Ministry of Housing and Urban Affairs
Government of India

Climate Smart Buildings

Training Program on Innovative Construction Technologies & Thermal Comfort in Affordable Housing

USER GUIDE

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Azadi Ka Amrit Mahotsav | प्रधान मंत्री आवास योजना-शहरी | GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA | bmtpc

RACHNA
RESILIENT, AFFORDABLE AND COMFORTABLE HOUSING THROUGH NATIONAL ACTION

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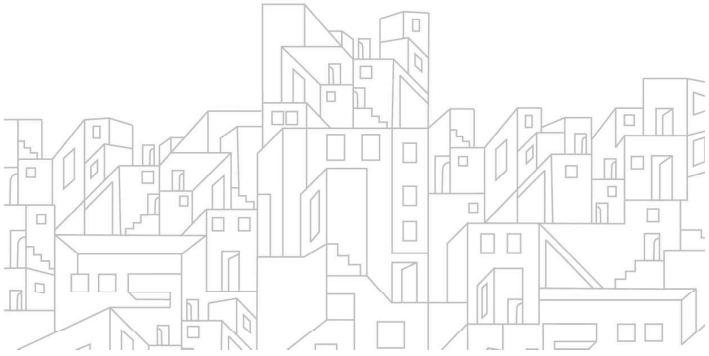
Training Program on Innovative Construction Technologies & Thermal Comfort in Affordable Housing

Training of Trainers
USER GUIDE FOR TRAINERS



Ministry of Housing and Urban Affairs
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Ministry of Housing & Urban Affairs, Government of India
Nirman Bhawan, New Delhi - 110001

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Climate Smart Buildings (IGEN-CSB),
B-5/5, Safdarjung Enclave,
New Delhi 110029, India

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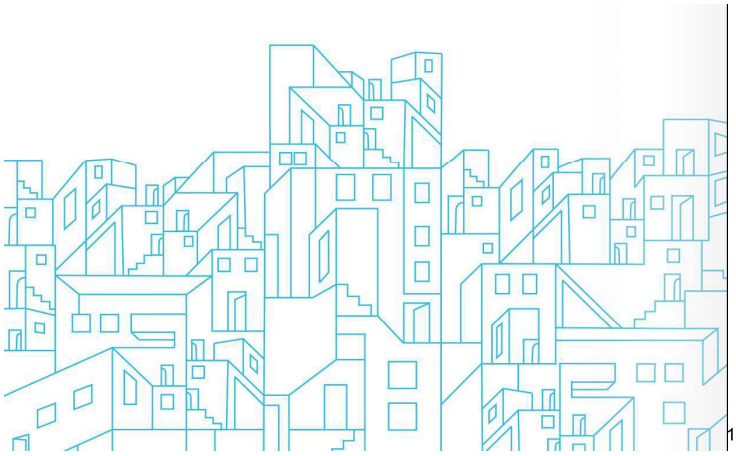
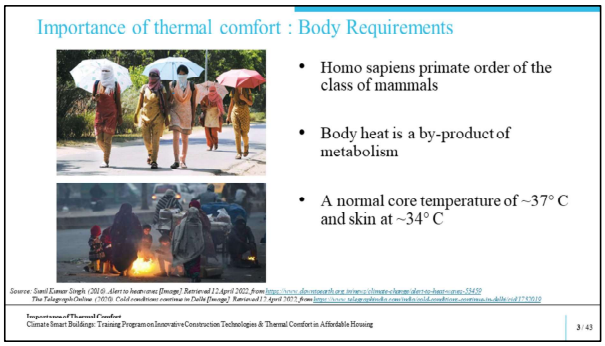
1. Importance of Thermal Comfort



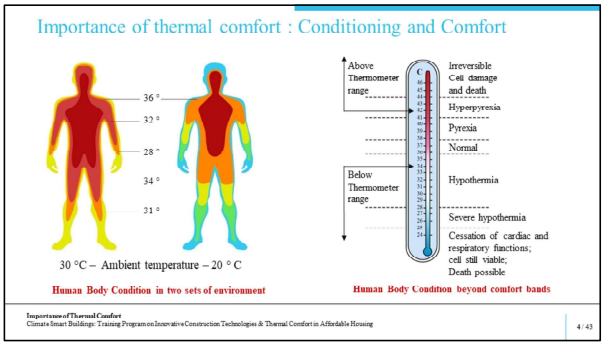
This session introduces the thermoregulation mechanisms of the human body to throw light on the concept of thermal comfort, thermal discomfort, and thermal stress. The narrative proceeds to scale up from thermal comfort at an individual level to an entire population. The interplay between provision of thermal comfort at the larger scale and multiple systems such as national economy, global climate change phenomenon, and approaching energy crisis are also presented in this chapter. Further, the session highlights the provisions for thermal comfort in national codes of India. Finally, addressing the building scale, the session describes factors that affect thermal comfort of humans in indoor spaces.

Humans are part of animal kingdom. The various vertebrates of the animal kingdom are categorized as either endotherms or ectotherms based on their thermoregulation mechanisms. Endothermic animals, like mammals and birds generate heat within their bodies to sustain life. Opposite to that, ectotherms depend on external conditions for regulation of their internal temperatures.



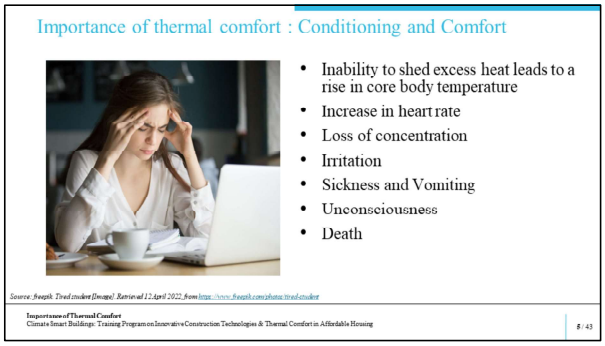
When the food consumed by endotherms is broken down to generate chemical energy for survival, heat is released as a by-product. The generated metabolic heat maintains a constant core body temperature for survival. This thermoregulatory mechanism makes endotherms capable of existing in a wide range of outdoor temperatures. In case of humans, the core body temperature lies in a narrow range around 37° C.

The human body is constantly acclimatizing itself to its external environmental conditions through exchange of heat facilitated by the largest organ of the human body- the skin. The thermal receptors in the body sense the microscopic heat exchange making us feel hot or cold. The same is termed as thermal sensation of human body. Normally, the skin surface temperature of a human body is around 34°C while core of the body is maintained at 37C. Both core body temperature and skin surface temperature are relevant in understanding thermal comfort.



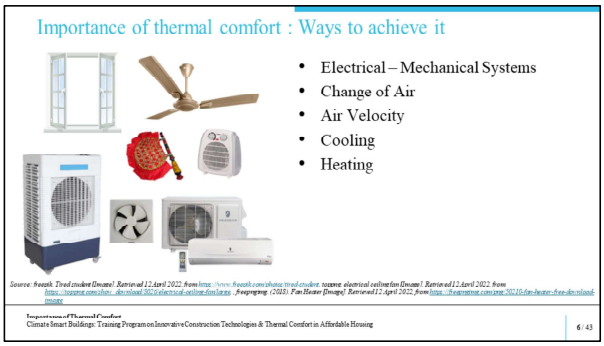
The heat generated from metabolism is distributed throughout the human body by blood. As a result, the core of human body houses maximum amount of heat due to concentration of blood vessels. Moreover, surface temperature of skin over a specific body part is a function of the temperature of the core and the distance of the skin surface from the core.

The skin temperature is different at different external temperatures, despite same or nearly same core body temperature. The area of skin surface in direct contact with surrounding air and amount of heat present in the immediate air also determine the rate of local heat transfer. In different ambient temperatures, the skin temperatures changes due to different heat transfer rates allowing the core body temperature to remain steady. When core body temperature is not maintained in given range, the body feels discomfort. On the hotter side, the body may suffer from pyrexia when approaching the upper limit of core body temperature while on the lower side, it can start to experience hypothermia.



Prolonged exposure to discomfort can increase the stress on the body with respect to bringing back the core temperature to the comfortable range. In this case, physiological effect such as elevated heart rate, sickness, vomiting and unconsciousness may be induced by the body. If still untreated, it may lead to severe or permanent cell damage and even death.

Hence, the health, well-being, and survival of a human or an endotherms is directly linked to the thermal conditioning of their bodies at all times.



In buildings, certain electro-mechanical systems can be used to regulate the indoor thermal environment for occupants. These systems may condition the indoor air temperature, Relative Humidity or movement. However, changing the temperature of the indoor air for cooling requires electrical energy. Moreover, these systems have associated economic and environmental impacts such as purchase and operation costs, CO_2 and other GHG emissions. The cumulative effect of these impacts at the urban and national scale is relevant, especially in the current climate change scenario. This includes consideration of growth in the rate of appliance ownership and usage, residential building stock, increase in peak loads. Together, they significantly increase the ecological and economic footprint; suggesting that minimizing dependence on the systems through smarter alternatives is required. Indoor environment variations can be lowered through design and construction measures. Well planned residential buildings account for the impacts of the outdoor climate through spatial design, construction materials, and building envelope performance.

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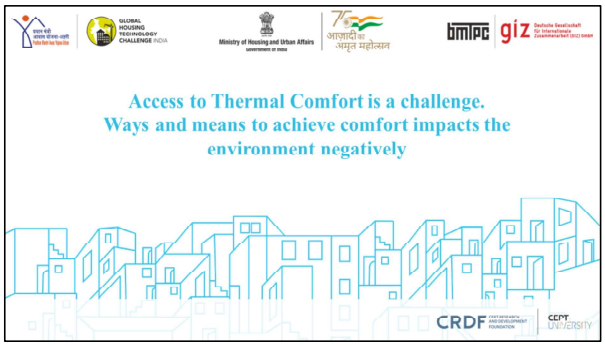

The residential sector in India faces an urgent challenge in providing suitable environment-friendly and economic alternatives for thermal comfort provision in residential building stock. The first step in addressing it, is understanding the thermal needs of the residential sector. Existing literature contains metrics that quantify this need at various scales- specifically, national and urban while considering multiple influencing factors. Moreover, it also offers an understanding of the cascading and interconnected effect of this demand on the environment and national economy.

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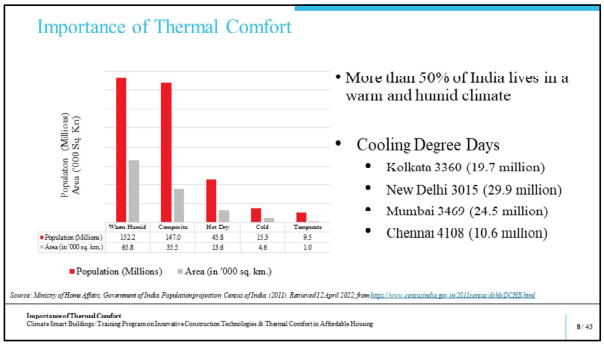

Majority of Indian population lives in warm - humid and composite climate together. The density of Indian population (obtained from census 2011) was understood against the climate zone under which the areas fell, to obtain this conclusion. The graph indicates that major metropolitan cities of India that house the urban population lie in warm - humid and composite climates. This urban population forms nearly 35% of the total Indian population and is steadily growing due to mass migration and urbanisation.

Residents of these cities and climate zones experience high cooling degree days every year. Cooling degree days is the sum of total number of degrees by which the average daily temperature of each day is higher than acceptable for given duration. For example- If the average daily temperature is 30C for given location over 5 days, the CDD for that duration would be 5 x (30-26) assuming 26 as comfortable. An estimated 19.7 million people living in Chennai require nearly 3360 degree days of cooling in a year.

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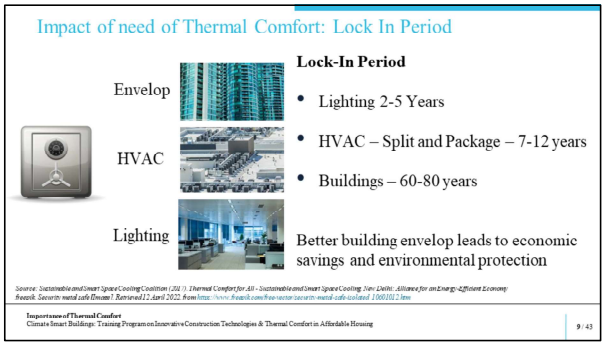

While electro-mechanical systems can be used to meet the cooling demand in residential building stock, there are other approaches that can help tackle the challenge by reducing the cooling load in the first place. In India, buildings typically have a lifespan of 60-80 years. Within this lifespan, various systems may undergo improvements or upgrades at varied rates. For example, the lighting of a building may be replaced or upgraded once in 5 years. The scope of improving energy efficiency of a building by upgrading these systems is subject to technological advancements as well as their contribution in energy consumption. The duration for which the systems have a certain range of environmental and economic impact, until an improvement takes place, is referred to as the lock-in period for the system. The lock-in period of building envelope is much higher than lighting and HVAC systems. This translates into high energy and environmental costs for decades. Moreover, when the envelope is not optimized to reduce energy requirements, the impact of other systems like HVAC remains escalated throughout the building life.

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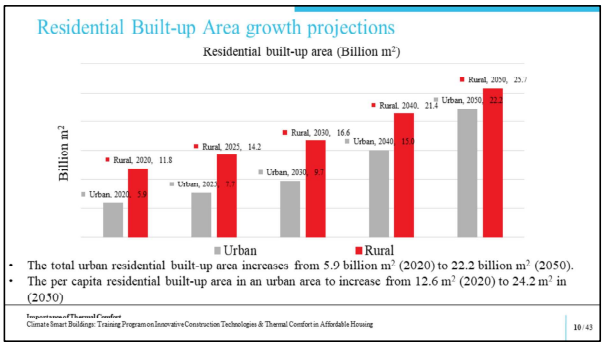
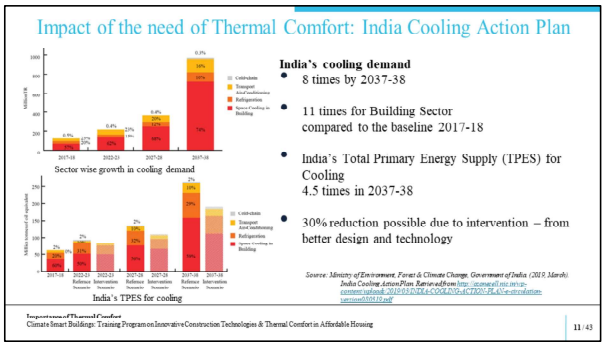
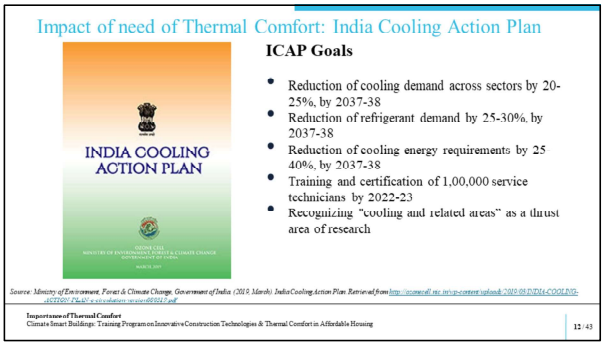


Projections of cooling demand at urban level are key indicators in designing pathways to efficient cities that house the population in thermally comfortable residential spaces. Firstly, this includes the growth projections of the city in terms of its population and therefore, residential building stock.

The residential built-up area in Indian urban areas is expected to grow more than three-fold from 5.9 billion sq. m. in 2020 to 22.2 billion sq. m. in 2050. This is attributed to rapid urban migration. Simultaneously, the per capita residential built-up area in these cities is also expected to increase from 12.6 to 24.2 sq. m. as a result of greater access to better living conditions. Conclusively, nearly two-thirds of the Indian residential stock that will exist in India is yet to be built. This demonstrates the urgent need for Indian cities to be equipped with greater share of affordable housing to efficiently support the population.

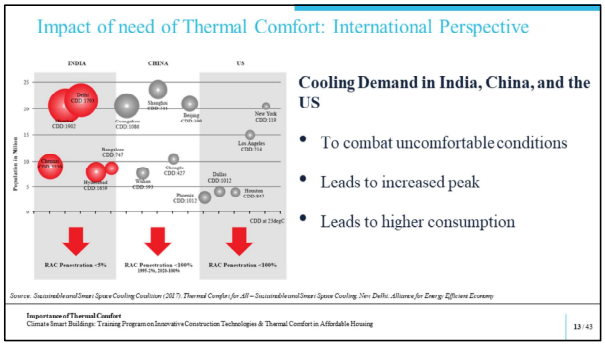


Secondly, the growing built-up area translates into increased cooling demand. While the total cooling demand arising from various sectors is expected to grow nearly eight times from 2017-18 to 2037-38, the space cooling requirement of buildings is projected increase nearly 11 times during the same time. From contributing to 57% of the total cooling demand in 2017-18, it will grow to 74% in 2037-38. The increased cooling demand reflects an estimated 5-8% increase in refrigerant demand by 2037-38. Moreover, assuming a constant efficiency rate of primary energy consumption, the Total Primary Energy Supply (TPES) of India will grow 4.5 times by 2037-38. Ultimately, this means that pressure to increase energy generation with a higher share of renewables is increasing exponentially and space cooling in buildings are a major contributor. The ICAP also suggests pathways to reduce this escalating situation. By considering efficient building design and technology implementation in an intervention scenario, it predicts the possibility of 25-30% reduction in refrigerant demand and nearly 30% less TPES.



The India Cooling Action Plan (ICAP) enlists few goals that can be targeted to reduce the environmental and economic impacts of space cooling provisions in residential buildings. These include:

- Reduction of cooling demand across sectors by 20-25%, by 2037-38
- Reduction of refrigerant demand by 25-30%, by 2037-38
- Reduction of cooling energy requirements by 25-40%, by 2037-38
- Training and certification of 1,00,000 service technicians by 2022-23
- Recognizing "cooling and related areas" as a thrust area of research



The cooling demand in urban areas or cities of India is much higher than those in China and USA. This is because major Indian cities, that house the most population lie in climate zones that require more cooling.

When residential buildings in these cities are designed without the intention to reduce the cooling requirement, the reliance on active cooling i.e., devices such as air-conditioners, increases to achieve thermal comfort. This can be understood by studying the penetration of Room Air-Conditioners (RAC) in the households. In 20211, the RAC penetration was less than 5% in Indian cities. However, contemporary phenomenon such as urbanization, urban heat island effect, climate change events and surging disposable incomes, indicate that it is bound to increase to 11-12% or more at a rapid rate.