely, poor design can increase discomfort by admitting and trapping heat indoors, leading to severe heat stress during peak hot and humid seasons.

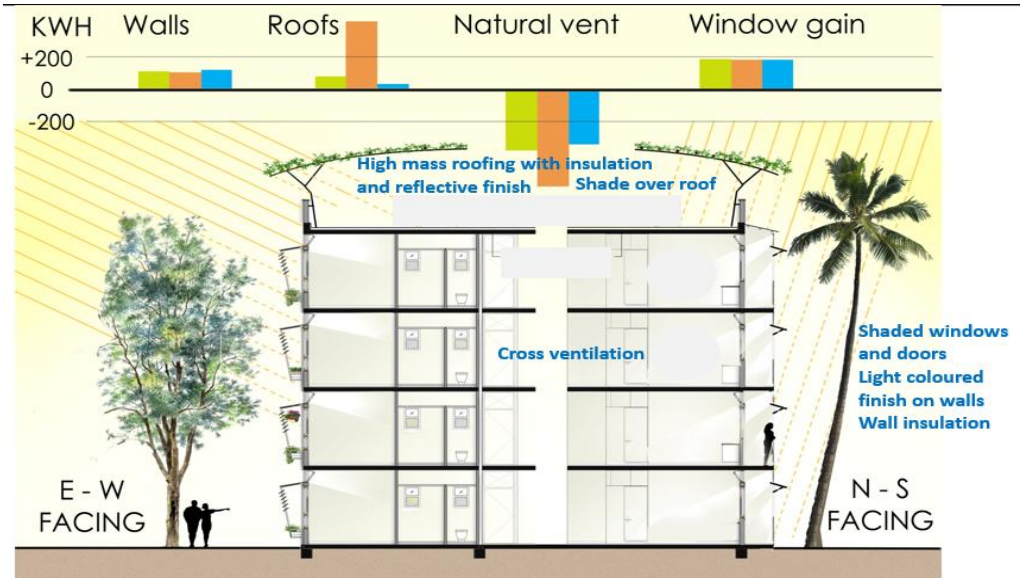


Figure 14 Design measures to minimise heat gain and get the benefit of cooling breezes (Source: Ashok B Lall Architects)

A broader application of PCS would also include space-planning features such as courtyards and *verandahs*, and building orientation in relation to sun and wind. These guidelines, however, are limited to the elements of the building envelope. An integrated deployment of PCS in building design and construction can ensure that indoor temperature and humidity levels do not reach thresholds that cause heat stress.
In summary, the potential of optimising PCS is:

- To eliminate severe heat stress indoors and minimise the degree and duration of discomfort during extreme heat seasons.
- To maximise the duration of thermal comfort indoors, without resorting to air-conditioning.

3.4.1 Roof

The roof receives the maximum heat, as the sun bearing down from late morning till late afternoon is at its hottest. The habitable spaces of the floor directly below the roof are the most affected. In addition, the roof absorbs heat from the hot outside air during the day. At night, the roof will lose heat to the outside. Being close to the equator Tamil Nadu experiences 10 to 12 hours of daylight on an average with strongest radiation in the months of March to August. Roof shapes and shading roof construction can be designed to resist and dampen the transfer of heat both from outside to inside and vice versa. Pitched, vaulted and domed roofs allow a part of the roof and the walls to be shaded by the geometry of the shape except during the peak hours of noon time when the sun is directly overhead. Also, they permit easy evacuation of hot air with roof level vents.

For flat roofs, pairing insulation with reflective surfaces such as Cool roof tiles and high-albedo paints with a high Solar Reflective Index (SRI) reduces heat gain effectively. Insulation materials such as Autoclaved Aerated Concrete (AAC) tiles that is light weight with micro air pockets effectively block heat transfer into the building.

Table 3 Strategies for minimizing heat gain through roof(Source: Authors)

Objective	Strategy	Action	Output
Minimizing Heat gain	Roof insulation	• Insulation of roof for reducing heat gain into the building	Reduces heat gain
	Reflective	• Roofing with reflective	• Reduces peak

	materials	materials such as • cool roof tiles/mosaic tiles • Walls and roofs painted with white or light • coloured paints for high albedo	heat gain through roof • •Reduction in the surface temperature - UHI mitigation
	Roof shape and shading	• Pitched, vaulted, and domed roofs reduce heat gain due to their geometric form. • Sloped overhangs maximize wall shading. • Evacuation of hot air from beneath pitched and vaulted roofs is easier and more effective.	• Reduces heat gain • Reduces heat transfer • Shades walls

The roof receives the maximum heat, as the sun bearing down from late morning till late afternoon is at its hottest. The habitable spaces of the floor directly below the roof are the most affected. In addition, the roof absorbs heat from the hot outside air during the day. At night, the roof will lose heat to the outside. Roof construction can be designed to resist and dampen the transfer of heat both from outside to inside and vice versa.

3.4.2 External walls

External walls, if not shaded, receive the second and third highest solar heat gains when facing west (afternoon sun) and east (morning sun), respectively. Wall surfaces facing north and south receive little direct solar radiation. Additionally, walls absorb heat from the hot outdoor air during the day and release it at night. Well-designed wall construction can resist and moderate the transfer of heat from outside to inside and from inside to outside.

Heat gain can be minimized to a certain extent through the strategies of orientation, shading, insulation, and landscaping. However, under certain site conditions, it may not be possible to adopt these measures in the design of the building (e.g. small plots with insufficient setbacks, higher than G+2). Here, the only strategy is to use building materials that have low thermal transmittance (U-Value) or high heat resistivity or double walls.

Table 4 Strategies for minimizing heat gain through external walls(Source: Authors)

Objective	Strategy	Action	Output
Minimizing heat gain	Heat resilient building materials (poor thermal conductivity)	• Walls with thermal insulation layer • Building materials with minimal U-value o Autoclaved Aerated Concrete (AAC) block wall o Extruded hollow clay blocks o Rattrap bond wall (air cavity wall) o Rammed earth wall	Reduces thermal transmittance

		o Poured earth wall o Waste Cuddapah wall o Achikalu (brick tile) with lime mortar o AAC Panel	

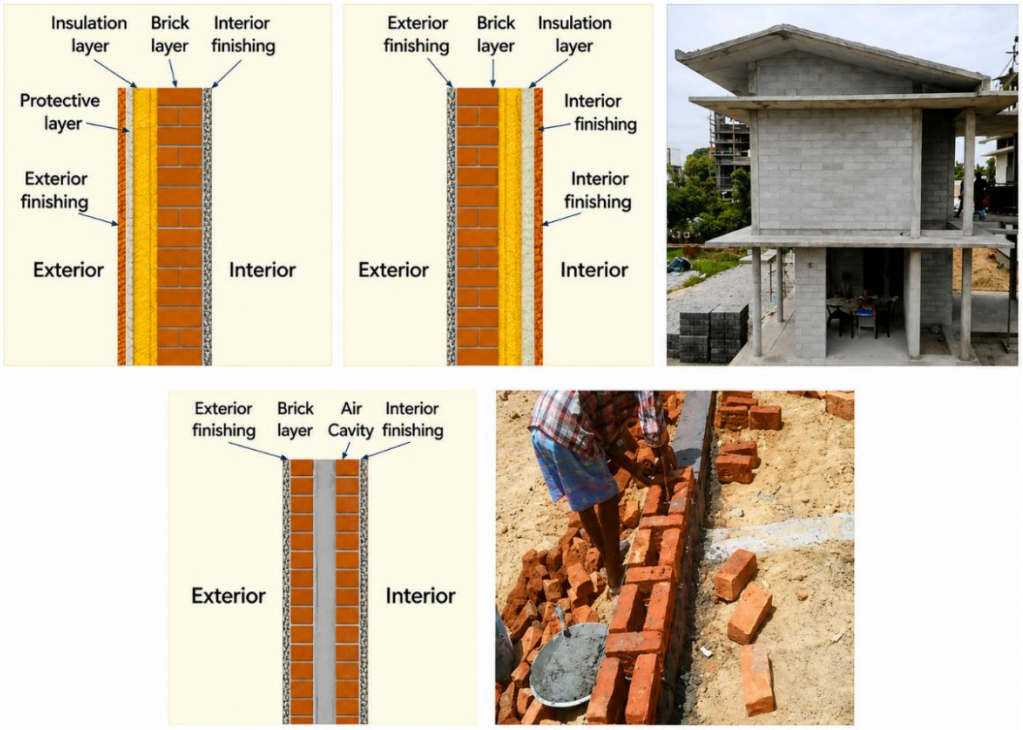


Figure 15 Different heat resilient building materials and wall construction methods: (clockwise from top) wall with internal insulation, wall with external insulation, AAC block wall and air cavity wall(Source: Authors)

3.4.3 Windows Shading

Windows, if not externally shaded, admit all incident solar radiation, including diffuse radiation from the sky. Most heat enters through windows—and it enters very rapidly. When glass windows are closed, the radiation that enters gets trapped inside, as in a solar cooker. Internal curtains do not stop this heat from entering the indoor space. Windows with external shading that intercepts direct sunlight and filters diffuse radiation can significantly reduce heat gain. Windows also bring daylight into interior spaces. They should be sized and arranged to provide comfortable daylight distribution while avoiding direct sun through external shading. Over-sizing windows and glazed openings in external walls can cause undesirable heat gain and uncomfortable glare.

Table 5 Strategies for minimizing heat gain through external shading on windows and fenestrations(Source: Authors)

Objective	Strategy	Action	Output
Minimizing heat gain	External shading	• Vertical and horizontal shading devices on windows to avoid direct sun and reduce glare • Wall shading with louvers, jallis, perforated metal sheets and trellis with creepers	• Blocks direct sunlight • Reduces heat gain • Blocks low - angle sun • Reduces glare

3.4.4 Natural Ventilation

Dissipation of heat accumulated in interiors is achieved through increasing air exchange or enhancing air flow. Natural ventilation helps in cooling when cooler outdoor air flows through and replaces warmer indoor air. When the outdoor air is cool and pleasant, windows are kept open to allow cooling. This removes accumulated heat and replaces stale, humid air with fresh air. The faster the air flows, the quicker the space cools. When outdoor air is uncomfortably hot, windows and doors are kept closed or slightly open. This allows limited ventilation to remove stale and humid air while minimising additional heat gain. During cool periods (mornings, evenings, and nights), natural ventilation is highly desirable. When a breeze is present, ventilation increases.

1. For the cooling benefit to be effective, the breeze must be able to pass through all habitable spaces.
2. Air movement through windows and other openings must be directed at body level and surfaces.
3. Window and opening placement on building façades must be optimized to enable effective airflow patterns in accordance with the intended ventilation strategy. Windows or other openings must be in the windward direction but should have an outlet in opposite orientation. Otherwise, pressure will build up inside because of lack of path for air to exit.
4. During still periods when there is no breeze, natural ventilation is negligible. It is also impeded in dense urban areas. In such scenarios:

    a. Ceiling fans serve a similar purpose.
    b. Ventilators above internal doors help allow airflow through rooms.
    c. Small exhaust fans installed in toilets or kitchens can help accelerate ventilation through habitable spaces and bring in cooler air more effectively.

Table 6 Strategies for heat dissipation through natural ventilation(Source: Authors)

Objective	Strategy	Action	Output
Dissipating heat	Placement of openings (windows, ventilators etc.)	• Opposite/adjacent wall openings • Inlets facing prevailing winds • Outlets placed on leeward side • Diagonal openings maximize airflow inside	• Captures natural breeze • Enhances airflow
	Window operable area (WOA)	• Appropriate openable area in windows depending on geographical location of building, orientation of openings and shading elements	• Ensures proportionate openings for ventilation and daylighting

The window operable area (WOA) is an indicator of the potential of air exchange considering wind direction, speed, and surroundings. Ensuring an appropriate WOA based on these factors will enhance ventilation and improve thermal comfort while also managing heat gain.

Coastal areas of Tamil Nadu experience a sea breeze from the east in the late afternoon/evening and a land breeze from the west during the night/early morning. Inland Tamil Nadu experiences breeze from the south-east during summer monsoon and north east during winter monsoon along with the prevailing land breeze. Windows, ventilators and doors should be strategically placed to face these winds.

3.4.5 Building orientation[2]

The orientation of a building's walls and windows has a significant bearing on the amount of solar radiation received. East- and west-facing sides receive much more incident radiation than north- and south-facing sides. Similarly, the benefit of natural ventilation depends on the placement of openings in walls aligned with local wind flows, or the design of the building form and windows to catch prevailing winds.

3.4.6 Thermal Mass

Walls and roofs can control heat transfer into buildings through resistive and capacitive insulation. The first helps in managing the rate of heat transfer through the construction. Capacitive insulation, also 'thermal mass' leads to dampening of the maximum indoor temperature and utilizes the 'Coolth' stored in the building mass (mostly walls and roofs) to improve thermal comfort at night and loose heat build-up during the day.

Dense or heavy weight materials have high thermal mass; they absorb and store heat and release it slowly (thermal lag). This moderates the daily temperature swings in building interiors (difference between daytime and night time peak; the hottest and coolest parts of the day respectively). High thermal mass materials or walls and roofs of such materials have high thermal lag.

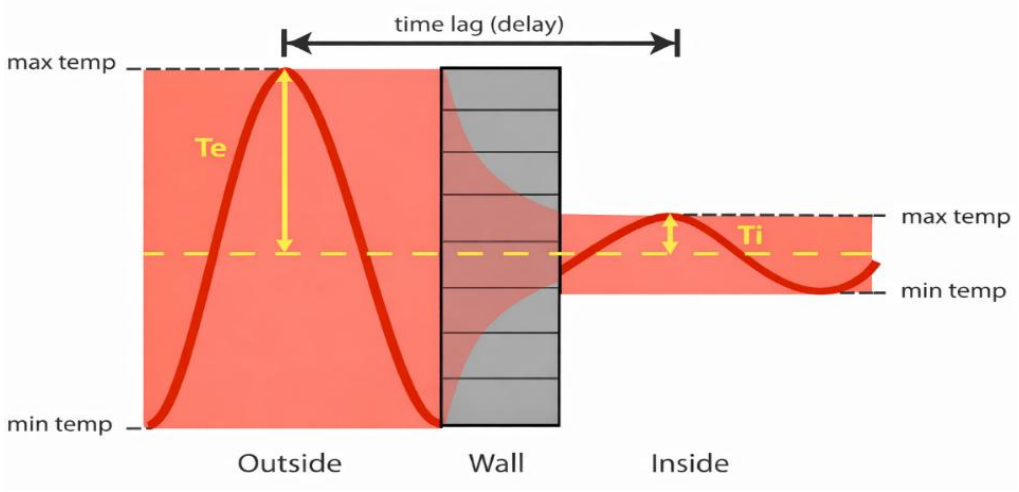


Figure 16 The concept of thermal mass (Source: Authors)

Thermal mass as a strategy works best in climates with significant diurnal swing i.e. difference between night and daytime peak. Performance of thermal mass improves with night ventilation and shading. Ventilation helps in drawing away heat dissipated from such walls or roofs. During the day, as outdoor temperatures rise rapidly, indoor temperatures remain relatively cooler. Windows and external doors, if shut or kept only slightly open, keep out the hot midday and afternoon air. In the early part of the night, indoor temperatures often remain higher than the falling outdoor temperatures. This necessitates copious night ventilation to flush out the accumulated heat and take advantage of the cooler outdoor air. Shading helps in limiting the solar radiation and thus decreases the heat stored in high thermal mass structures
Figure 17 compares the temperature profile on a typical summer day in a hot-humid climate location and a warm-humid climate location. In the hot-humid climate, the peak temperature is 5°C higher than in the warm-humid location. The hot-humid region is not only hotter, but also experiences a higher diurnal temperature variation—7.2°C compared to only 3.2°C in the warm-humid climate.

[2] Building orientation in relation to the sun and wind flows is usually addressed through urban design guidelines for town planning and site planning of large land parcels. This guideline is limited to the design and construction of the building envelope.

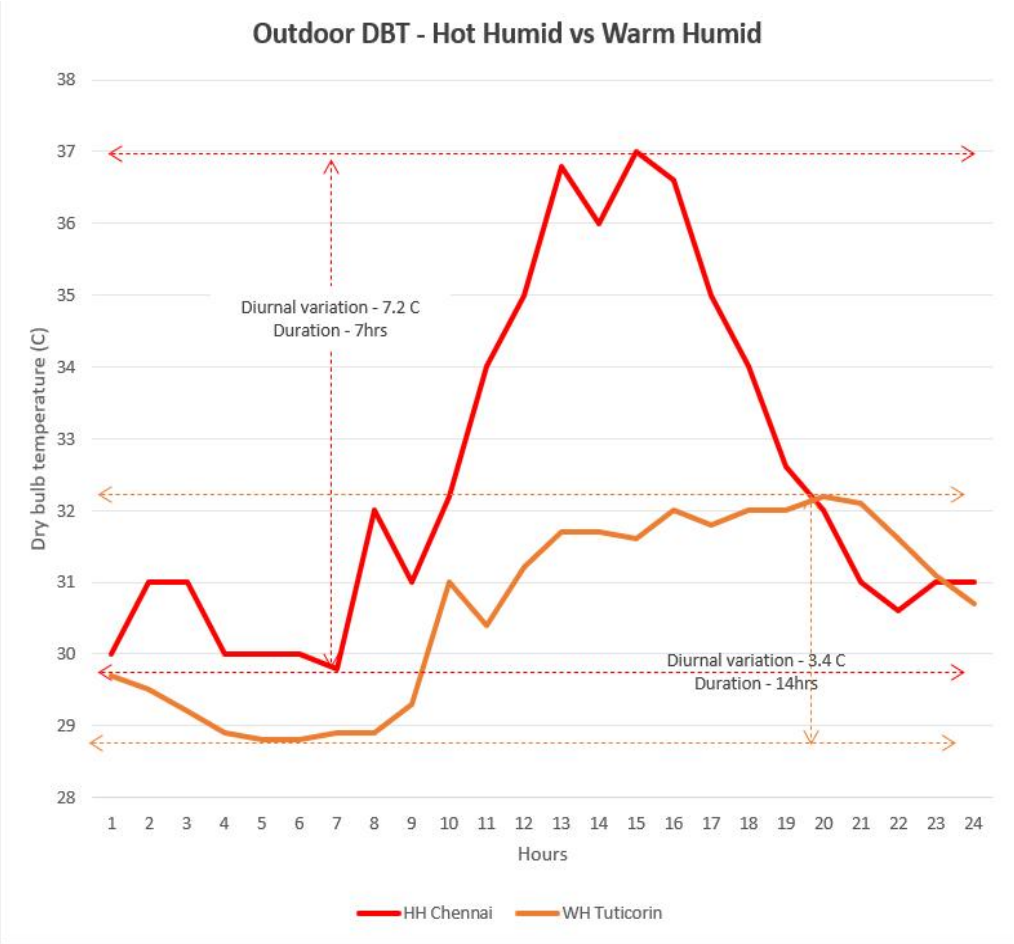


Figure 17 Temperature profile on a typical summer day in a Hot-humid climate location and a Warm-humid climate location. (Source: Authors)

Figure 18 compare the internal surface temperatures of walls with the same U-value (0.85 W/m²K) but different thermal mass. It is evident that there is a significant benefit to increasing thermal mass in the hot-humid climate. In the warm-humid climate, however, the advantage of additional thermal mass is marginal.

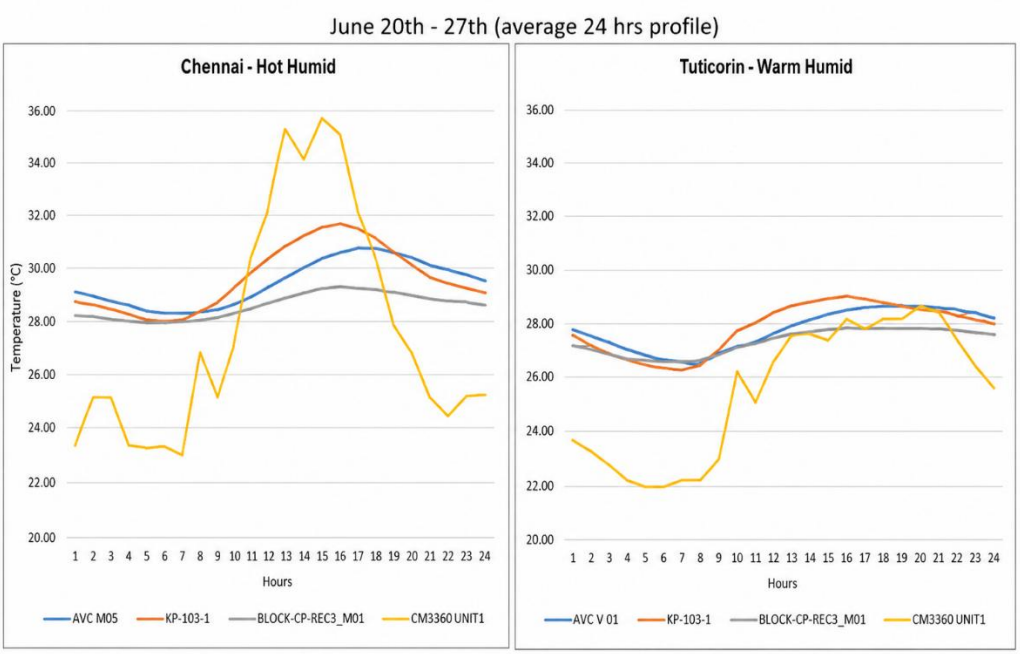


Figure 18 Internal surface temperatures with walls of the same U-value and different thermal mass in Hot-Humid and Warm-Humid climate zones. (Source: Authors)

The graphs also compare the indoor air temperature in a hot-humid climate (Coimbatore considered) during peak summer days in May. The comparison is between three wall assemblies (Table 7). The internal specific heat capacity (Km) of the AAC block wall assembly is 163 kJ/m²K, while that of the sandwich wall is only 45 kJ/m²K. Given the same resistive insulation, the additional benefit of *capacitive insulation*—provided by thermal mass—ensures a delay in peak indoor temperature and allows better utilisation of the diurnal range in outdoor conditions.

Table 7 The impact of thermal mass along with insulation in hot-humid and Warm-humid climates. (Source: Authors)

Wall assembly	Thickness (mm)	U-value (W/ m². K)	Specific Heat (kJ/ m².K)
250mm AAC block wall with plaster	285	0.85	165
100mm RCC + 25 mm extruded polystyrene (XPS) +115 mm brick wall with plaster	275	0.85	440
30mm polyurethane foam (PUF) panel with PPGI sheet	30	0.8	9.5

Thermal mass in Hot-Humid climates

In the hot-humid regions of Tamil Nadu, during the hot season from March to July, maximum temperatures reach around 39°C, while minimum temperatures drop to 29°C. The diurnal temperature variation is between 7°C and 10.5°C. In this climatic condition of high diurnal temperature variation, the thermal mass of the walls and roof has a beneficial effect by dampening the variation in indoor temperatures. There is also a time delay in the pulse of outdoor temperatures reaching the indoor spaces. High thermal mass walls and roofs should be considered.

Thermal mass in Warm-Humid climates

In the warm-humid southern coastal areas of Tamil Nadu, where maximum temperatures reach around 32°C and minimum temperatures drop to 27°C, the diurnal temperature variation is less than 5°C. In this condition of low diurnal variation, walls

and roofs need not have high thermal mass—lighter wall construction is adequate. Low to medium thermal mass walls are optimal.

3.5 Evidence of PCS effectiveness

The examples below demonstrate the benefits of optimally deployed passive strategies.

Window Design, External Shading, and Ventilation

The case illustrates the importance of window design and external shading. The base case is a room on an intermediate floor, with AAC block walls and a southwest-facing window. The window is oversized, inadequately shaded, and has limited openable panels for ventilation.

The improved case reduces the height of the window, improves external shading, and provides more openable panels to allow better ventilation. In addition, a small exhaust fan is added in the kitchen to enhance ventilation during evenings and nights, when the outdoor temperature is cooler than the indoor temperature.

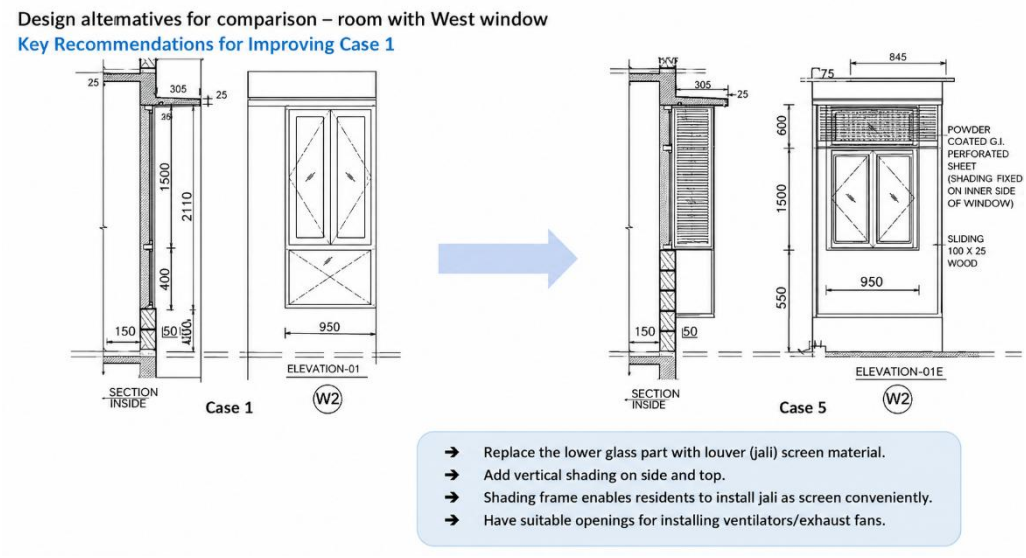


Figure 19 Importance of window design and shading. (Source: Authors)

The graph below shows the variation in outdoor and indoor temperatures over three successive typical hot days during the hot season in a warm-humid location. The outdoor temperature peaks at 36°C during the day and drops to 23°C at night. The two horizontal lines indicate the comfort band of temperatures within which occupants feel thermally comfortable.

Indoor temperature is brought down progressively through successive improvements in window design and external shading. The openable area for night ventilation is increased. Finally, night ventilation is further enhanced mechanically with the exhaust fan. The combined result shows that, with all improvements in place, thermal comfort is achieved indoors and the need for air-conditioning is avoided.

For residential, institutional, or commercial buildings, the construction cost for basic civil works typically ranges from ₹15,000 to ₹20,000 per square metre of built-up area. For non-air-conditioned buildings, the additional cost of implementing PCS would be ₹300 to ₹500 per square metre. This is an essential and relatively small investment to ensure protection from heat stress and improve overall thermal comfort. For air-conditioned buildings, the PCS specifications require higher levels of insulation for the roof, walls, and windows. The additional cost in this case would be ₹800 to ₹1,200 per square metre of built-up area. With PCS integration, the cooling load attributable to external heat ingress can be reduced by at least 30%. This results in a reduction in the

capital cost of air-conditioning systems (due to smaller sizing requirements) as well as a significant decrease in electricity consumption. Thus, the additional cost of PCS is effectively compensated.

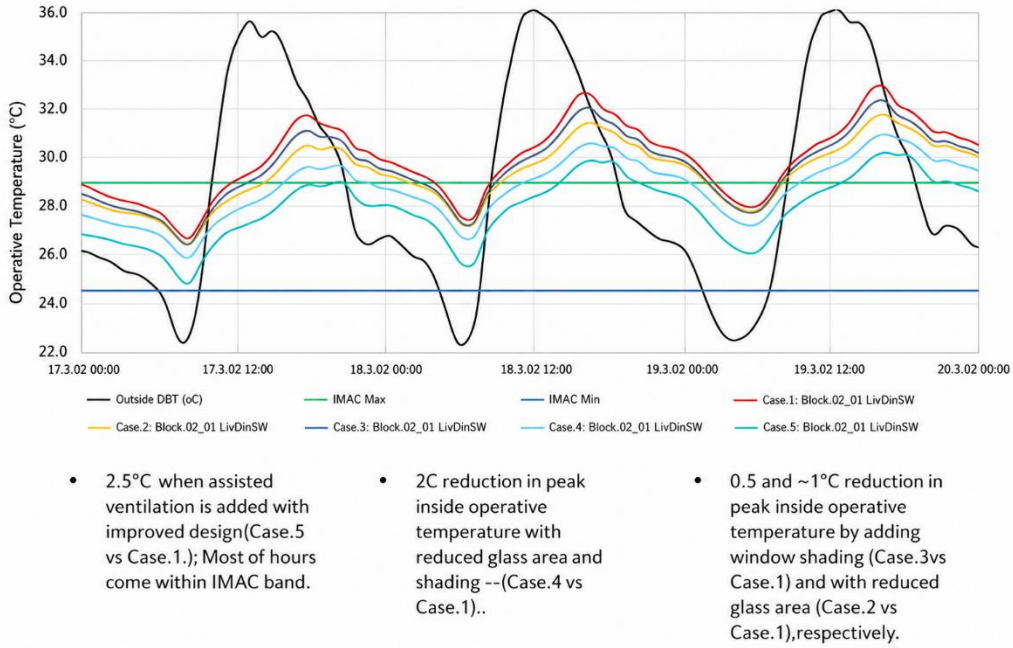


Figure 20 The variation in outdoor and indoor temperatures and improvement with reduction in glass area, shading, and assisted ventilation. (Source: Authors)

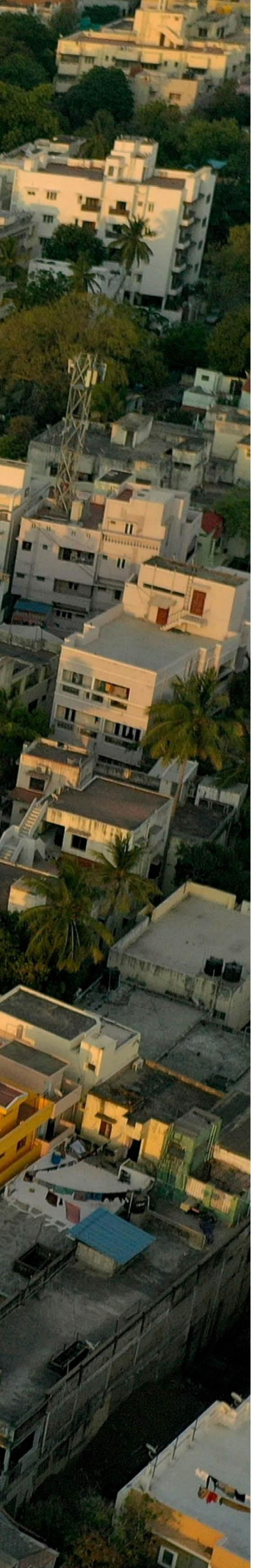
Table 8 Assessment for the incremental cost of implementing passive cooling strategies compared to baseline building. (Source: Authors)

PCS	Description	Unit	Incremental cost: Naturally ventilated	Incremental cost: Air conditioned
Roof Reflectance	High Reflective Paint	m^2	₹357.60	₹357.60
Roof Insulation	40mm over-deck Insulation with waterproofing and screed	m^2	₹520.00	₹912.50
Insulated Window Glass	Regular clear glass	m^2	₹0.00	₹3,000.00
Casement window + openable shutters	Double rebate Casement window with openable panels	m^2	(₹656.30)	₹0.00
External Shade	Lightweight detached shading, External shading devices	m^2	₹5,000.00	₹5,000.00
Wall Insulation	200 mm AAC Blockwork wall	m^2	(₹482.47)	₹1,012.76

4 Building Categories



Photo: Karl Janisse/Unsplash



The concept of 'cooling energy demand' anticipates the use of air-conditioning to achieve thermal comfort indoors. With global temperature rise, increasing humidity, and longer, more intense heat waves—exacerbated by the Urban Heat Island (UHI) effect—the experience of thermal discomfort and heat stress is steadily rising. Air-conditioning is being adopted progressively as incomes rise and as its capital and operational costs become more affordable. For certain functions, it is now considered essential. To optimise the thermal performance of a building's external envelope through Passive Cooling Strategies (PCS), buildings are being categorised into three types based on their use of air-conditioning and ensuing cooling energy demand.

4.1 Non–air-conditioned buildings

Not more than 10% of habitable spaces use air-conditioning; balance areas rely on natural wind movement through openings and ceiling or wall mounted fans. Low income single or multifamily housing, hostels, primary or secondary educational institutions are included in this category. These buildings use air-conditioning selectively—either in certain spaces or only during peak heat seasons—while relying on natural ventilation during the rest of the year. They are likely to represent most of the future construction and will be built on modest budgets.

The approach for passive cooling here must be that while occasional spaces may be air-conditioned, the primary aim is to minimise discomfort and reduce the felt need for air-conditioning. The technical recommendations for naturally ventilated buildings would, in the first instance, ensure the protection of habitable indoor spaces from extreme heat stress and, secondly, minimise the duration of thermal discomfort without recourse to air-conditioning. For this category, simple, cost-effective PCS are recommended. These PCS measures will be based on simple, proven construction techniques that entail no or negligible additional costs when compared to conventional practices. They will be aligned with and complementary to the Eco-Niwas Samhita (ENS) or ECSBC Residential 2024.

4.2 Partially air-conditioned buildings

Upto 30% of habitable area is air-conditioned in this category of buildings. Service and circulation spaces are not air conditioned. Institutional buildings, government offices, premier higher education institutions, no-star hotels, middle income single-family housing to be included in this category. For instance, schools and colleges may use air-conditioning only during the hottest seasons and often only during the day. Being relatively more expensive than non–air-conditioned buildings, they can accommodate more rigorous PCS requirements to further reduce heat transfer across the envelope.

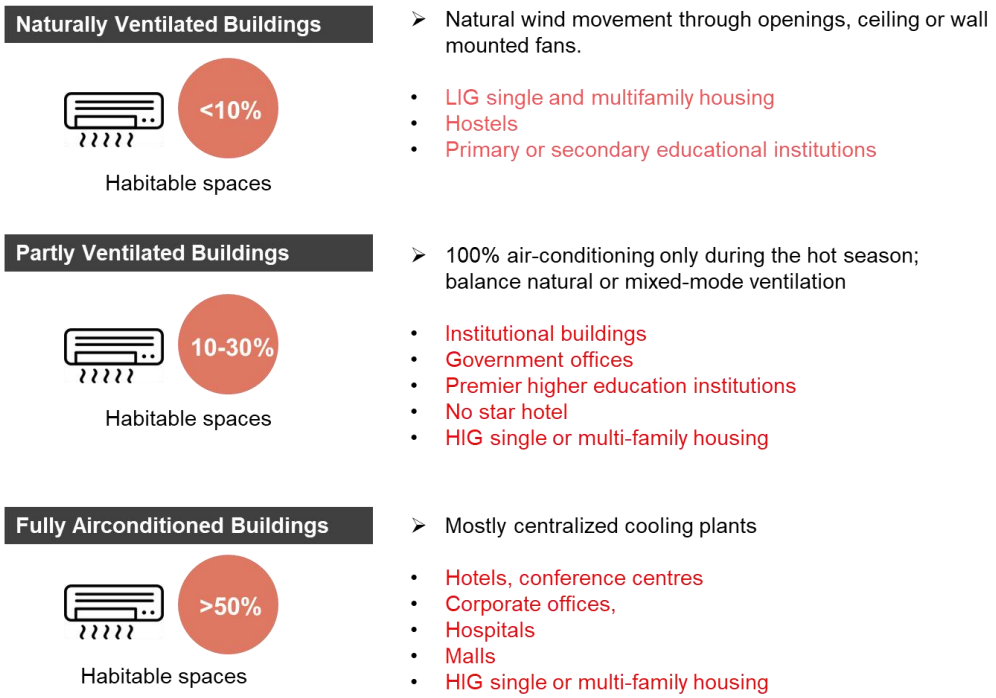


Figure 21 Building categorisation based on extent of air conditioning (Source: Authors)

4.3 Fully air-conditioned buildings

Greater than 50% of the habitable spaces are air-conditioned in this category. Four-star and above hotels, conference centres, corporate offices, hospitals, shopping malls and high-income multi-family housing are included in this category. They are designed to offer a high degree of environmental control throughout the year. Such buildings inherently command higher budgets for advanced air conditioning systems and controls.

The objective for thermal comfort and energy efficiency her must be to minimise peak cooling loads and reduce overall energy consumption for air-conditioning. For buildings that use air-conditioning to achieve higher thermal comfort and remove internally generated heat and humidity, PCS recommendations must be more stringent. These measures should be calibrated to curtail the cooling energy demand at marginal additional costs in the construction of the building fabric. While they may involve marginal additional construction costs, these are offset by reduced sizing of electromechanical cooling systems and lower long-term energy consumption. These recommendations will be consistent with and complementary to the Energy Conservation and Sustainability Building Code (ECSBC), and are suitable for adoption within building regulations.

5 Passive Cooling Requirements



Photo: Hunter/Pexels

This section outlines the recommended performance standards to optimise thermal comfort with minimal or no reliance on air-conditioning in buildings across Tamil Nadu. It aims to establish prescriptive performance requirements tailored to different building types and climatic conditions within the state. The recommended standards are categorised based on:

- **Building type as per mode of operation:** Air-conditioned, partially air-conditioned, and non–air-conditioned.
- **Climatic sub-classification:** Warm-Humid, Hot-Humid, and Cold.

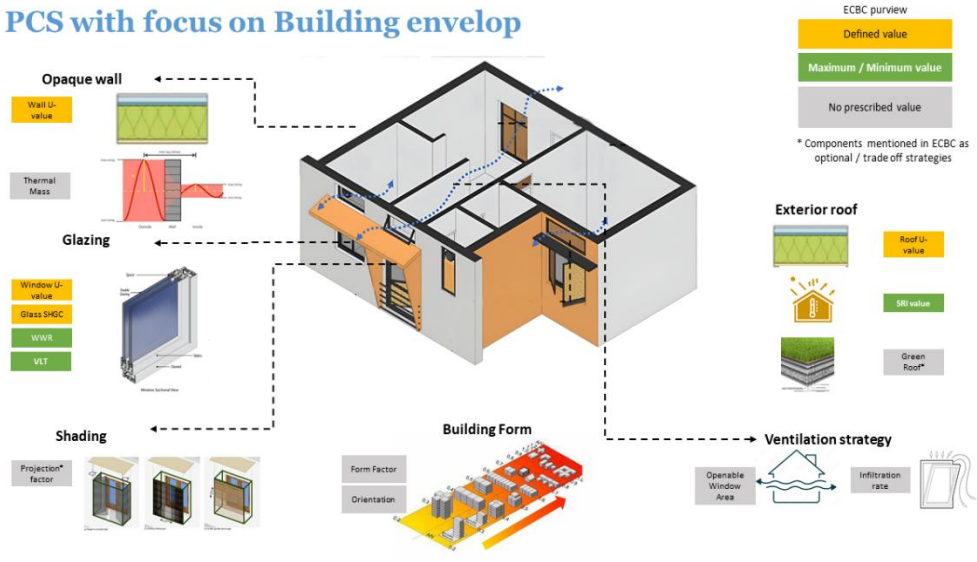


Figure 22 Aspects of Passive cooling strategies considered in these Guidelines(Source: Authors)

Figure 22 presents a framework for selecting passive comfort strategies, including building envelope elements crucial for achieving thermal comfort. The proposed requirements are aligned with the Energy Conservation and Sustainable Building Code 2024 (ECSBC) and the Eco-Niwas Samhita (ENS), ensuring a smooth transition from initial implementation of PCS-related building bylaws to full compliance with ECSBC and ENS in larger-scale projects.

5.1 Passive Cooling by Mode of Operation and Climate Sub-Zone

Efficacy of passive strategies vary across different modes of building operation and climatic sub-zones. The following matrix illustrates key distinctions across these parameters.

Table 9 Passive cooling approach based on climate sub- classification

	Hot-Humid	Warm-Humid	Cold
Shading on windows	100% from 9 am to 4 pm from March to November.	100% from 10 am to 4pm throughout the year.	100% from 10 am to 3 pm from March to November
Window Operable Area	Restricted opening size primarily focused on Night purge ventilation	Higher openable area with provision of opaque shutters and louvres to increase window area	Restricted opening size primarily focused on daytime ventilation in the summer
Thermal Mass in Walls	Required	Not required	Required

5.2 Opaque Wall Insulation

1. Two heat transfer properties are required to be addressed in wall assemblies.
    a. **Resistive Insulation** measured as U- value ($W/m^2.K$) which determines the rate at which heat transfers through the construction.
    b. **Capacitive insulation** (thermal mass) measured as K value ($KJ/m^2.K$) that leads to dampening of the maximum indoor temperature and utilize the 'Coolth' stored in the building mass to improve thermal comfort at night and loose heat build-up during the day.

2. All opaque, above grade external walls must meet the requirements in Table 9.

Table 10 Maximum U value and minimum specific heat for opaque external, above-grade wall assembly(Source: Authors)

Effective for all external walls*	Warm & Humid	Hot & Humid	Cold
Non Air-conditioned Buildings			
U value ($W/m^2.K$)	0.85	0.85	0.85
Specific Heat ($kJ/m^2.K$)	N.A.	160	160
Partially Air-conditioned Buildings			
U value ($W/m^2.K$))	0.63	0.63	0.63
Specific Heat ($kJ/m^2.K$	N.A.	160	160
Fully Air-conditioned Buildings			
U value ($W/m^2.K$))	0.4	0.4	0.4
Specific Heat ($kJ/m^2.K$)	N.A.	160	160

Note: Effective U-value for external wall area must include all exposed vertical facades, including structural members. Use weighted area average for different construction assemblies to arrive at the effective Wall U-value. Wall areas of shafts can be excluded from this calculation.

5.2.1 Opaque Wall Solution Sets

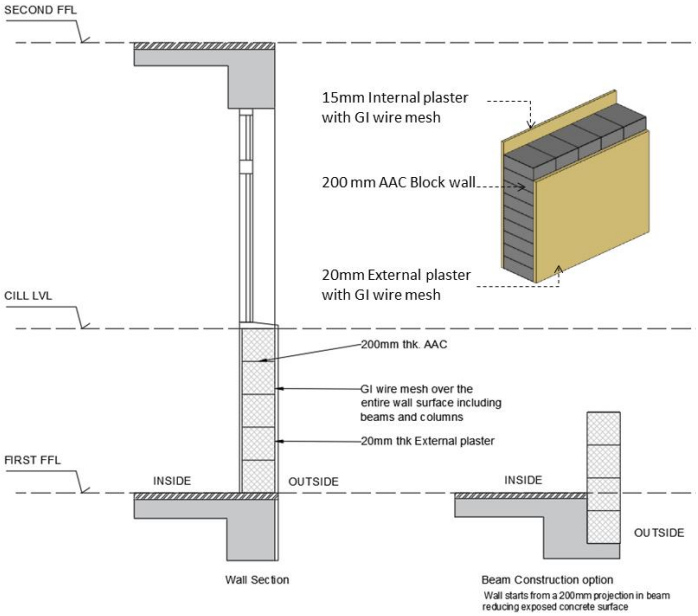
Wall specifications can be altered to generate multiple Options for U-values that comply with performance requirements across different modes of air-conditioning operations and climate zones. Table 9 can be used to generate multiple U-value combinations.

Table 11 Recommended U-values (W/m2. K) for opaque wall assemblies(Source: Authors)

	Air conditioned	Partly Air-conditioned	Non-Air-conditioned
Warm-Humid	0.4	0.63	0.85
Hot-Humid	0.4	0.63	0.85
Cold	0.4	0.63	0.85

WALL ASSEMBLY 1:

Autoclaved Aerated Cellular Concrete (AAC) blockwork with cement plaster on both internal and external faces



	Option1	Option 2	Option 3
	200 mm AAC Block	250 mm AAC Block	400 mm AAC Block
Thickness (mm)	235	285	435
U-value (W/m^2. K)	0.78	0.63	0.41
Specific Heat (kJ/kg. k)	160	190	272
Cost / Sq. Mt. (INR)	₹1,950	₹2,187	₹3,510

Tender Specifications

1. 200 mm AAC Blockwork:

Providing and constructing masonry work of Grade I Autoclaved Aerated Cellular Concrete (AAC) blocks conforming to IS 2185-1984 Part 3 and IS:6441 1972, of height 200 mm, width 200 mm, and length 600 mm (from approved sources), using fly ash content as per IS 3812-1981 and Portland Pozzolana Cement PPC, with cement mortar 1:6 (1 Cement :6 coarse sand) in superstructure, including conveyance of materials to site, labor, taxes, and other applicable charges, as approved by engineer-in-charge. AAC blocks should have dry density of 551 to 650 kg/cu. mt., compressive strength of at least 3N/sq. mm., water absorption less than 15%, and thermal conductivity less than 0.24 W/m.K. Section 6.14 of CPWD Specifications 2019 (Volume 1) to be referred for additional specifications.

2. 250 mm AAC Blockwork:

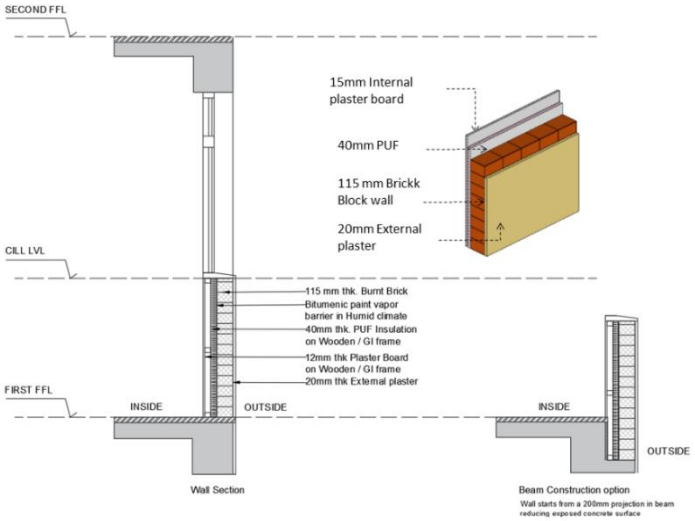
Same as above with changes in dimension of AAC Blocks: height 200 mm, width 250 mm, and length 600 mm (from approved sources).

3. 400 mm AAC Blockwork:

Same as above with changes in dimension of AAC Blocks: height 200 mm, width 400 mm, and length 600 mm (from approved sources).

WALL ASSEMBLY 2:

115 mm Brick Wall + Polyurethane Foam (PUF) + 15 mm Cement Board



	Option1	Option 2	Option 3
	40 mm PUF	50 mm PUF	75 mm PUF
Thickness (mm)	190	200	225
U-value (W/m2. K)	0.7	0.57	0.4
Specific Heat (kJ/kg.k)	192	192.5	193
Cost / Sq. Mt. (INR)	₹3,150	₹3,190	₹3,225

Tender Specifications

1. Brickwork plus 40 mm PUF Insulation:

Providing and fixing 50 mm OR 75 mm thick (tolerance +2/-0 mm) Grade-B2 (fire retardant properties as per DIN 4102, Part 1) rigid polyurethane (PU) sheet, confirming to IS: 12436, temperature limit +110 °C to -180 °C, Chlorofluro and hydrofluoro carbon (CFC and HFC) free, closed cell content between 90-95%, sheet size of 1000mm x 500mm or as specified, density of the sheet between 32-36 kg/m3, compressive strength at 10% deformation (in direction of rise) of ~170 KN/ m2 , thermal conductivity (at 50 °C) of .021 to .023 W/m.k as per IS:3346, maximum horizontal burning of 125mm as per IS:11239 or BS:4735, maximum water vapour transmission < 5.5 ng/Pa·s·m, on inside, non-plastered face of brick wall (third class kiln burnt bricks with palstering on external face).

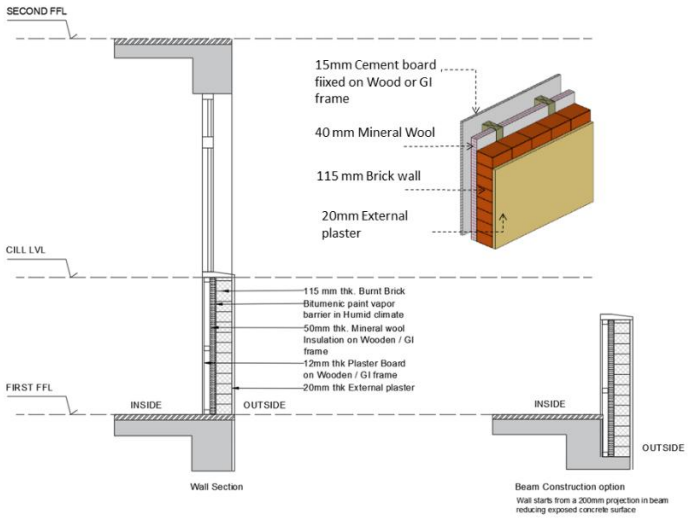
PUF to be fitted in framework of 50 x 50 x 0.6 mm GI channels/ runners or wooden frame, supplied and fastened to wall at 600 mm centers using nylon sleeves and steel/ dash fasteners, including cutting, bending, securing with necessary accessories, and ensuring a rigid, straight, and level framework

PUF sheet to be covered with 12 mm thick fiber cement board Type B(minimum 1250 kg/m3 density as per IS: 14862:2000), of size and make as approved, fixed to GI/ wood framework with corrosion resistant screws @ 300 mm centres, to either side of GI/ wood studs. The square and tapered edges of the boards are to be joined and finished to have a flush look which includes filling and finishing with cement-based filler, fiberglass mesh tape, cement-based putty (surface preparation), as per drawing

	and manufacturer specifications. Cement fiber board to be finished with primer and 2 coats of plastic emulsion or acrylic paint OR other finishing material of approved brand and colour. **2. Brickwork plus 50 mm PUF Insulation:** Same as above but with 50 mm PUF insulation. **3. Brickwork plus 75 mm PUF Insulation**: Same as above but with 75 mm PUF insulation.

WALL ASSEMBLY 3:

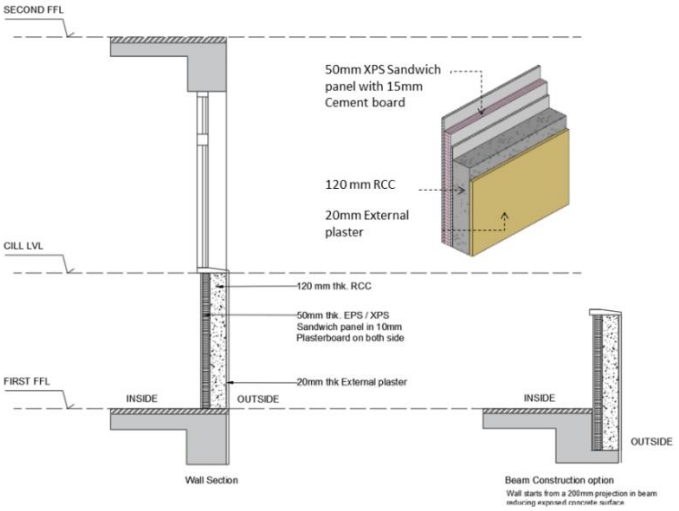
115 mm Brick Wall + Mineral wool with Wood frame + 15 mm Cement board



	Option1	Option 2	Option 3
	40 mm Mineral Wool	60 mm Mineral Wool	100 mm Mineral Wool
Thickness (mm)	215	215	250
U-value (W/m2. K)	0.75	0.6	0.4
Specific Heat (kJ/kg. K)	200	205	208
Cost / Sq. Mt. (INR)	₹2,440	₹2,562	₹2,767
Tender Specifications	Providing and laying 115 mm thick brick wall on exterior face. Providing 40–100 mm mineral wool insulation within a wooden framework fixed to wall. Cement board to be fixed on the wooden framework to enclose the insulation.		

WALL ASSEMBLY 4:

120 mm RCC Wall + Extruded Polystyrene (XPS) Sandwich Cement Board



	Option1	Option 2	Option 3
	40 mm XPS	50 mm XPS	75 mm XPS
Thickness (mm)	215	225	250
U-value (W/m2. K)	0.7	0.57	0.4
Specific Heat (kJ/kg. K)	300	301	303
Cost / Sq. Mt. (INR)	₹3,400	₹3,570	₹3,749

1. **RCC with 40 mm XPS Insulation:**

Technical Specifications

Providing and making RCC wall as per specification. Providing and fixing a prefabricated sandwich panel wall compromising 50 mm thick extruded Polystyrene (XPS) rigid insulation with shiplap joints and 20 mm thick cement board on both faces. Thermal conductivity = < 0.028 W/m. K (ASTM C518 aged 90 days at 24 °Celsius), compressive strength >= 250 kPa (ASTM D1621), tensile strength >= 300 kPa (ASTM D1623), water absorption < 1% (ASTM D2842), flammability class B2 (DIN 4102). The panel is to be fixed over finished external walls using minimum 2 mm thick polymerized mortar adhesive and mechanical fasteners as per manufacturer's guidelines. Over the external cement board, apply a 3-4 mm polymerized mortar base coat reinforced with 150 gsm fibreglass mesh, embedded using a notched trowel, finished as directed by the Engineer-in-Charge.

5.3 Window Shading and High-Performance Glazing

Tamil Nadu is located between 8°04'N and 13°35'N latitude, and buildings in this region experience significant solar exposure on the northern façade, unlike in higher latitudes. Windows and fenestration significantly influence heat gain through five critical factors: window-to-wall ratio (WWR), window openable area (WOA), solar heat gain coefficient (SHGC), window U value and external shading. In warmer climates, SHGC is more prominent in controlling heat gain and must be minimized for enhanced cooling.

The Energy Conservation and Sustainability Building Code (ECSBC) 2024 specifies a maximum Solar Heat Gain Coefficient (SHGC) of 0.27 for vertical fenestration assemblies, including both the glass and frame area, with a weighted average SHGC.

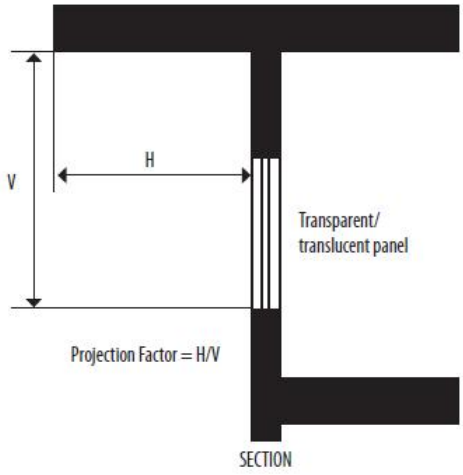
While the selection of glazing with appropriate SHGC values is crucial, external shading of windows and walls is equally important to reduce direct solar radiation and the surface temperature of façades. Adding external shading devices, vertical or horizontal or a combination, further limits solar heat gain. To promote the adoption of shading devices, these guidelines mandate a minimum Projection Factor (PF), as defined in ECBC 2017. With sufficient shading, an effective SHGC for the entire window assembly can be calculated using the method outlined in Annex 1 (ECBC 2017, Section 4.33, Equation 4.1). The recommendations here are applicable for static shading.

1. Projection Factor (PF)

The Projection Factor (PF) measures the proportion of the window area that is shaded. It is defined as:

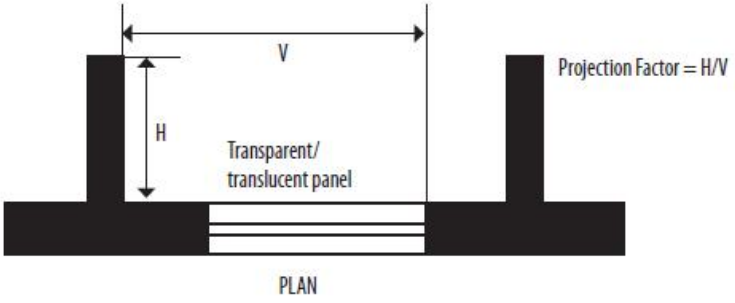
a. For horizontal shading: PF = Depth of shading / Height of window

It is derived as the ratio of the horizontal depth of the external shading projection to the sum of the height of the fenestration and the distance from the top of the fenestration to the bottom of the farthest point of the external shading projection, in consistent units.



b. For vertical shading: PF = Depth of shading / Width of window

It is derived as the ratio of the horizontal depth of the external shading projection to the distance from the window jamb to the farthest point of the external shading projection, in consistent units. For windows having both overhangs and side fins, projection factor is average of ratio projection factor for overhang only and projection factor of side fin only.



2. Solar Heat Gain Coefficient (SHGC):

SHGC is the property of the glass that determines the ratio of incident solar radiation transmitted through the glass as long-wave infrared radiation, which increases indoor heat gain. Solar heat gain includes directly transmitted solar heat (as longwave infrared radiation) and absorbed solar radiation, which is then reradiated, conducted, or convected into the space.

3. Effective Solar Heat Gain Coefficient (SHGC_eff):

The Effective SHGC (SHGC_eff) modifies the SHGC by accounting for the impact of external shading. It is calculated by dividing the glass SHGC by the Shading Equivalent Factor (SEF), as specified in ECBC 2017, Section 4.33, Equation 4.1.

4. All vertical fenestrations with glazing should meet the following requirements:
a. Minimum Visual Light Transmittance (VLT) for non-residential buildings is 0.27 and for residential buildings is 0.17
5. All vertical fenestrations, openable or otherwise, can demonstrate compliance by exceeding the minimum Projection Factor and optimising the glass SHGC to meet the Effective SHGC requirements in Table 12.
6. Shading devices for windows must be installed externally as a detached lightweight structure and not as an extension of the internal floor.
7. The soffit of the internal floor should be at least 300 mm above the top of the window shading device.

Table 12 Minimum requirements for shading and glazing material in vertical fenestrations(Source: Authors)

	Warm & Humid	Hot & Humid	Cold
Non-air-conditioned Buildings			
Projection Factor	>=0.6	>=0.7	>=0.5
Maximum Glass SHGC	<=0.7	<=0.5	<=0.7
SHGC eff	*0.5*	*0.35*	*0.54*
Partially Air-conditioned Buildings			
Projection Factor	>=0.6	>=0.7	>=0.5
Maximum Glass SHGC	<=0.5	<=0.5	<=0.5
SHGC eff.	*0.35*	*0.35*	*0.38*
Fully Air-conditioned Buildings			
Projection Factor	>=0.6	>=0.7	>=0.5
Maximum Glass SHGC	<=0.35	<=0.35	<=0.5
SHGC eff.	*0.25*	*0.25*	*0.38*

Note: G+6 buildings with RCC shading projections can maintain projection factor at 0.45 but achieve the required SHGCeffective by increasing SHGC of the glazing

- SHGC-eff is averaged across all orientations.
- Balconies, terraces, or floor cantilevers within the permissible FSI can be considered to meet the Projection Factor requirement for the glazing on the floor below.

5.4 Window Area

1. The WWR for habitable rooms must not exceed the limits prescribed for specific building typologies and climate sub-zones in Table 13.
2. The WWR for non-habitable spaces and the building as a whole must not exceed 40%, both:
    - Individually for each exterior wall (defined as a contiguous wall in a single plane/orientation), and
    - In total across the entire building envelope.

3. An additional 5 percent WWR can be considered in the form of opaque/non-glazed shutters such as louvred ventilators or operable panels with opaque/louvred shutters.

Table 13 Minimum requirements for window to wall ratio (WWR) and window openable area (WOA) (Source: Authors)

	Warm & Humid	Hot & Humid	Cold
Non-Air-conditioned Buildings			
WWR	<=30%* Glazing <=25% Opaque shutters- 5%	<=25%* Glazing <=20% Opaque shutters- 5%	<=30%* Glazing <=25% Opaque shutters- 5%
WOA	>=90%	>=90%	>=90%
Window U-value including frame (W/m^2K) **	<=5.5	<=5.5	<=5.5
Partially Air-conditioned Buildings			
WWR	<=30%* Glazing <=25% Opaque shutters- 5%	<=25%* Glazing <=20% Opaque shutters- 5%	<=30%* Glazing <=25% Opaque shutters- 5%
WOA	>=90%	>=90%	>=90%
Window U-value including frame (W/m^2. K) **	<=4.5	<=4.5	<=4.5
Fully Air-conditioned Buildings			
WWR	<=40%	<=40%	<=40%
WOA	>=50%	>=50%	>=50%
Window U-value including frame (W/m^2. K) **	<=3	<=3	<=3

Notes:

1. *Exterior glazed doors are included in the WWR calculation.*
2. *Exterior opaque entry doors are not included in the WWR calculation.*
3. *The Window U-value is influenced by both the glass and the frame conductivity. For guidance on frame selection, refer to ECBC 2017, Section 10.2.*

5.5 Cross Ventilation

Cross ventilation is essential for thermal comfort in non-air-conditioned buildings. It should be achieved through appropriately designed window openings, supported by ceiling fans and mechanical exhaust fans. Simulation studies indicate that 12–15 air changes per hour (ACH) are needed to efficiently remove stored heat from the building fabric, provided the outdoor air temperature is at least 2°C lower than the indoor temperature.

Climate zones and ventilation are linked as follows:

1. In Hot-Humid climate zones (e.g., much of Tamil Nadu), night temperatures fall rapidly post-sunset and continue to drop until early

morning. To maximise the benefit from this cooling, internal heat stored during the day must be flushed out quickly by drawing in the cooler night air.

2. In Warm-Humid zones, where the diurnal temperature variation is small and night-time cooling is slower, more copious ventilation is required to expel the internally stored heat.

5.5.1 Windows and Ventilator Location

The following provisions should be followed to facilitate adequate cross ventilation in non-airconditioned or partially air-conditioned buildings.

1. At least 75% of the regularly occupied spaces (by area) in a building must have an opening (doors*, ventilators, or windows) to the outdoor environment in at least two orientations.
2. Openings should not have any permanent obstruction within 2 metres of the external surface.
3. For habitable rooms where openings in opposite or adjacent walls are not possible or with only one external face, internal transfer-grilles (ventilator panels) of surface area ≥ 10 % of the room's floor area but not less than 0.5 square meter, at high and low levels, must be provided on the opposite wall to facilitate airflow across the room.
4. All naturally ventilated and partially air-conditioned buildings must allow 12- 15 air changes per hour (ACH) in habitable spaces for thermal comfort. Kitchens, bathrooms, corridors, and lobbies must have 6-10 ACH.
5. Exterior entrance doors to the building or to individual dwelling units in residential buildings cannot be counted in this calculation.



Figure 23 Example of an effective window design – shaded window with ventilator, openable window, with opaque panels for the bottom shutters. (Source: Authors)

5.5.2 Mechanically Assisted Ventilation

Mechanically assisted ventilation using exhaust fans during nights, when the outside temperature is cooler than the indoor temperature, accelerates the flushing out of heat stored in the internal fabric of the building. This is especially beneficial for homes which need to be comfortable during the night. In dense urban areas, this natural air exchange

rate may not be achievable. Here also, appropriately located mechanical exhaust fans are recommended to assist cross ventilation.

1. To achieve 12–15 ACH, the minimum capacity of the exhaust fan should be 2.5 CFM per square feet of floor area. For larger rooms, additional fans may be required. Fans should be located opposite the inlet windows to draw in cool air effectively via negative pressure.
2. All habitable rooms must be provided with ceiling fans confirming to Table 14 or NBC 2017 Part 8 - Building Services - Section 1 Lighting and Natural ventilation, Clause 5.7.4. Table 13, whichever is more stringent.
3. Optimum fan-blade axis must be at ~ 2.5 meter above floor (for a 3-meter ceiling), with blade-to-ceiling clearance ≥ 0.3 meter.

5.5.3 Provision for Extract Fan in Kitchens

Heat generated in kitchens should be vented out swiftly by

1. Installing an exhaust fan on the external wall or window of the kitchen, with a dedicated electrical connection.
2. Installing exhaust fabs with recommended minimum capacity of 2.5 cubic feet per minute (CFM) per square feet of floor area.

5.5.4 Ventilation Shafts

In deep-plan residential buildings, vertical shafts are often used for light, ventilation, and to route plumbing/electrical services. All building must comply with the following:

1. The minimum size of shafts for effective ventilation must be designed as per specifications in the NBC.
2. Ventilation shafts should be open at the roof level and protected from rain.
3. Outdoor condensing units of air conditioners should neither be installed in ventilation shafts nor be allowed to discharge hot exhaust air into them.

5.5.5 Air Tightness of Windows for Air-conditioned Spaces

1. All building types must ensure construction details to minimize gaps and cracks at junctions particularly between window and door frames and jambs.

Table 14 Optimum ceiling fan sweep (diameter) and number of ceiling fans as per room size(Source: Authors)

	Optimum ceiling fan size or sweep (mm) / number for fans and room length (m)										
Room Width (m)	**4 m**	**5 m**	**6 m**	**7 m**	**8 m**	**9 m**	**10 m**	**11 m**	**12 m**	**14 m**	**16 m**
3	1200/1	1400/1	1500/1	1050/2	1200/2	1400/2	1400/2	1400/2	1200/3	1400/3	1400/3
4	1200/1	1400/1	1200/2	1200/2	1200/2	1400/2	1400/2	1500/2	1200/3	1400/3	1500/3
5	1400/1	1400/1	1400/2	1400/2	1400/2	1400/2	1400/2	1500/2	1400/3	1400/3	1500/3
6	1200/2	1400/2	900/4	1050/4	1200/4	1400/4	1400/4	1400/4	1500/4	1500/4	1500/4
7	1200/2	1400/2	1050/4	1050/4	1200/4	1400/4	1400/4	1400/4	1500/4	1500/4	1500/4
8	1200/2	1400/2	1200/4	1200/4	1400/4	1400/4	1400/4	1400/4	1500/4	1500/4	1500/4
9	1400/2	1400/2	1400/4	1400/4	1400/4	1500/4	1500/4	1500/4	1500/6	1500/6	1500/6
10	1400/2	1400/2	1400/4	1400/4	1400/4	1500/4	1500/4	1500/4	1500/6	1500/6	1500/6
11	1500/2	1500/2	1500/4	1500/4	1500/4	1500/6	1500/6	1500/6	1500/6	1500/6	1500/6
12	1200/3	1400/3	2000/3	2000/4	2000/4	2000/4	2000/6	2000/6	2000/6	2000/6	2000/6
13	1400/3	1400/3	1200/6	1200/6	1400/6	1400/6	1400/9	1400/9	1400/9	1500/9	1500/9
14	1400/3	1400/3	1400/6	1400/6	1400/6	1400/6	1400/9	1400/9	1400/9	1500/9	1500/9

5.6 Cool Roof: Solar Reflective Top Finish

1. All flat roofs exposed to the sky (slope less than 20°) in structures upto G+3, with less than 40 percent area covered with solar rooftop photovoltaics, solar hot water system or any other services, should have the top finishing layer of paints, tiles or membranes of minimum Solar Reflective Index (SRI) of 90. The minimum initial surface reflectance must be 0.60 and the initial emittance 0.90. Solar reflectance shall be determined in accordance with ASTM E903-96, and thermal emittance shall be determined as per ASTM E408-71 (RA 1996).

5.7 Cool Roof Solution Sets Roof Insulation

2. The roof contributes to approximately 30% of the total heat ingress in the floor directly below it. Therefore, it is essential to effectively resist heat gain through the roof. Given that roofs in Tamil Nadu (and the broader Indian context) are predominantly constructed in RCC, the thermal capacity requirement of 160 kJ/m². K is typically met.
3. All exposed roofs must comply with the requirements in Table 15.

Table 15 Maximum U-values and minimum specific heat for opaque roof assemblies

	Warm & Humid	Hot & Humid	Cold
Non and Partially Air-conditioned Buildings			
U value (W/m^2. K)	0.47	0.47	0.47
Specific Heat (kJ/m^2. K)	N.A.	>=160	>=160

Fully Air-conditioned Buildings			
U value (W/m^2. K)	0.33	0.33	0.33
Specific Heat (kJ/m^2. K)	N.A.	>=160	>=160

5.7.1 Roof Solution Sets

Description		Option1	Option2
150 mm RCC + Polyurethane Foam (PUF) + 40 mm Screed + 20 mm Ceramic Heat Resistive Tiles		50 mm PUF	75mm PUF
	Thickness (mm)	265	285
	U-value (W/m^2. K)	0.48	0.33
	Specific Heat (kJ/kg. K)	386	387
	1. Providing and fixing 50 mm OR 75 mm thick (tolerance +2/-0 mm) Grade-B2 (fire retardant properties as per DIN 4102, Part 1) rigid polyurethane (PU) sheet, confirming to IS: 12436, temperature limit +110 °C to -180 °C, Chlorofluro and hydrofluoro carbon (CFC and HFC) free, closed cell content between 90-95%, sheet size of 1000 mm x 500 mm or as specified, density of the sheet between 32-36 kg/m^3, compressive strength at 10% deformation (in direction of rise) of ~170 KN/ m^2 , thermal conductivity (at 50 °C) of .021 to .023 W/m.K as per IS:3346, maximum horizontal burning of 125 mm as per IS:11239 or BS:4735, maximum water vapour transmission<5.5ng/ Pa·s·m 2. Roof slab to be dried and freed of all depressions or protrusions and to be cleaned to ensure all debris, dirt and loose particles are removed. Roof slope to be checked and if lacking, slope to be provided for free flow of water (1:100). 3. Coat of polyurethane (PU) primer to be provided and applied at the rate of 6-8 m² per litre on the cleaned and prepared concrete roof surface. Insulation board to be installed on the top and fixed with cementitious or bituminous adhesives and fasteners. All joints between boards/ panels to be sealed with polymerized mastic. Providing and fixing minimum 150 gm Geotextile membrane or 400 gm polythene sheet over the fixed insulation panel/ board for protection. Providing and laying over polythene/ Geotextile membrane in slope gradient minimum 40 mm thick PCC (1:2:4), in chequered rough finish, in panels of 2.5m x 2.5 m panels, reinforced with welded mesh of 75mm x 75mm x 1.5mm embedded in between. The protection profile in edges/ corners, etc., complete complying with standard specification. Final top finishing layer to be applied or installed as per specifications or instructions of project in charge.		

6 Retrofit for Passive Cooling



Pierre Author



The sharp rise in sales of room air conditioners and package AC systems signals an increasing demand for indoor comfort. This trend highlights both a desire for air-conditioned comfort when financially accessible, and, the inadequacy of current building designs in maintaining passive thermal comfort.

Older buildings with shaded windows and higher-mass envelopes perform better in resisting heat transfer. It is indeed ironic that many of the existing buildings that were designed and built before the advent of air-conditioning or shortly after air-conditioning arrived were more climate responsive than the modern glass-clad air-conditioned buildings built in the past two decades. This is certainly true of high-end commercial buildings and institutional buildings. Earlier buildings were typically built with thick masonry walls, shaded windows, and sloping tiled roofs—naturally minimising solar heat gain. In contrast, many modern buildings favour unshaded glazing and uninsulated RCC roofs and walls.

Recent buildings with low-mass, unshaded glass facades and uninsulated walls tend to become heat traps, leading to discomfort and higher energy use. High-rise buildings are particularly vulnerable, being more exposed to solar radiation and wind. This results in higher air infiltration through windows and doors, making natural ventilation difficult. In residential buildings for upper-middle and high-income groups, there is a growing trend of large glazed areas without adequate external shading. Buildings taller than seven storeys increasingly rely on uninsulated, all-concrete external walls—either precast or cast-in-situ. These high-conductivity walls significantly increase discomfort during hot seasons and elevate cooling loads.

6.1 Passive Cooling Strategies in Existing Buildings

Retrofitting existing buildings to incorporate passive comfort strategies in the has multiple advantages:

1. Avoids heat stress and improve thermal comfort for the health and wellbeing of occupants.
2. Reduces the demand for air-conditioning, thereby curtailing the rate of adoption and duration of AC use.
3. Lowers overall energy consumption in existing buildings.

It may be reasonably estimated that effective PCS retrofitting has the potential to reduce the energy consumption of air-conditioned buildings by 10–15%. This can contribute to reducing Tamil Nadu's peak electricity demand and the electricity consumption intensity of existing buildings, thereby lowering the greenhouse gas (GHG) emissions intensity.

6.1.1 Approach to retrofitting for passive cooling

Once a building is in use, modifying its external envelope while the building is in use causes some disruption and inconvenience. The inevitable additional cost of retrofitting requires financing and cost-benefit evaluation based on the specifics of each building – its design and construction, as well as its age and condition. Each aspect of potential improvement – roof, walls, windows, shading, enhanced air-movement and cross ventilation - would need to be evaluated separately to establish an order of priorities according to its cost-benefit.
The scope for retrofits can be guided with the following markers:

1. Measures that can be installed from the outside are easier to execute.
2. Addition of supper-efficient ceiling fans and mechanical exhaust fans is easy in naturally ventilated or partially air-conditioned buildings.

3. External window shading is the most effective retrofit intervention in such cases. Adding external shading arrangements can be done conveniently in low-rise buildings.
4. For upper floors, roof insulation and reflective finishes are essential. Roof insulation and finishing with reflective surfaces is the first action that can be taken on without disturbing the operations of the building.
5. Once a building begins to rely on air-conditioning, upgrading windows and external walls becomes necessary to reduce unwanted heat transfer and improve energy performance.
6. Measures that are likely to be more intrusive and technically elaborate, and more expensive are:
    a. External shading of all glass or curtain glazing buildings.
    b. Insulating external walls.
    c. Replacing windows.

6.1.2 Roof Insulation

a) High-SRI Paint or Tiles for Flat Roofs

Applying high Solar Reflectance Index (SRI) paint on flat roofs can reduce heat gain from solar radiation by 40–50%, compared to dark surfaces. This directly benefits the topmost occupied floor. Since SRI paints reflect nearly 80% of incident radiation back to the sky, their widespread application across rooftops can also help reduce urban heat island (UHI) effects.

1. High SRI paints are suitable for roofs where the top finish or surface material is in good condition and does not require replacement in next 3-5 years.
2. Buildings where the existing top finish of roof requires replacement or deep repairs, high SRI tiles can be installed.

.

b) Roof Insulation

Adding insulation over the roof is recommended in the PCS Guidelines for new buildings and is consistent with ECSBC standards. The target U-values differ for air-conditioned and non-air-conditioned buildings and can be achieved through several approaches detailed in the solution sets. Best practice is to combine roof insulation with high-SRI finishes or light-coloured ceramic tiles (also available in high-SRI variants). The advantage of this solution is that it is non-intrusive and relatively easy to implement.

6.1.3 Window and glazed areas

Retrofitting windows is relatively intrusive but crucial. The following aspects must be addressed in the retrofit:

1. **External window shading** against direct and diffuse solar radiation, to offset the solar heat gain coefficient of glazing, is the most effective strategy to reduce heat gain through windows.

a) For Residential Buildings:

Residents often attach awnings or improvised screens to counter glare and heat. A more durable approach is to fix a light metal frame around windows and install bamboo blinds (chiks) or spring-loaded retractable roller blinds. Similar frames can be extended to balconies to serve as adjustable shading devices. Installation in multistorey buildings will require careful planning and specialist equipment.



Figure 24 Examples for retrofitting windows with external shading (Source: Authors)



Figure 25 Examples for retrofitting windows with external movable shading (Source: Authors)

b) For Commercial Buildings:

Large glazed façades pose technical challenges for retrofitting external shading. If structural elements exist at floor levels or panel edges, fixed louvre systems or perforated shading panels can be installed. Costs will vary by design, material and accessibility.



Figure 26 Examples for retrofitting windows, in a commercial building, with external shading (Source: Authors)

2. **Window glazing** should be guided by following principles
    a. glazed area of the external envelope - window to wall area ratio (WWR) of 40% or less as recommended in Section 5.4.
    b. glass specification – the optimal solar heat gain coefficient that minimizes ingress of solar radiation.
    c. provision for ventilation through operable windows to ensure optimal cross ventilation.

Retrofit should focus on:

a) Reducing excessive glazed area

Install opaque sandwich insulation panels—with mineral wool, reflective aluminium foil on the outer face, and gypsum board on the inner side—on the inside of the glass. This reduces glazed area to 40% of the wall surface, significantly lowering solar heat gain.

b) Improving U-Value of single glazing

Fix an additional openable clear-glass panel inside the window with a 50 mm air gap. In this cavity, install an operable venetian blind with a silver reflective coating on the sun-facing side. This improves insulations as the U value is lowered, allows modulation of daylight and provides effective solar shading.

c) Replacing single glazing with double glazed unit (DGU)

Where possible, replace existing single-glazed units with double-glazed units (DGUs) of low SHGC. This is intrusive process and may expose interiors temporarily during installation.



Figure 27 Example for retrofitting glazed window area with shading (Source: Authors)

6.1.4 Wall Insulation

For habitable areas, external walls should ideally have U-values recommended in Section 5.2.

a) Proprietary External Insulation Systems

Available systems provide performance guarantees and are non-intrusive. However, installation on tall buildings is expensive due to the need for scaffolding or suspended platforms.

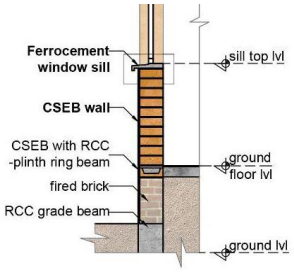
b) Internal Wall Insulation

Install mineral wool blankets within a timber frame, clad internally with gypsum board, is an option in retrofits. There is moderate but manageable intrusiveness – the retrofit can be executed in stages, room by room.

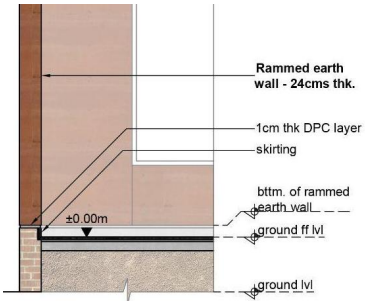
7 Annexure 1
Additional Solution Sets



Photo: Author

#	Description	Specification
1	**Compressed Stabilized Earth Block (CSEB) Wall**	CSEB walls of 24cm thick for load bearing and filler walls in framed structure up to 6 storeys, deducting for the doors and windows. Including and providing blocks from storage site, preparing scaffoldings and laying the blocks with Stabilised Earth Mortar SEM 1:4:8 (cement, soil, sand) where the proportion are to be adapted as per the soil test. Laying proportional part of half blocks 240 and other special provisions like chipping the wall for services where necessary. For curing, labour, material and equipment cost. Rate: Rs. 10,500 per cu.mt. (Year 2022-23)  
2	**Rammed Earth Wall**	**Stabilised Rammed Earth Wall (SREW)** Walls of 24 cms width for load bearing and filler walls in framed structure up to 6 storeys. Each batch of stabilized earth will be made with 500 litres soil excavated on site, sieved with a # 10 mm sieve, mixed with river sand of 200 litres for every bag of cement of 50 kgs. This batch will be then wet with 48 litres of water that is sprinkled while mixing and batch will be used with 30 mins of wetting. 12cms depth of soil is laid between the shuttering in an even layer, using a gauge to ensure the evenness. This mix is to be then rammed with 200 cm2 rammers twice back and forth and then second level ramming with a 100cms rammer done twice over the entire length of the wall within the shuttering. When the sound of the rammer hitting the soil sounds clear with a good ringing tone the ramming is considered to be even and of sufficient compactness. Check the compression with the penetrometer provided with the shuttering kit and ensure that it does not penetrate more than 6 mm at any given point. Continue with this process with 12 cms layers will the wall reaches the height within the shuttering. The shuttering may be removed the following day or after 18 hours and the resultant wall should be covered with hessian bags and kept moist for a minimum of 2 weeks before any further construction is carried out over it.

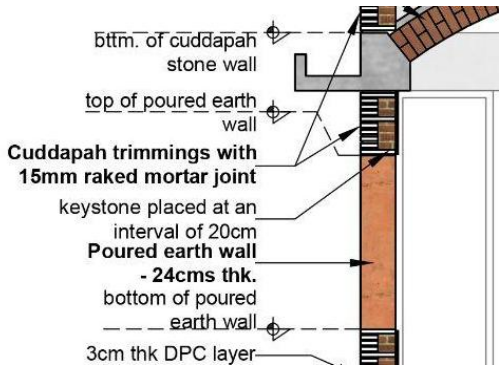






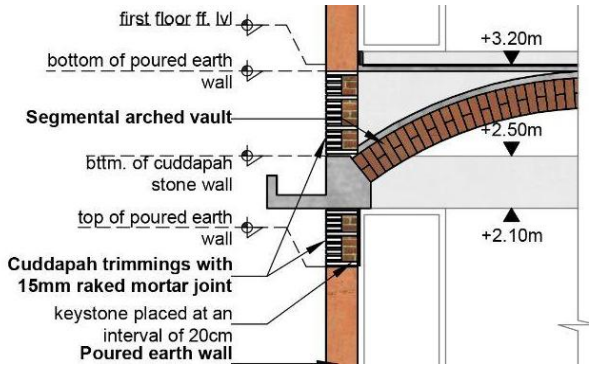
3	Poured Earth Wall	**Poured Earth Concrete (PEC) walls** Load bearing and filler walls in framed structure up to 6 storeys. Each batch of mix composed of Cement 50 Kg (10.09%), Soil 75 Liters. (25%). Sand sieved 4 mm 45 Liters (16.01%), Gravel 1/2”60 Liters (20%), Gravel 1”60 Liters (20%) Gravel 1.5” 60 Liters (20%) Water of 56 Liters (12.57%) Based on the soil composition the above mix may vary. Preparation of the stabilized mix for walling. 1) Pour the specified quantity of water in the drum. Load the hopper with specified quantity of Sand, Crushed or sieved soil and Cement. Lift the hopper to the drum and let the mixer run for a minute till the mix is a slurry. 2) Then load the hopper with the following in the specified quantities; Gravel 1.5”, Gravel 1”, Gravel 1/2”. Lift the hopper to the drum and let the mixer run for a minute till the mix is evenly mixed. 3) Tilt the drum of the mixer and let it mix for a minute. 4) Lift the hopper to fill the drum and let it mix for ~1 more minute, and repeat with the tilt almost horizontal. This mix should then be poured into the cone for a slump test, wherein it should not exceed 20 mm. The mix is poured within the pre-set wall shuttering in layers not exceeding 30 CMS and well vibrated. The de-shuttering may be done 8 hours after casting. Cost including shuttering. Rate: Rs. 10,500 per cu.mt. (year 2022-23)
4	Waste Cuddapah Wall	**Waste Cuddapah Wall** Coursed stone rubble masonry (first sort) walls with factory waste Cuddapah trimmings of mini-mum 15 x 10 x 5 cms size for load bearing up to 2 storeys and filler walls in framed structure up to 6 storeys with cement mortar of 1:6 (1 cement: 6 coarse sand). Every 30-35 cms there should be a stone laid in header to provide lateral stability.

Rate: Rs. 5,250 per sq. mt. (year 2017- 18)



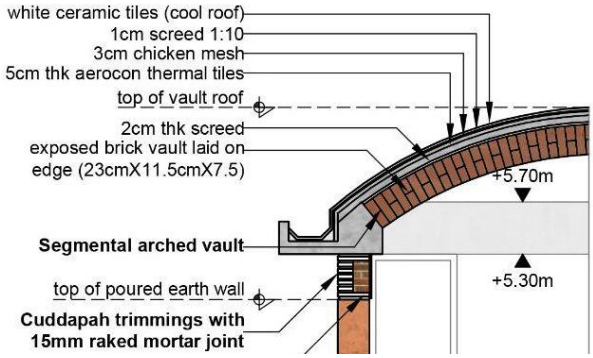


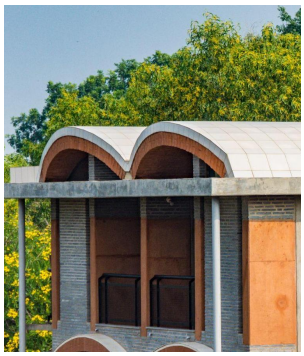
5	Vaulted Intermediate Floor	**Segmental Arch Vault for Intermediate Floor** Building of segmental arch vault using Brick work 22 cm thick with FPS brick of class designation 35 in cement mortar 1:3 (1 cement: 3 coarse sand) laid over a metal centring of the specified span / rise and ht. The bricks will be laid over the centring which is well cleaned, coated with shuttering oil and laid level to the finished floor as per the drawings with wedges to spirit level. The mortar used will be fluid with appropriate water content to have plasticity that is better than standard mortar. The Springer block should be cast and cured for 2 weeks before the vault works is carried out on them. The mortar joint between the bricks in the segmental vault should be nil at the base that sits on the centring and evenly "V" shaped to the exterior of the arch. The larger end of the mortar joint should be tightly packed with a mix of stone aggregate and mortar to reduce the shrinkage and to avoid the slipping of the bricks on removal of the centring. For use of the surface as floor the valley is filled with a mix of shredded Styrofoam (thermocol) of no more than 30 mm size mixed with 1 cement: 4 sand and laid to achieve a level surface. Above this a layer of screed of no more than 30-35 mm is laid to receive the flooring finish of tiles, stones or IPS.	-





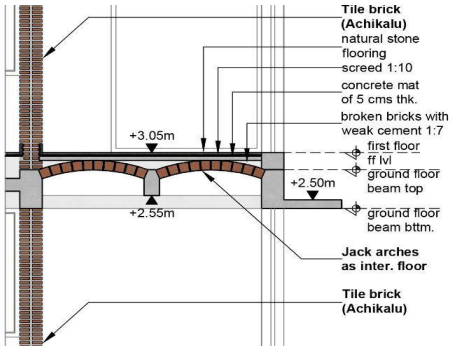
6	Vault as Roofing	**Segmental Arch Vault as Roofing** Building segmental arch vault using Brick work 22 cm thick with FPS brick of class designation 35 in cement mortar 1:3 (1 cement: 3 coarse sand) laid over a metal centring of the specified span / rise and ht. The bricks will be laid over the centring which is well cleaned, coated with shuttering oil and laid level to the finished floor as per the drawings with wedges to spirit level. The mortar used will be fluid with appropriate water content to have plasticity that is better than standard mortar. The Springer block should be cast and cured for 2 weeks before the vault works is carried out on them. The mortar joint between bricks in the segmental vault should be nil at the base that sits on the centring and evenly "V" shaped to the exterior of the arch. The larger end of the mortar joint should be tightly packed with a mix of stone aggregate and mortar to reduce the shrinkage and to avoid the slipping of the bricks on removal of the centring. The top of the segmental arch roof is insulated with ACC tiles of 50 mm thick, with a screed with waterproofing compound and a layer of reflective cool tiles.	-





7	Jack Arch Intermediate Floors	Place prefab trapezoidal reinforced concrete beams, I steels sections or wooden beams spaced of no more than 600 - 650 mm as per the centring in wood or steels to span the room. Using bricks of common burnt clay F.P.S (non-modular) bricks of class designation 3.5 with 1 cement: 4 sand mortar	-

lay the bricks on the centring as tight as possible with minimum mortar joint with 1 cement: 4 sand mix. The centring should be removed immediately after the arch brickwork has been completed to allow the arch to settle between the beams. Above these arches the filling could be done using any light weight filler materials like broken bricks of no more than 50 mm size in 1 cement: 8 sand to achieve a level surface upon which the flooring finish can be laid.



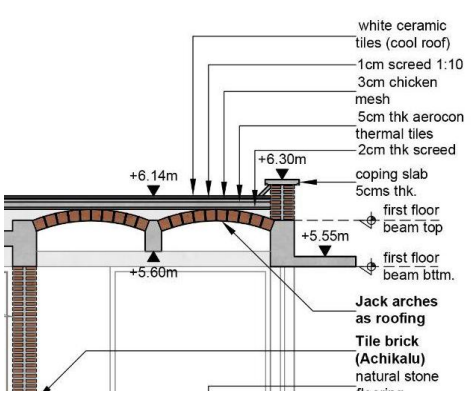


8 **Jack Arch Roofing**

Jack Arches as Roofing

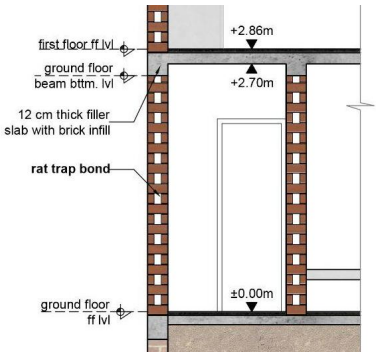
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Place prefab trapezoidal reinforced concrete beams, I steels sections or wooden beams spaced of no more than 600 - 650 mm as per the centring in wood or steels to span the room. Using bricks of common burnt clay F.P.S (non-modular) bricks of class designation 3.5 with 1 cement: 4 sand mortar lay the bricks on the centring as tight as possible with minimum mortar joint with 1 cement: 4 sand mix. The centring should be removed immediately after the arch brickwork has been completed to allow the arch to settle between the beams. Above these arches the filling could be done using any light weight filler materials like broken bricks of no more than 50 mm size in 1 cement: 8 sand as filler to and a layer of insulation is laid to slope for good drainage, with waterproofing and topped off with heat reflective paint or tiles.



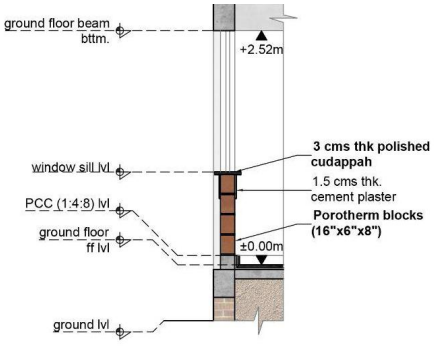


9	Rattrap Bond Wall	**Rattrap Bond Wall** Brick work laid on edge with long face to the outside with every alternative brick used as a header to provide lateral stability (Rattrap bond) with common burnt clay F.P.S (non-modular) bricks of class designation 3.5 in superstructure (above plinth) as load bearing up to 2 storeys and filler walls up to 6 storeys in - cement mortar 1:4 (1 cement: 4 sand)	-





10	Extruded Hollow Clay Brick Wall	**Extruded Horizontally Perforated Clay Bricks (Porotherm HP)** Building of walls with horizontally perforated clay bricks (Porotherm HP 200) of 40 x 20 x 20 cms for filler walls in non-load bearing up to 6 storeys and as load bearing walls up to 2 storeys. The mortar could be 1 cement: 4 fine sand mix or use of Dryfix. System product which is a specially formulated adhesive that creates perfect bonding between the Porotherm blocks specially when used with Porotherm HP G, enhancing the strength of the walls. The exposed surface of the perforated clay bricks is available with smooth finish to use as exposed clay walls or with grooved finish for external plastering with 1 cement: 4 fine sand mix or lime cement and with gypsum for internal plasters.	

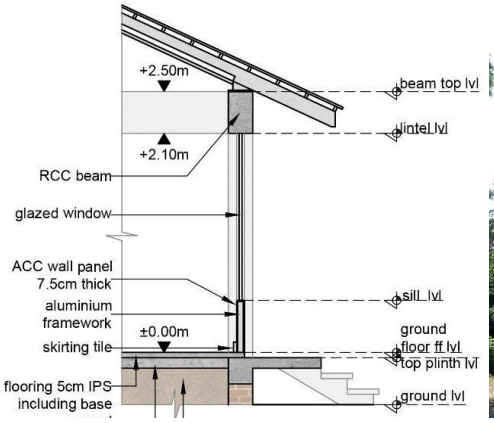




11 **AAC Wall Panel**

AAC Wall Panel

AAC wall panels of 50mm to 200mm, with panels thickness of 75 mm or less to be used only as non-load bearing internal partitions Made of autoclaved aerated concrete (AAC), factory-cured under high-pressure steam. Composed of: Cement, fly ash, lime, gypsum, water, and aluminum powder (as aerating agent). Dry Density- 550–700 kg/m3, Compressive Strength - ≥4 Mpa. These panels may also be used as shading fins for windows to provide shading from the sides, creating a box window.

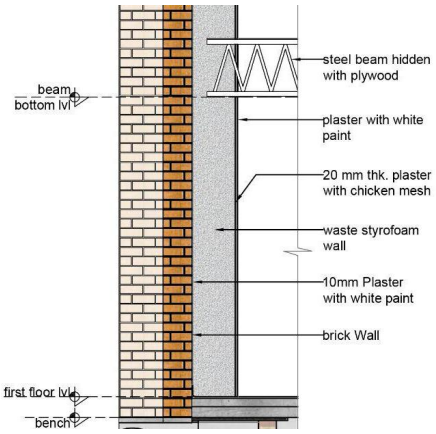




12 **Waste Styrofoam Wall**

Waste Styrofoam Wall (Thermocol)

Mixing of shredded Styrofoam (thermocol) sourced from waste packing material with cement and sand, proportions dependent on the shredded Styrofoam size. For walls panels of 100 - 150 mm with shredded Styrofoam of pieces no more than 25-40 mm, mixed in a concrete mixer with 1 cement: 2 Styrofoam: 2 sand with sufficient water for workability, laid over a mat of 2 layers of chicken mesh, wall shall be cast-in-situ. The lightweight concrete panels/blocks incorporating recycled waste Expanded Polystyrene (EPS / Styrofoam beads) as a partial replacement of natural aggregates. Compressive strength: typically, 2–8 MPa. The panels to be used as non-load bearing internal partition walls. The blocks are manufactured in a mould of 60 x 40 x 20 cms and for rendering with plaster, a layer of chicken mesh is fixed on the surface.

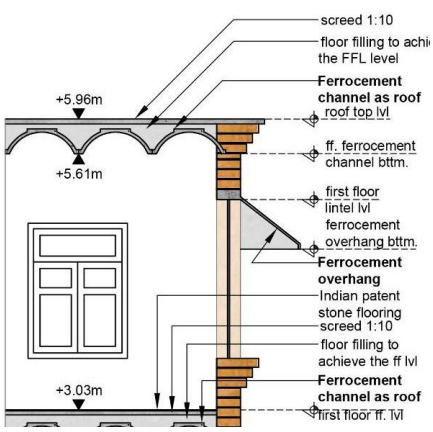




13 **Ferrocement Channel Roof**

Ferrocement Channel Roof

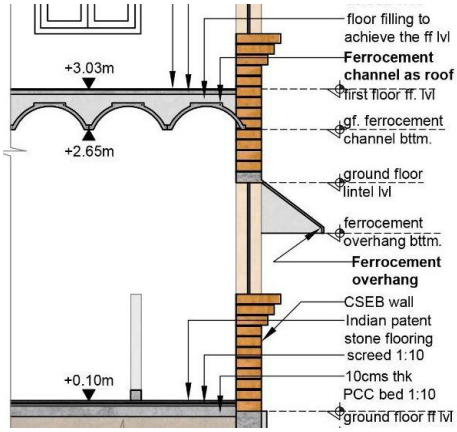
Manufacturing of Ferrocement Channel: Mix proportion CSM 1: 3 (cement, sand) is spread over a fixed mould on the floor in a thin layer. A mat of three layers of chicken mesh with 3 steel rods (2 bottom + one top) specified by the engineer as per the span is laid over the cement mortar and tamped till there is no bulging or deformation of the chicken mesh mat. Over this another layer of mix proportion CSM 1: 3 (cement, sand) is spread and using a template the shape is maintained. After curing for 7 days the channel is de-moulded and cured further for 10 days. Assembly of Ferrocement channel as roofing - Continuous succession of FC semi-circular round channels, flat top of projected area on floor; Including: Providing the channels from curing site; Laying and levelling the channels; Laying hooks; Pouring a layer (0.009 m3/m2 of floor area) of plain cement concrete PCC 1: 2: 4 (cement, sand, 1⁄2" gravel) between channels; Filling fine powder of quarry dust (passing through the sieve)between and till the top of channels (0.07 m3/m2 of floor area); Plastering ceiling joints between channels with CSM 1:4 (cement, sand); Curing; Labour, material and equipment cost. Roofing is finished either with the FC channel laid to slope and painted with reflective paint for shed and open structures. For closed rooms, a layer of insulation is laid to slope for good drainage, with waterproofing and topped off with heat reflective paint or tiles.





14 **Ferro-Cement Overhang**

Pre-casting and fixing of ferrocement overhangs. For windows of 900 mm or less width, preparing a design with shape that provides stiffness and structural stability for fixing to the external wall with overhang of 600- 750 mm. Based on the shape, preparing a steel or masonry mould to precast the overhangs. Preparing of m in 30mm thk in 1:3, welding 8mm Ms bar@ 20cm c/c both ways for ferrocement walling with welded mesh of size 100x 100x2.30mm and 2 layer of chicken mesh including curing, 1 - tensile strength is 80 - 90 kg/cm2, 2 - Strength to Weight Ratio is 450 to 90. Demoulding after minimum 7 days and curing for 10 days before it is fixed on the facade with appropriate hardware.



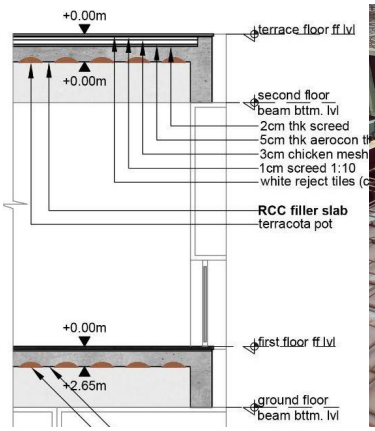


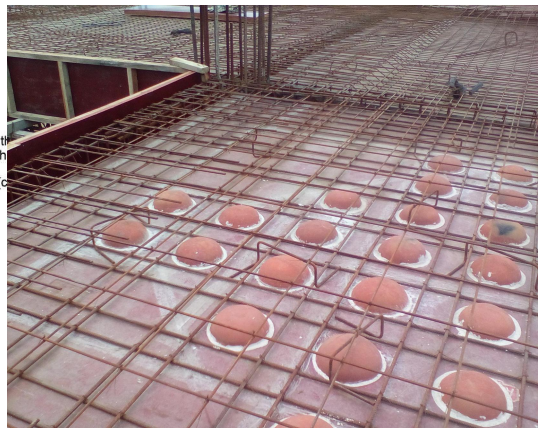
15 **RCC Filler Slab Roof**

RCC Filler Slab Roof

RCC filler slab is a reinforced concrete slab where lightweight materials (like clay pots, Mangalore tiles, or foam blocks) replace the non-structural component of the slab to reduce the volume of concrete and steel needed along with overall reduction in the build weight, making them a greener alternative. By incorporating waste

materials or local resources as fillers, the environmental footprint of the construction process is further minimized. Above the filler slab a layer of insulation is laid to slope for good drainage, with waterproofing and topped off with heat reflective paint or tiles.

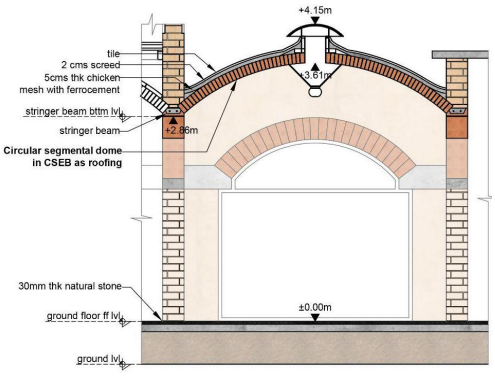




16 **Domes Roofing**

Circular segmental dome in CSEB as roof terrace

Circular dome of projected area on floor; Including: Preparing scaffoldings; Fixing the compass: Providing blocks (190 & Mini CSEB blocks) from storage site; Cutting and grinding the blocks; Laying the CSEB blocks with Stabilised Earth Mortar SEM 1: 3: 6 (cement, sand, soil) (proportion to be adapted to the soil quality); Cleaning surfaces with sponge and water; Curing; Labour, material and equipment cost. The top of the dome roof is insulated with ACC tiles of 50 mm thick, with a screed with waterproofing compound and a layer of reflective cool tiles.



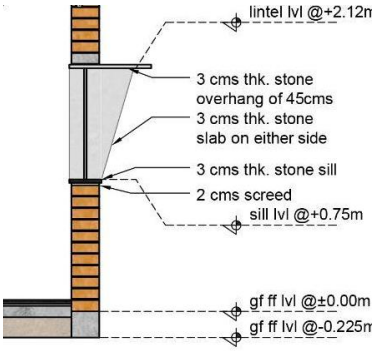


17 **Stone Overhang**

Cuddapah Stone Window Overhang

This combines a traditional shading/rain guard feature (chajjas or jharokha) with the rugged elegance of local stone. The result: a functional, durable architectural detail that also celebrates regional craft, climate heritage, and aesthetics. 40 -

50mm thk slabs projecting 300 to 450 mm from the surface of the walls.

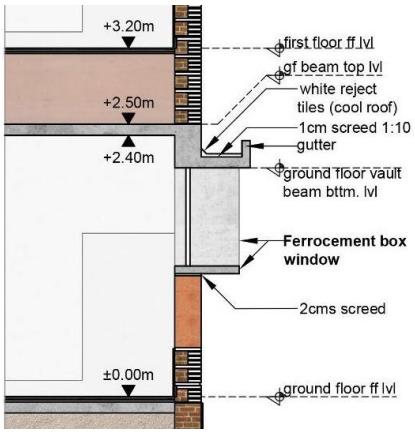




18 **Ferro-cement Box Window**

Box Window Overhang

Providing and fixing of ferrocement in 30mm thick in 1:3, welding 8mm Ms bar @ 20cm c/c both ways for ferrocement walling with welded mesh of size 100x 100 x 2.30mm and 2 layer of chicken mesh including curing, 1 - tensile strength is 80 - 90 kg/ cm2, 2 - Strength to Weight Ratio is 450 to 90.





8 Annexure 2
Building Byelaws

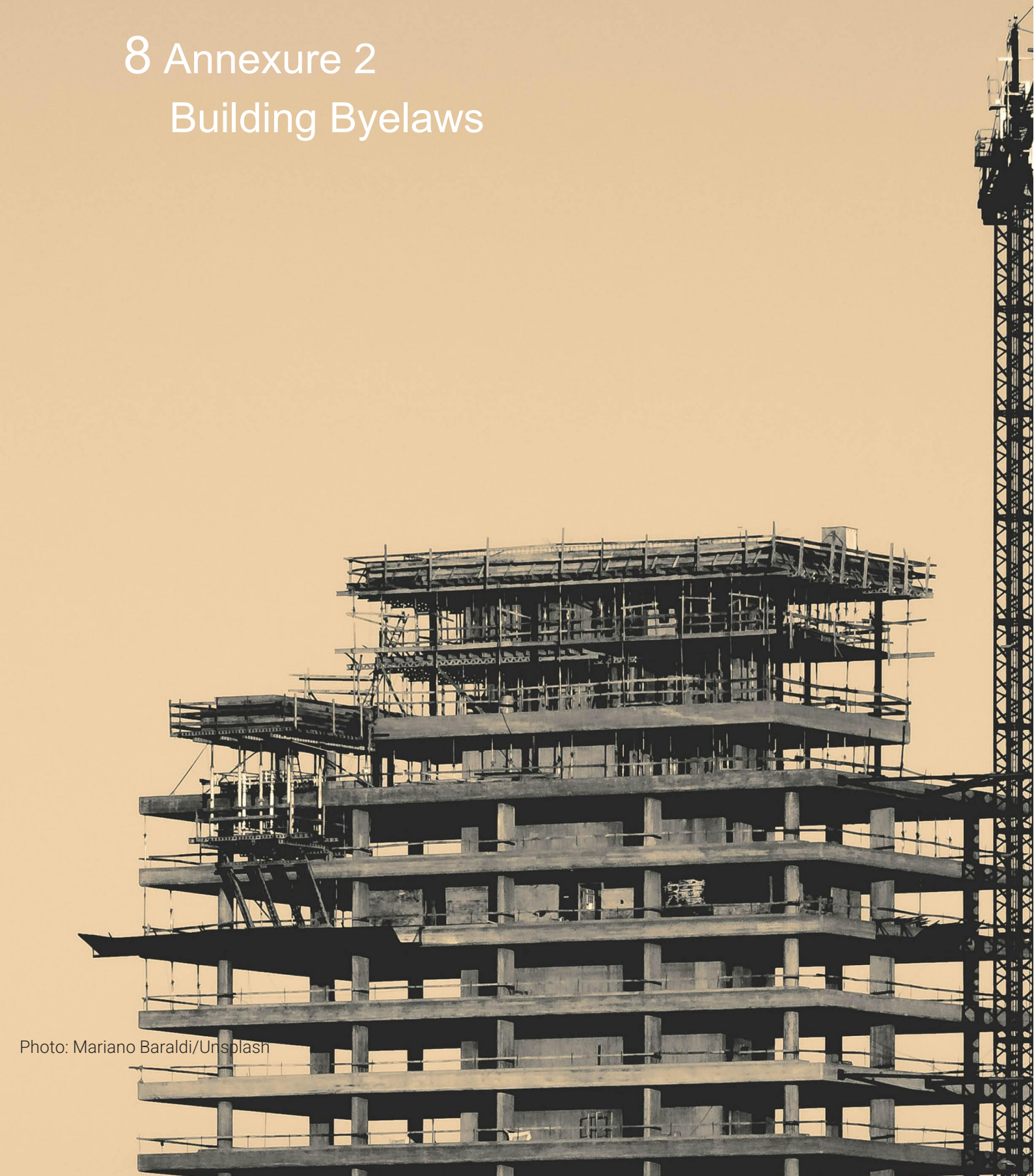


Photo: Mariano Baraldi/Unsplash

The Government of Tamil Nadu has taken the following steps for ECSBC implementation:

1. **ECBC was notified in December 2022** but has not been mandated and not incorporated in building bye-laws.
2. **Stakeholder capacity building training programs** are continuously conducted to promote ECBC adoption, compliance, and enforcement.
3. Guidelines were issued in 2022 for mandatory ECBC compliance in buildings with connected load above 100 kW or contract demand above 120 kVA and with built-up area more than 2,000 square meter.
4. **Incentives** of up to 25% subsidy was announced on cost of green solution for industrial unit and data centers and for GRIHA, LEED and IGBC certified projects.
5. Tamil Nadu's State Designated Agency (SDA) has been permitted to create a special purpose vehicle (SPV) to manage and execute rooftop solar photovoltaic (RTSPV) projects on public buildings using the Renewable Energy Service Company (RESCO) model.
6. Tamil Nadu advocates sustainability in affordable housing through the Urban Housing Habitat Policy 2022 at the urban level.

8.1 Implementation framework for passive cooling and state-wide ECSBC compliance

Tamil Nadu can consider four tracks, incrementally leading up to compliance with whole of ECSBC Commercial and Residential for both new and existing building stock, to safeguard its citizens from extreme heat in a climate friendly manner (figure 6).

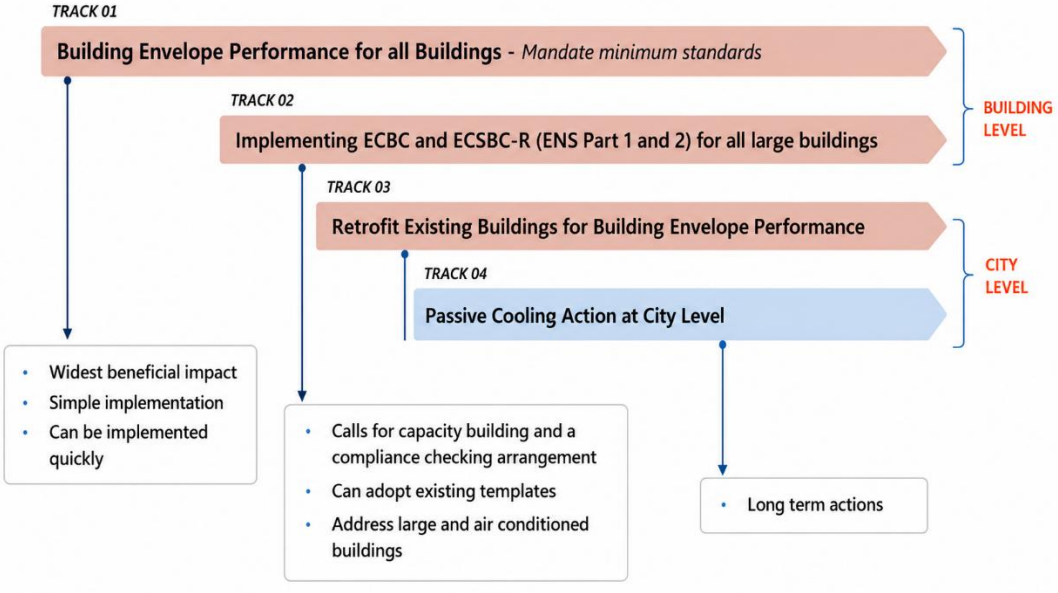


Figure 28 Implementation framework – Track 01 to Track 04, at the building and city levels. (Source: Authors)

8.1.1 Track 01: Minimum performance standards for Passive Cooling for building envelope

To enhance thermal comfort across all buildings, we propose **Minimum Performance Standards (MEPS) for Passive Cooling,** based on the prescriptive requirements framed in the Building Passive Cooling Guidelines**.** These are consistent with building envelope performance requirements in the ECSBC and ENS.

1. The standards can be first mandated for government projects, and then integrated into the Tamil Nadu Combined Development and Building Rules (TNCDBR) for broader application across the entire state. Precedent for environmental sustainability and climate adaptation measures TNCDBR 2019 already exists (e.g. inclusion of rainwater harvesting norms).
2. Capacity building, and training sessions for TANGEDCO, Chennai Metropolitan Development Authority (CMDA), Tamil Nadu Green Climate Company (TNGCC), Urban Development Department, Tamil Nadu Urban Habitat Development Board (TNHUDB), Public Works Department (PWD), urban local bodies (ULBs) etc. should be conducted to support effective implementation and continuous adoption across all building types.

Track 01 serves as a foundational step before the state establishes operational systems for the implementation of full scope of ECSBC (Track 02), ensuring immediate improvements in thermal comfort across a wider category of buildings—including those that may not yet fall under the purview of current energy codes. This framework will be superseded by ECBC, ECSBC, and ENS where they become applicable.

Implementation Mechanism for track 01:

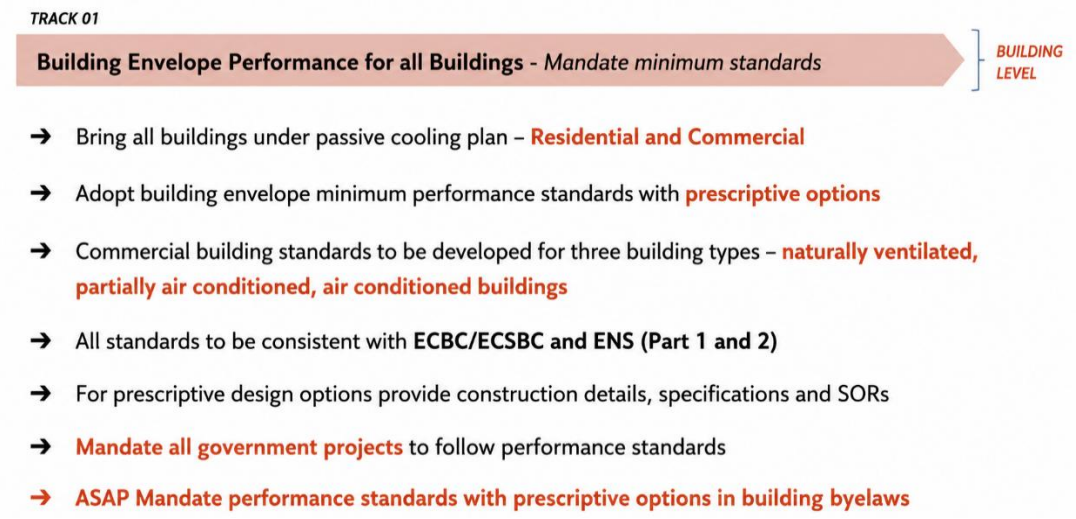


Figure 29 Implementation framework for Track 01: Mandating minimum standards for Building Envelope Performance for all buildings (Source: Authors)

8.1.2 Track 02: Scaling and integration

Once the state formally adopts ECSBC and ECSBC-R (Residential version) for new buildings, this **Minimum Energy Performance Standards for Passive Cooling** can be seamlessly integrated into the full ECBC compliance architecture.

1. Buildings under the scope of the building energy codes (non-residential buildings with greater than 100 kW connected load and residential buildings in greater than 500 square meter plot area) should follow all the requirements of ECSBC and/ or ENS.
2. Buildings not under scope of either code should continue to follow the MEPS for Passive Cooling.
3. Capacity building, and training sessions for TANGEDCO, CMDA, TNGCC, Urban Development Department, TNHUDB, PWD, ULBs etc. should continue for leading full code implementation for new construction.

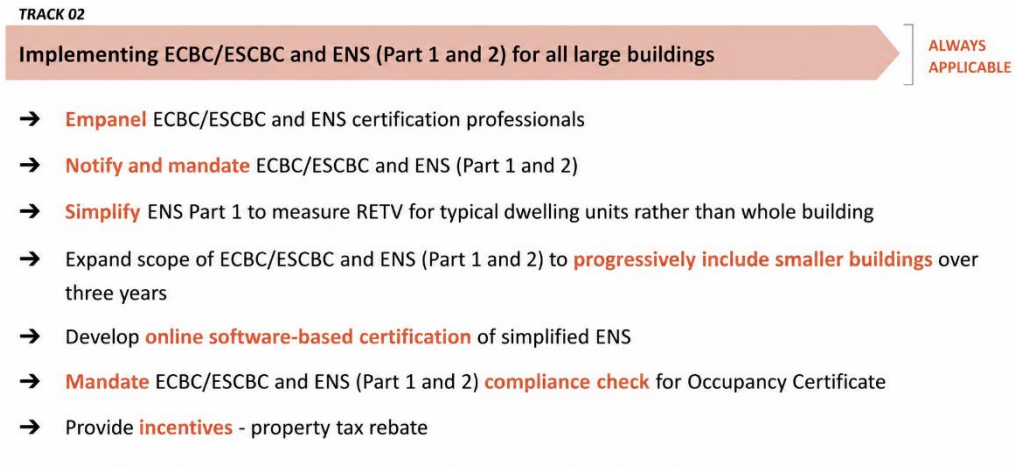


Figure 30 Implementation framework for Track 02: Implementing ECBC/ECSBC and ENS for all large buildings (Source: Authors)

8.1.3 Track 03: Retrofit Existing Building Stock

Track 03: The scope of the MEPS can next include existing buildings (say by 2030). The construction market, knowledge of real estate developers and enforcement capacity of government agencies and ULBSs will have evolved to be able adopt thermal comfort and energy efficiency measures in existing buildings through retrofits to building envelope and other buildings systems such as air conditioning.

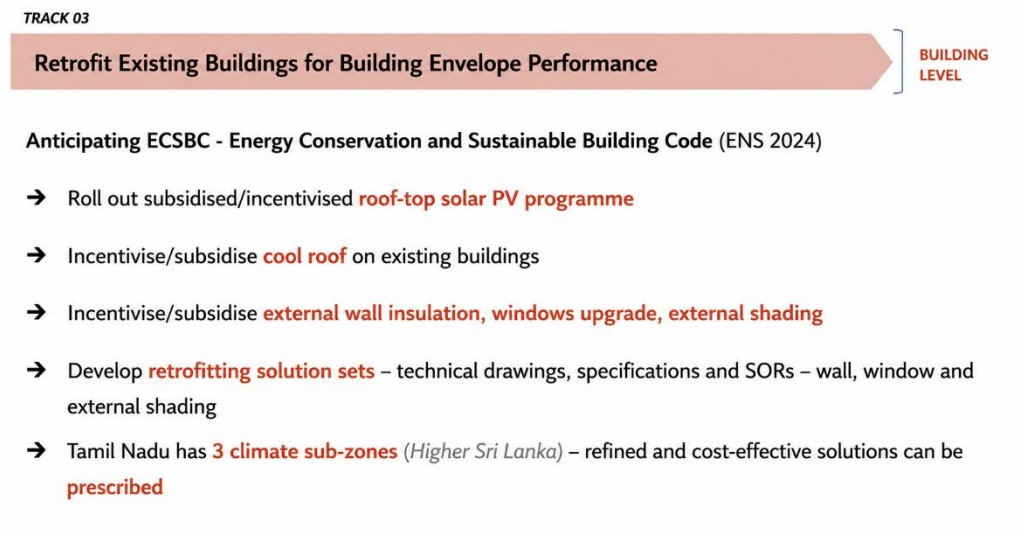


Figure 31 Implementation framework for Track 03: Retrofit Buildings for Building Envelope Performance (Source: Authors)

8.1.4 Track 04: Passive cooling at city and neighbourhood level

Track 01,02 and 03 are focussed on building level regulations and policies while Track 04 is on city and neighbourhood level regulations. To augment thermal comfort and energy efficiency regulations in Tracks 1,2 and 3, and, mitigate urban heat island effects, planning instruments such as masterplans, local area plans etc. must be updated to include microclimate control strategies. The strategies could be nature-based solutions (minimum permeable surfaces, tree cover, soft or green ground), land use planning principles (e.g. mixed land use and optimal development density), street design, sky view factor etc.



Figure 32 Implementation framework for Track 04: Passive Cooling Action at City Level (Source: Authors)

8.1.5 Compliance

Once an adequate number of trained professionals are empanelled district-wise and building regulatory agencies are adequately strengthened through capacity building, the rules for verification of building plans for compliance with the prescribed standards shall be notified.

9 Annexure 3
Global and Local Approaches



Photo: Joshua Rawson Harris /Unsplash

This section presents a review of global and local best practices in implementing passive cooling in buildings with the objective of informing a strategy for Tamil Nadu. Policies, development control regulations, implementation models, and financial mechanisms followed successfully in other cities, states and countries were studied to understand opportunities for Tamil Nadu.

9.1 Singapore

Singapore has experienced a 1.1 C temp increase since 1972 (National Climate Change Secretariat). This warming is amplified by urban heat island effect in urban zones by as much as 7 °C as compared to nearby non-urban areas.

9.1.1 City Level Cooling Singapore Initiative:

Aims to mitigate the Urban Heat Island effect and improve thermal comfort. 86 measures across urban planning, greenery, building design, and transportation. Strategies include: Increasing urban vegetation, optimizing urban geometry, enhancing urban ventilation through improved design, use of specific materials and surfaces, and mandating shading.

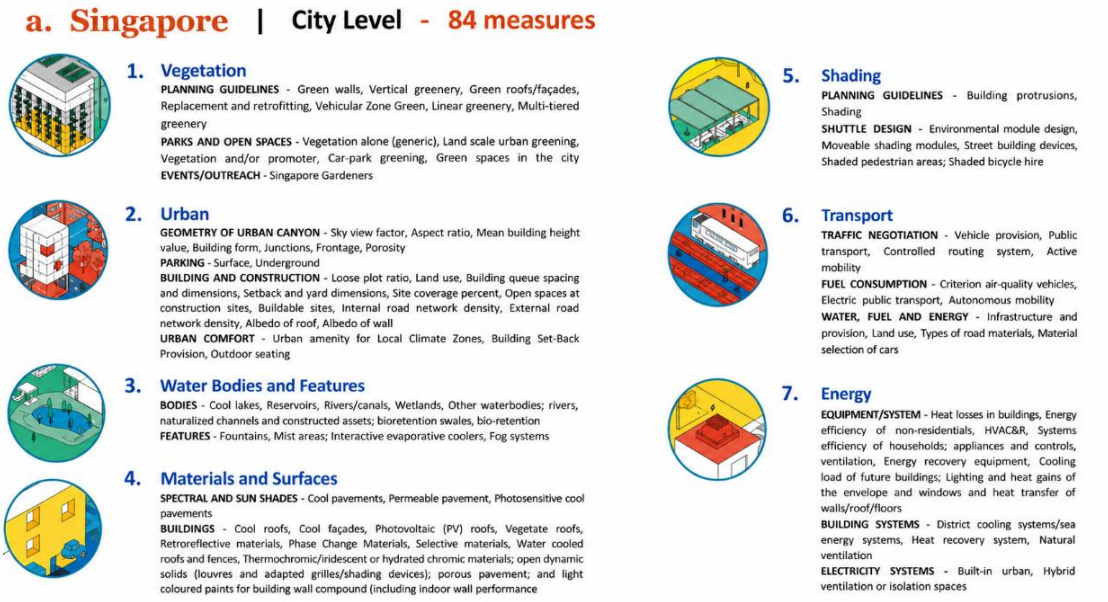


Figure 33 City planning measures in Singapore to address urban heat islands and extreme heat (Source: Ashok B Lall Architects)

9.1.2 Building Level - Singapore Green Mark Certification Scheme:

A sustainability rating system for buildings, The Building and Construction Authority's Green Mark 2021 (GM: 2021) is an internationally recognized green building certification scheme tailored for the tropical climate. Its evaluation categories are: energy efficiency, water conservation, environmental protection, indoor environmental quality, adoption of green practices. Four levels of ratings are awarded through a point-based evaluation criterion: Ratings: Certified, Gold, Gold PLUS, and Platinum.

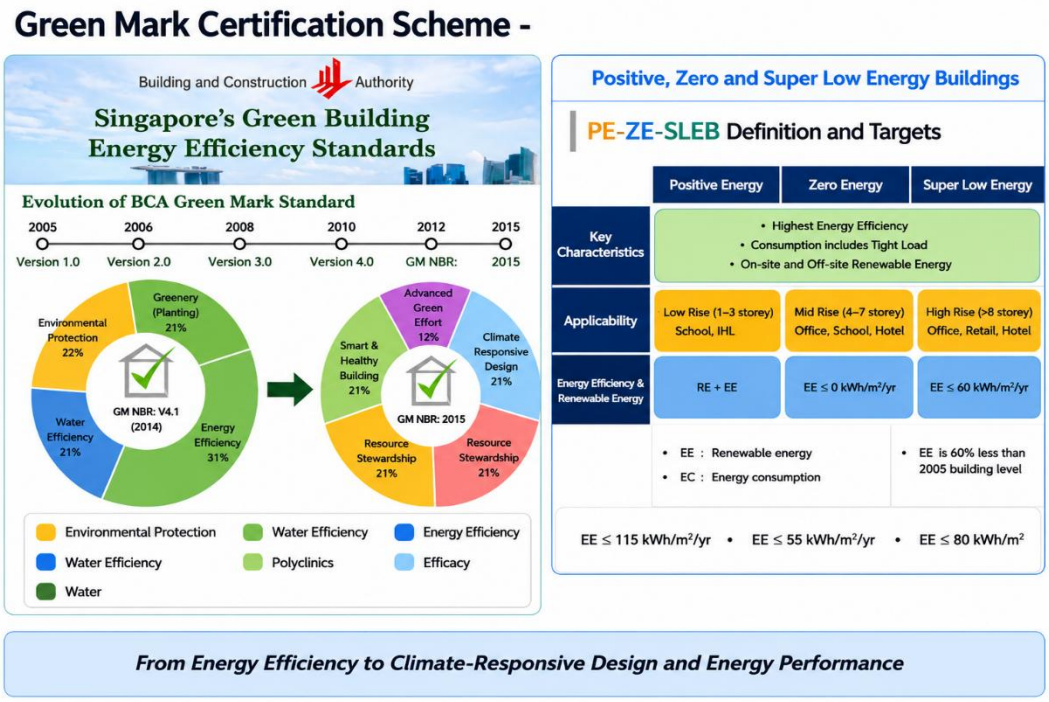


Figure 34 Overview of Singapore's Green Mark Certification Scheme (Source: Ashok B Lall Architects)

The following pathways are feasible to demonstrate compliance with Green Mark Scheme:

Pathway 1: Benchmark Energy Use Intensity (EUI)

Detailed measurement and calculation (existing buildings) or energy model (new buildings) shall be used to calculate and justify the design EUI.

Pathway 2: Prescriptive Performance Fixed Metrics

The prescriptive performance values shall be met in all areas. Where there is a shortfall of performance, this shall be annualized and required to be offset through onsite renewables with the listed multiplication factor. Detailed calculations, drawings, and specifications would be required to substantiate the declared performance.

Pathway 3: Energy Savings

The energy modelling for evaluating the energy performance of a building shall be carried out in a prescribed manner to quantify the potential savings based on energy efficiency measures and improvements that reduce cooling load requirement over the Reference Model. Benchmark Energy Use Intensity (EUI), detailed measurement and calculation (Existing buildings) or energy model (new buildings) shall be used to calculate and justify the design EUI.

Table 16 Energy Efficiency Pathway for Different Building types(Source: Authors)

Building Type	**Pathway 1**	**Pathway 2**	**Pathway 3**
Commercial			
Office Buildings	●	●	●
Hotels	●	●	●
Retail Buildings	●	●	●

Educational			
IHL (University, Polytechnics and ITE)	●	●	●
Private Schools and Colleges	●	●	●
Junior Colleges (MOE)	●	●	●
Secondary Schools (MOE)	●	●	●
Primary Schools (MOE)	●	●	●
Healthcare			
Hospitals (Private and General)	●	●	●
Community Hospitals	●	●	●
Polyclinics	●	●	●
Nursing Homes / Youth Homes	●	●	●
Other Non-Residential			
Mixed Developments (by GFA mix)			
Community Centres	●	●	●
Civic Buildings	●	●	●
Cultural Institution	●	●	●
Sports and Recreation Centres	●	●	●
Religious / Places of Worship	●	●	●
Industrial			
High Tech Industrial Buildings		●	●
Light Industrial Buildings		●	●
Warehouses, Workshops and Others		●	●
Residential			
Non-Landed Residential (HDB, EC, Condominiums, private apartments)		●	
Cluster Housing		●	
Landed Housing		●	

Table 17 Energy Efficiency Pathways for Non-Landed Residential(Source: Authors)

NON-LANDED RESIDENTIAL			
PATHWAY 2 FIXED METRICS			
PARAMETER	Gold EE >50%	Platinum EE a 55%	SLE EE a 60%
Reduced Heat Gain (RETV) [New Development only]	22	20	20
Ventilation Performance of Dwelling Units [New Development only]	OPTION 1: PLAN LEVEL 40% of applicable spaces with unobstructed air flow between spaces and the outside OPTION 2: SIMULATION Area weighted average wind speed 0.4m/s for 40% of applicable areas. OR PMV of +/- 1	OPTION 1: PLAN LEVEL 50% of applicable spaces with unobstructed air flow between spaces and the outside OPTION 2: SIMULATION Area weighted average wind speed 0.4m/s for 60% of applicable areas. OR PMV of +/- 0.8	OPTION 1: PLAN LEVEL 60% of applicable spaces with unobstructed air flow between spaces and the outside OPTION 2: SIMULATION Area weighted average wind speed 0.6m/s for 60% of applicable areas. OR PMV of +/- 0.6
	NOTE-For both options, the main entrance door (where the		

	developer provides a lockable gate / grille), all windows and internal doors are assumed to be open. Simulations are to be conducted in accordance with the Green Mark 2021 Guideline for Computational Fluid Dynamics Simulation. PMV recognises the use of assisted ventilation where this is provided once minimum wind speeds are met.

OFFICE			
PARAMETER	Gold EE >50%	Platinum EE >55%	SLE EE >60%
Reduced Heat Gain (ETTV) [New Development only]	40	38	38
Non-AC Areas	-	10%	25%
HOTEL			
PARAMETER	Gold EE >50%	Platinum EE >5%	SLE EE 260%
Reduced Heat Gain (ETTV) (New Development only)	40	40	40
MOE JUNIOR COLLEGE			
PARAMETER	Gold EE >50%	Platinum EE >55%	SLE EE >60%
Reduced Heat Gain (ETTV) (New Development only)	40	40	40
Non-AC Areas	20%	40%	60%
CIVIC BUILDINGS			
PARAMETER	Gold" EE >50%	Platinum EE >5%	SLE EE > 60%
Reduced Heat Gain (ETTV) (New Development only)	40	38	38
Non-ac areas	-	15%	30%

Table 18 Energy Performance Benchmarks by Building Typology (Gold, Platinum & SLE) (Source: Authors)

9.2 Thailand

Building Level - Building Energy Code (BEC) set minimum energy efficiency requirements for new constructions or renovations of nine types of buildings that have an area of 2,000 square meter or more. BEC expanded its scope to smaller buildings: it started with buildings of built-up area greater than 10,000 square meters, progressed to buildings of built-up area greater than 5,000 square meter and then eventually, to buildings with built up area greater than 2,000 square meters.
Buildings must be designed to conform to the minimum energy usage or performance standards, covering six systems, namely building envelope system, lighting electrical system, air conditioning system, hot water producing equipment, overall building energy usage, and energy circulation. Different building envelope (or passive cooling) energy performance standards are recommended for three groups of building types (figure 13).

Two compliance pathways are available:

1. Prescriptive: building must pass the prescribed minimum energy performance standards for four key systems: building envelope, lighting system, air conditioning system, and hot water generation system (if used).

2. Whole building energy performance: whole building energy use must be lowers than the building typology's reference energy performance.

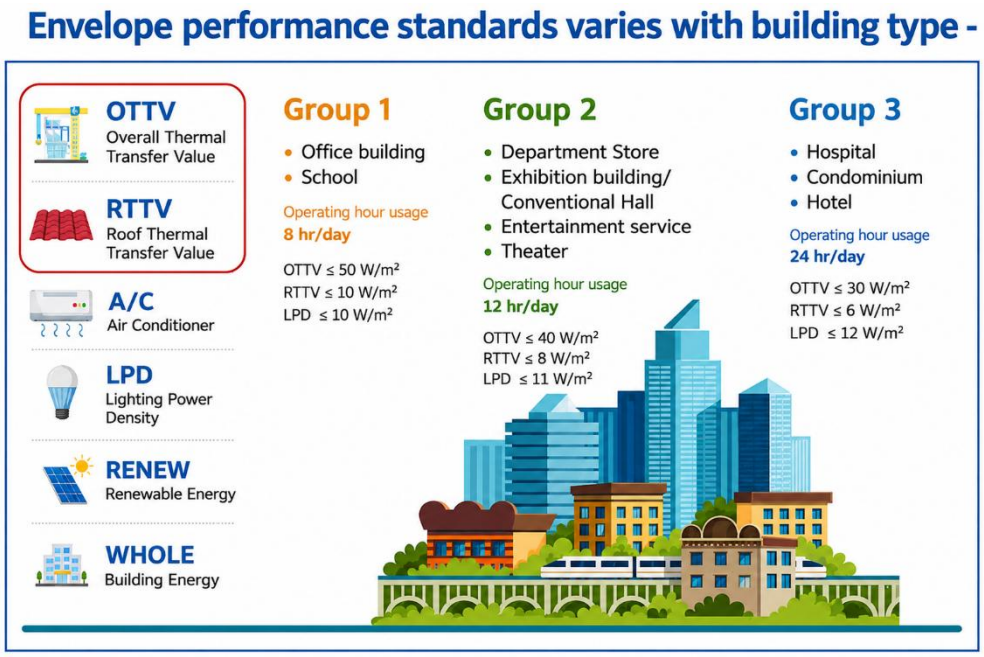


Figure 35 Building envelope performance standards for different building categories in BEC, Thailand(Source: Ashok B Lall Architects)

9.3 Sri Lanka

This Energy Efficiency Building Code (EEBC) of Sri Lanka outlines the requirements for the design of new facilities or retrofits of commercial buildings, industrial facilities, and large-scale housing developments. It covers building elements such as building envelope, heating, ventilation, and air conditioning (HVAC), service water heating, electric power distribution, lighting, and other equipment. Buildings and facilities must comply with the Code if they meet any of these criteria:

1. A floor area of 1,000 m² or more.
2. Electrical power demand of 500 kVA or greater.
3. Air-conditioning cooling capacity above 350 kW (thermal) or heating capacity above 250 kW.

EEBC is a voluntary code and offers both prescriptive and performance-based compliance pathways. Prescriptive requirements for walls, roofs, fenestrations and shading for different climate zones are recommended. Envelope Thermal Transfer Value (EETV) is also defined to encompass the minimum required thermal performance (in terms of U value) of walls, roofs, fenestrations and external shading projections.

Warm humid												
	Conditioned cooled				Conditioned heated				Unconditioned			
	Day-time		Extended		Day-time		Extended		Day-time		Extended	
Walls (maximum U Value) W/m²K	3.25		2.50		NR		NR		2.50		2.50	
Roofs (assembly maximum U Value) W/m²K	1.3		0.8		NR		NR		0.80		0.80	
Fenestration (Wall)	**U Value •**	**SHGC ••**	**U Value •**	**SHGC ••**	**U-Value •**	**SHGC ••**	**U Value •**	**SHGC ••**	**U-Value •**	**SHGC ••**	**U Value •**	**SHGC ••**
WWR Ratio (<20%)	1.25	0.25	1.25	0.25	1.25	0.25	1.25	0.25	NR	NR	NR	NR
WWR (20% - 30%)	1.25	0.25	1.25	0.20	1.00	0.25	1.00	NR	NR	NR	NR	NR
Fenestration (Roof)	**U Value •**	**SHGC all**	**U Value •**	**SHGC all**	**U-Value •**	**SHGC all**	**U Value •**	**SHGC all**	**U-Value •**	**SHGC all**	**U Value •**	**SHGC all**
Skylight Coverage <5% roof area*	11.24	0.27	11.24	0.27	11.24	0.39	11.24	0.39	NR	NR	NR	NR
*Incorporating the frame of the fenestration **Weighted by the multiplier for external and internal shading of fenestration (separate table for the multiplier factor) SHGC – Solar Heat Gain Co-efficient												

Figure 36 Prescriptive requirements for thermal performance of walls, roofs, fenestrations in EEBC, Sri Lanka(Source: Ashok B Lall Architects)

9.4 Energy Efficiency Building Codes in India States

Several states in India have adopted, or are in the process of adopting, climate-responsive building guidelines within their respective building codes to enhance thermal comfort. Among these, the mechanisms of ECBC implementation in Punjab, Kerala, and Telangana are of particular interest.

9.4.1 Overview of codes

The Energy Conservation Building Code (ECBC) 2017 and Eco Niwas Samhita (Part 1, Part 2) have been revised as the Energy Conservation and Sustainable Building Code - Commercial and Residential. These are now the two energy-efficiency codes for commercial and residential buildings in India.

The presence of two different codes for different type of buildings stems from the fact that for commercial buildings, the main parameter considered is energy consumption. Hence ECBC relies on use of Energy Performance Index (EPI) as the primary metric of measurement of compliance. In residential buildings, thermal comfort is considered to be the primary metric and hence Residential Envelope Transmittance Value (RETV) is the key factor for ENS 2018 compliance.

The Energy Conservation (Amendment) Bill, 2022, under which the building energy codes are framed, requires all states and municipalities in India to adopt the Eco-Niwas Samhita (ENS), or Energy Conservation Building Code-Residential. The Act also lays down directions for

1. Compliance mechanism: prescriptive or whole building performance method
2. Procedure of erection of compliant buildings: forms and document certified by EAB, inspection process
3. Empanelment of energy auditors for Buildings (EAB) and their role, responsibilities, and duties.
4. Committees: formation of State designated agencies and their duties and responsibilities.

5. Responsibilities of the owner and various forms required in the process.

The Energy Conservation and Sustainability Building Codes are a comprehensive standard encompassing multiple building systems. The Code can be improved by addressing the following:

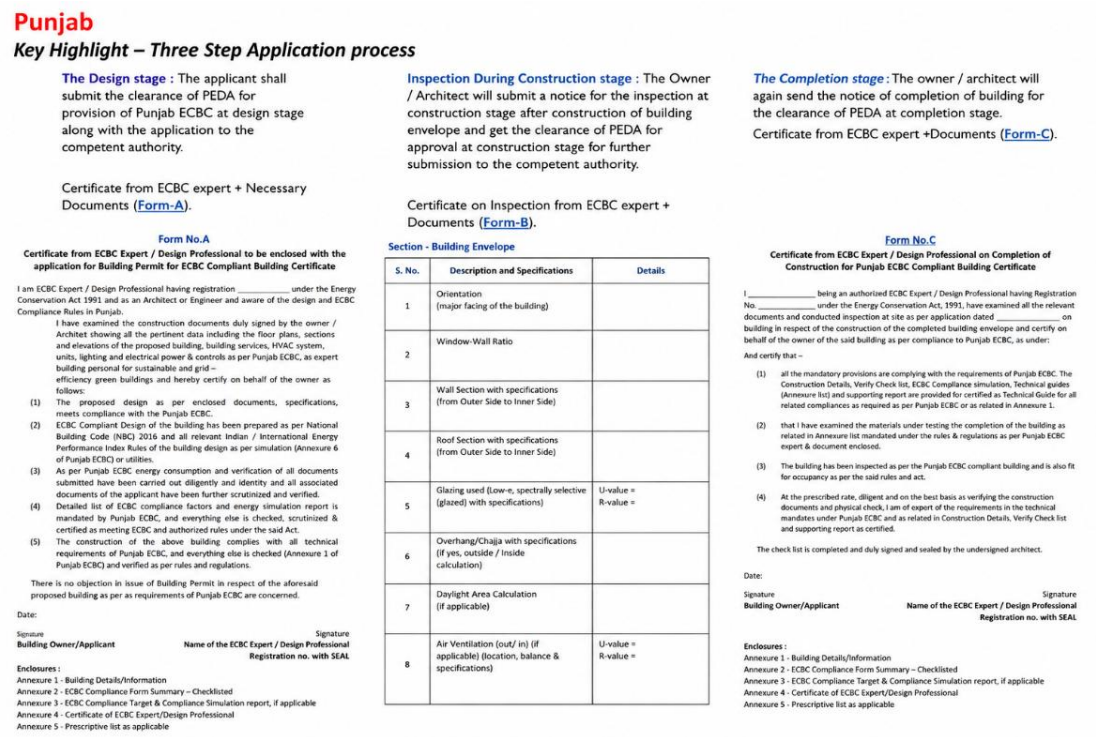
1. The present approach being limited to the design and construction of a single building misses the potential of site planning for optimising orientation of buildings with respect to solar exposure and natural wind flows. (Recognised in GRIHA and IGBC).
2. Requirements for building mass, building density and soft/green open areas for minimizing UHI can be included.
3. Large sector of simple, small and medium sized buildings can be included in the scope of these codes. ECSBC 2024 Commercial currently covers buildings with greater than 120 kVA contract demand or 100 kW connected load. ECSBC 2024 Residential currently covers only buildings in plot area greater than 500 square meters.
4. Systematic empanelment of experts to manage code compliance.

There are also opportunities to enhance heat adaptation and thermal comfort through the code –

1. Possibility of separating building envelope performance as step 1 in climate resilient design in commercial buildings in ECBC – first step toward inclusion in building bye laws.
2. Adopt prescriptive route of ECBC.
3. ENS Part 1 can be simplified for easier computation of ENSE.
4. ENS compliance can be reduced to prescriptive compliance.
5. Prescriptive compliances are easier to evaluate – ENS simplifies compliance and/or prescriptive compliance can be online software driven checks.

9.4.2 Punjab

The Government of Punjab revised ECBC applicability scope to buildings that have more than 500 m^2 of Air-conditioned area. Schedule of Rates for passive design strategies incorporated in Building Byelaws. The Government also decided to award 15% rebate in property tax to the building till the time the building is Punjab ECBC compliant. ECBC mandated for Building plan approval in 2018 and 89 ECBC compliant Government buildings completed till 2020.



Punjab

Key Highlight – Three Step Application process

The Design stage : The applicant shall submit the clearance of PEDA for provision of Punjab ECBC at design stage along with the application to the competent authority.

Certificate from ECBC expert + Necessary Documents (Form-A).

Inspection During Construction stage : The Owner / Architect will submit a notice for the inspection at construction stage after construction of building envelope and get the clearance of PEDA for approval at construction stage for further submission to the competent authority.

Certificate on Inspection from ECBC expert + Documents (Form-B).

The Completion stage : The owner / architect will again send the notice of completion of building for the clearance of PEDA at completion stage.

Certificate from ECBC expert +Documents (Form-C).

Form No.A

Certificate from ECBC Expert / Design Professional to be enclosed with the application for Building Permit for ECBC Compliant Building Certificate

I am ECBC Expert / Design Professional having registration _____ under the Energy Conservation Act 1991 and as an Architect or Engineer and aware of the design and ECBC Compliance Rules in Punjab.

I have examined the construction documents duly signed by the owner / Architet showing all the pertinent data including the floor plans, sections and elevations of the proposed building, building services, HVAC system, units, lighting and electrical power & controls as per Punjab ECBC, as expert building personal for sustainable and grid – efficiency green buildings and hereby certify on behalf of the owner as follows:

(1) The proposed design as per enclosed documents, specifications, meets compliance with the Punjab ECBC.

(2) ECBC Compliant Design of the building has been prepared as per National Building Code (NBC) 2016 and all relevant Indian / International Energy Performance Index Rules of the building design as per simulation (Annexure 6 of Punjab ECBC) or utilities.

(3) As per Punjab ECBC energy consumption and verification of all documents submitted have been carried out diligently and identity and all associated documents of the applicant have been further scrutinized and verified.

(4) Detailed list of ECBC compliance factors and energy simulation report is mandated by Punjab ECBC, and everything else is checked, scrutinized & certified as meeting ECBC and authorized rules under the said Act.

(5) The construction of the above building complies with all technical requirements of Punjab ECBC, and everything else is checked (Annexure 1 of Punjab ECBC) and verified as per rules and regulations.

There is no objection in issue of Building Permit in respect of the aforesaid proposed building as per as requirements of Punjab ECBC are concerned.

Date:

Signature — **Building Owner/Applicant**

Signature — **Name of the ECBC Expert / Design Professional Registration no. with SEAL**

Enclosures :

Annexure 1 - Building Details/Information
Annexure 2 - ECBC Compliance Form Summary – Checklisted
Annexure 3 - ECBC Compliance Target & Compliance Simulation report, if applicable
Annexure 4 - Certificate of ECBC Expert/Design Professional
Annexure 5 - Prescriptive list as applicable

Section - Building Envelope

S. No.	Description and Specifications	Details
1	Orientation (major facing of the building)	
2	Window-Wall Ratio	
3	Wall Section with specifications (from Outer Side to Inner Side)	
4	Roof Section with specifications (from Outer Side to Inner Side)	
5	Glazing used (Low-e, spectrally selective (glazed) with specifications)	U-value = R-value =
6	Overhang/Chajja with specifications (If yes, outside / Inside calculation)	
7	Daylight Area Calculation (if applicable)	
8	Air Ventilation (out/ in) (if applicable) (location, balance & specifications)	U-value = R-value =

Form No.C

Certificate from ECBC Expert / Design Professional on Completion of Construction for Punjab ECBC Compliant Building Certificate

I _____ being an authorized ECBC Expert / Design Professional having Registration No. _____ under the Energy Conservation Act, 1991, have examined all the relevant documents and conducted inspection at site as per application dated _____ on building in respect of the construction of the completed building envelope and certify on behalf of the owner of the said building as per compliance to Punjab ECBC, as under:

And certify that –

(1) all the mandatory provisions are complying with the requirements of Punjab ECBC. The Construction Details, Verify Check list, ECBC Compliance simulation, Technical guides (Annexure list) and supporting report are provided for certified as Technical Guide for all related compliances as required as per Punjab ECBC or as related in Annexure 1.

(2) that I have examined the materials under testing the completion of the building as related in Annexure list mandated under the rules & regulations as per Punjab ECBC expert & document enclosed.

(3) The building has been inspected as per the Punjab ECBC compliant building and is also fit for occupancy as per the said rules and act.

(4) At the prescribed rate, diligent and on the best basis as verifying the construction documents and physical check, I am of expert of the requirements in the technical mandates under Punjab ECBC and as related in Construction Details, Verify Check list and supporting report as certified.

The check list is completed and duly signed and sealed by the undersigned architect.

Date:

Signature — **Building Owner/Applicant**

Signature — **Name of the ECBC Expert / Design Professional Registration no. with SEAL**

Enclosures :

Annexure 1 - Building Details/Information
Annexure 2 - ECBC Compliance Form Summary – Checklisted
Annexure 3 - ECBC Compliance Target & Compliance Simulation report, if applicable
Annexure 4 - Certificate of ECBC Expert/Design Professional
Annexure 5 - Prescriptive list as applicable

Figure 37 Application process in Punjab for ECBC compliance check(Source: Ashok B Lall Architects)

9.4.3 Kerala

Eco Niwas Samhita (ENS) was notified for residential buildings. ECBC incorporated and mandated in Building Plan approval. Successful empanelment and training were conducted for 140+ Building Energy Efficiency Experts (BEEE). The government also developed the Kerala Green Building Certification program. The state government also chose to offer the following incentives and programs:

1 Rebate in Property tax for ECBC Compliant buildings.
2 Kerala Finance Corporation provides soft loans for ECBC-compliant construction and retrofits.
3 Revised ECBC applicability for buildings with more than 500m2 air-conditioned area.

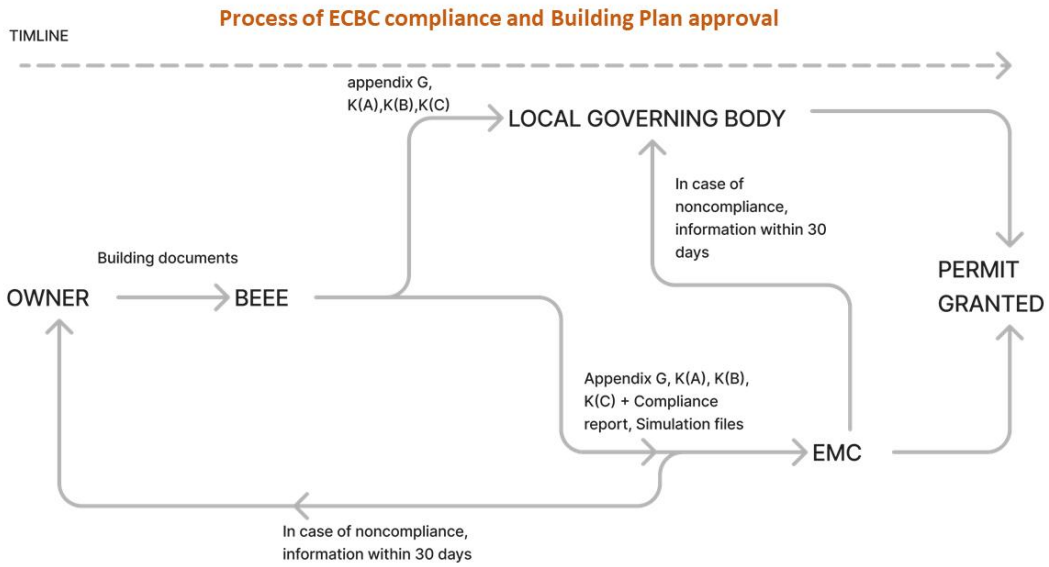


Figure 38 ECBC compliance and building plan approval process in Kerala (Source: Ashok B Lall Architects)

9.5 Precedents of Green Initiatives in Tamil Nadu

Tamil Nadu has a string history of mandatory schemes of environmental sustainability initiatives. The state is conversant with enforcing mandatory and voluntary initiatives, and that experience will enable Tamil Nadu to adopt passive cooling solution guidelines more easily.

9.5.1 Lifestyle for climate change – Tamil Nadu - DoECCF

The Lifestyle for Climate Change Certification is a key initiative under the Tamil Nadu Climate Change Mission, led by the Department of Environment & Climate Change. This Tamil Nadu-specific green rating framework recognizes buildings adopting climate-resilient, energy-efficient, water-conscious, and environmentally responsible practices. There are four levels: Outstanding (75-90 points), Excellent (60-74 points), Satisfied (45-59 points) and Certified (30-44 points).

Table 19 Key Components of the Evaluation System

Clean Energy & Energy Efficiency	-Promote renewable energy integration and energy-efficient appliances. -Use energy management systems and eco-friendly refrigerants.
Environmental Performance	-Monitor and manage energy/water use (EP1–EP2). -Adopt green building design and sustainable construction (EP3). -Optimize operations and use alternative energy/water sources (EP4–EP5). -Implement EMS and pursue green certifications (EP6).
Water Efficiency	-Install water-saving fixtures and promote conservation (WE1–WE2). -Use rainwater harvesting and greywater reuse (WE3). -Practice efficient landscaping and enforce water policies (WE4–WE5).

Material & Waste Management	-Encourage green procurement and responsible material use. -Ensure waste segregation and composting; install Manjappai vending machines.
Occupant Health & Comfort	-Address indoor air quality, thermal comfort, pest control, and lighting. -Ensure visual comfort and no-smoking policies.
Social & Cultural Inclusivity	-Provide universal access (ramps, braille signage). -Enable smart navigation (digital maps, footfall monitoring). -Use bilingual signage (local and international languages).

9.5.2 Development of portal for voluntary Industrial green rating - TNPCB

The Voluntary Industrial Green Rating Portal, developed by the Tamil Nadu Pollution Control Board (TNPCB), is a digital platform designed to encourage industries across Tamil Nadu to adopt sustainable and environmentally responsible practices. This initiative provides a structured system for industries to voluntarily assess and improve their environmental performance.

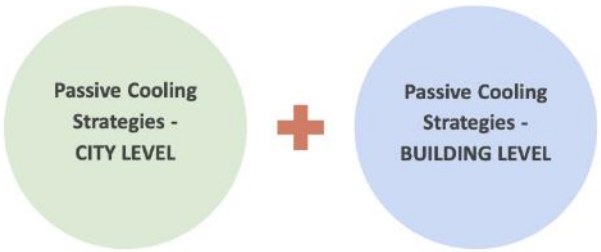
All industries operating within Tamil Nadu are the primary users of this system. The portal outlines clear roles and responsibilities to help industries navigate the green rating process effectively. The certification can be gained through an online platform: https://tnpcb.gov.in/greenrating/.

The initiative helps deliver TNPCB's broader mission of promoting green industrial growth through transparency, ease of access, and a robust evaluation mechanism. It is a key step in aligning industrial development with Tamil Nadu's climate and environmental goals.

9.6 Synopsis

A review of the approaches followed in Singapore, Thailand, Sri Lanka and the Indian states of Punjab and Kerala highlighted the following actions and approaches:

1. Recognition of **Urban Heat Island (UHI)** in urban areas compounded by climate change temperature rise and heat waves.
2. **Low-income citizens are most vulnerable –** all building types need protection from heat, to avoid potential heat stress and to curtail latent cooling energy demand.
3. **Integrated approach** for cooling cities is needed – town planning, site planning, urban design, building design, on-site renewable energy must be planned cohesively.



4. Singapore has evolved an integrated and comprehensive Green Mark Standard for mandating energy efficient, environmentally sustainable and

climate responsive (Passive Cooling Strategies or PCS) construction practices progressively for all buildings from 2005 onwards.

5 Other developing countries in warm-humid regions have started with energy-efficiency codes for large air-conditioned buildings. The code includes an integral component for Passive Cooling Strategies (PCS). They have mandated PCS through building bye laws for most building types.

6 **In all cases, PCS standards can be met by a simulated whole building performance or by following simple prescriptions laid out for different climate contexts.**

7 Supporting policies, programs or codes focusing on one of more of the following
   a. **Awareness raising** to inform the public and other stakeholders of urban heat mitigation and passive cooling in buildings.
   b. Leading by example, including **demonstration projects** implementation in government buildings, pavements, urban areas.
   c. **Incentives** to invest in urban cooling solutions in different forms, including regulatory, eg. faster permitting, or financial, eg discount in development charges, house tax or other forms of tax credits.

Notes

UN environment programme

UNEP Delhi Office:
55, Joseph Stein Lane, Lodhi Gardens,
Lodhi Estate, New Delhi – 110003, India.

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Embassy of Switzerland in India and Bhutan

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