प्रधान मंत्री आवास योजना-शहरी
Pradhan Mantri Awas Yojana-Urban

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

বাংলার বাড়ি
বাংলার বাড়ি স্বপ্নের দিশারী

Ministry of Housing and Urban Affairs
Government of India

आज़ादी का अमृत महोत्सव

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GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

RACHNA

RESILIENT, AFFORDABLE AND COMFORTABLE HOUSING THROUGH NATIONAL ACTION

" Innovative Construction Technologies & Thermal Comfort for Affordable Housing"

Location: Kolkata | Date: 20/05/2022

Session 1

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STATE OF CLIMATE REPORT 2021

TEMPERATURE

Global mean temperature in 2021:
1.11 ± 0.13 degree C above the 1850-1900 average

- 2021 was sixth warmest during the most recent seven years (2015-2021)
- 2021 was less warm than some recent years due to the influence of La Niña conditions at the start and end of the year
- 2015-2021 were, however, the seven warmest years on record

OCEAN

Higher

- Global mean sea level reached a new record high in 2021
- Increased at an average 4.5 mm per year over the period 2013 -2021
- This is more than double the rate between 1993 and 2002 due to the accelerated loss of ice mass from the ice sheets
- This has major implications for hundreds of millions of coastal dwellers
- It increases vulnerability to tropical cyclones

Hotter

- Ocean heat was record high, affecting marine life
- The upper 2000m depth of the ocean continued to warm in 2021
- It is expected that it will continue to warm in the future
- All data sets agree that ocean warming rates show a particularly strong increase in the past two decades
- Much of the ocean experienced at least one 'strong' marine heatwave at some point in 2021

More Acidic

- Ocean acidification increases, reaching new record level
- Higher acidification threatens organisms and ecosystem services, and hence food security, tourism and coastal protection

GREENHOUSE GAS (GHG)

- GHG concentrations reached a new global high in 2020, and continued to increase in 2021 and even in early 2022
- Increase in GHG levels in the atmosphere happens due to human activities
- It leads to global warming

MELTING OF ICE

- On an average, the world's reference glaciers have thinned by 33.5 meters (ice-equivalent) since 1950, with 76% of this thinning since 1980
- 2021 was a particularly punishing year for glaciers in Canada and the US northwest with record ice mass loss as a result of heatwaves and fires
- Greenland experienced an exceptional mid-August melt event

Scientists call for heat action plan after IPCC alert on Kol

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Kolkata: The recent Intergovernmental Panel on Climate Change (IPCC) report underlined Kolkata's vulnerability to extreme heat waves with the city remaining on the periphery of India's extreme heatwave atlas. Climate scientists urged the state to have its Heat Action Plan (HAP) ready to reduce heat-related deaths and address underlying conditions of vulnerability across spatial segregation of the urban poor.

The IPCC report said that on average Kolkata will experience heat equivalent to the 2015 record heatwaves every year. In 2015, heatwaves killed 2,500 people in India. Kolkata along with Delhi runs a high drought risk, the report said. Since March 1, Kolkata did not receive any rain till April 29 when there was a light drizzle for a couple of minutes. On Saturday, April 30, the city experienced the first thundershowers.

HAP combines both the early warning systems and coordinated responses to protect vulnerable populations and save lives.

A panel of experts at an event co-hosted by NRDC and Climate Trends drew attention to the monumental health risks posed by climate change-driven extreme heat. Panelists also offered actionable solutions for expanding heat adaptation across the country.

"India Meteorological Department is committed to providing improved early-warning heat forecasts that help hundreds of cities take action and reduce the harms of extreme heat," said IMD-DG Mrutyunjay Mohapatra.

Manish Bapna, president and CEO of NRDC, said: "Heat kills — but it doesn't have to. Over the past decade, NRDC and partners in India have been working with communities on the front lines to promote more inclusive health preparedness and build climate resilience. We've developed a model Heat Action Plan that hundreds of cities in India have adapted." "Architecture planning of the city buildings also needs a strong relook as Kolkata has turned into a heat island," said another expert.

Times View

This March-April season has been exceptional but, if we continue to ignore sane advice, this may well become the new normal. There is an urgent need to plan better to do our bit to reduce the impact of global warming.

Subhojyoti Kanjilal

HEATWAVE CONDITIONS

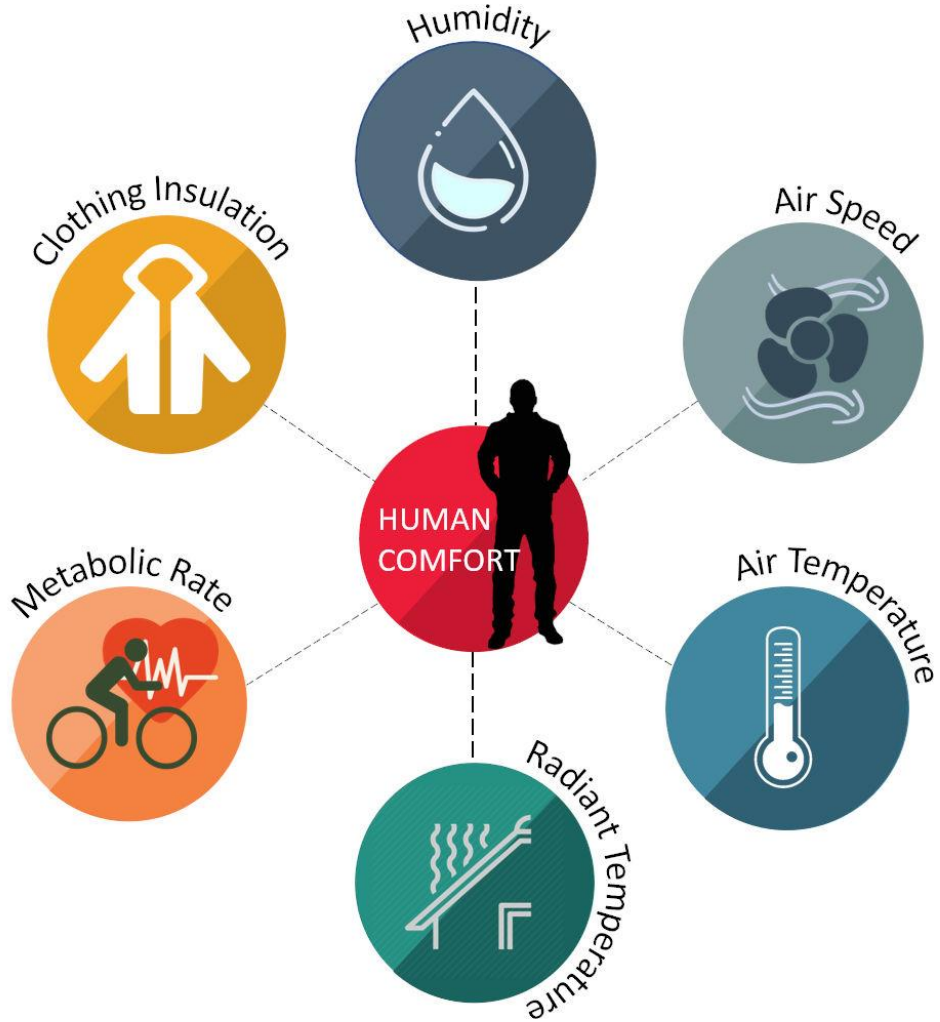
WHAT IS HEAT ACTION PLAN? HAP combines both the early warning systems and coordinated responses to protect vulnerable populations and save lives

- Max temp at any station 40°C or more for plains
- 37°C or more for coastal cities
- At least 30°C or more for hilly regions
- Temperature deviation above normal is 4.5 to 6.5°C for a regular heatwave and beyond
- 6.4°C for severe heatwave
- If such conditions prevail in at least two stations of a meteorological subdivision for at least two successive day

While heatwaves are a fairly common phenomena in India, typically in May and June, the country has experienced **heatwaves** in **2022** from **March** itself. Average maximum temperatures in the months were the highest in **122** years. Rising temperatures are driving people towards immediate relief with the need to achieve thermal comfort. The Cooling Demand in India is expected to grow by a factor of 9 by 2038 and Cooling is projected to contribute towards 50% of the peak electricity demand by 2050. Sustainable and smart space cooling solutions are the need of the hour.

THERMAL COMFORT

- It is that condition of Mind that expresses satisfaction with the thermal environment, and depends on 6 factors, which influences productivity.

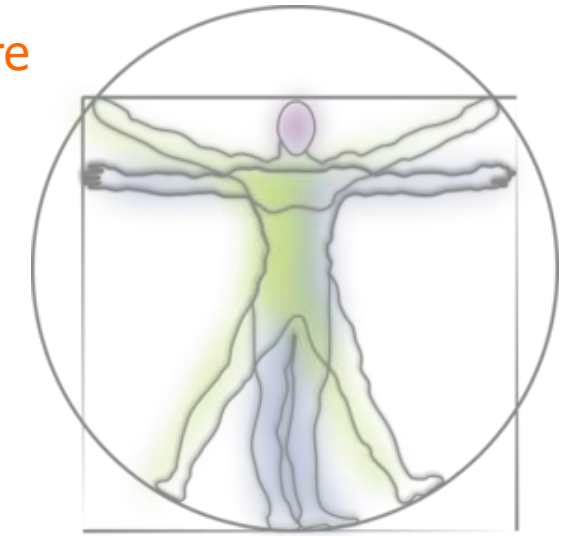


Factors affecting Thermal Comfort

PHYSICAL FACTORS

Environmental Parameters

- Mean Radiant Temperature
- Air Temperature
- Air Speed
- Humidity

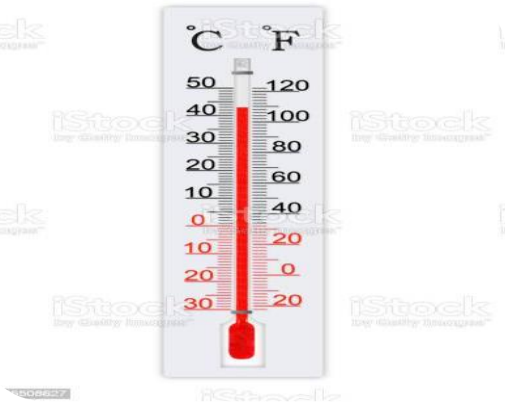


PHYSIOLOGICAL FACTORS

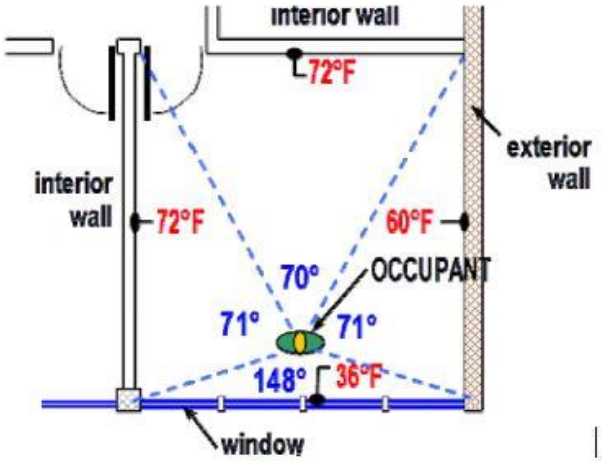
Individual Parameters

- Metabolic Rate
- Clothing

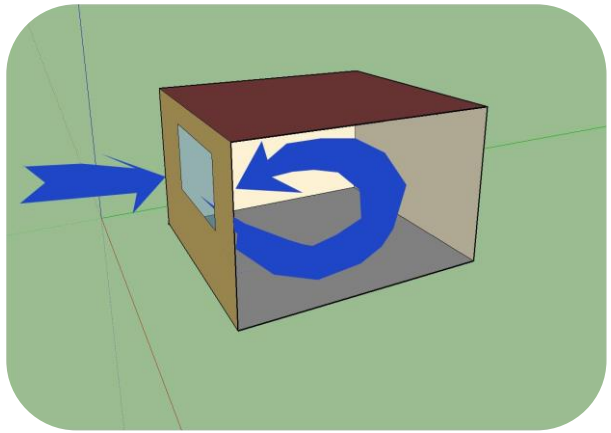
Physical Factors



AIR TEMPERATURE is the temperature of the air surrounding a body



RADIANT TEMPERATURE is the heat that radiates from a warm object



AIR VELOCITY is the speed of air moving across

HUMIDITY is the amount of evaporated water in the air

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PHYSIOLOGICAL FACTORS

CLOTHING LEVEL

Because it affects heat loss and, as a result, the thermal balance, the amount of thermal insulation worn by a person has a significant impact on thermal comfort. Air movement and relative humidity can reduce the insulating effectiveness of clothing, depending on the type of material it is constructed of.

METABOLIC RATE

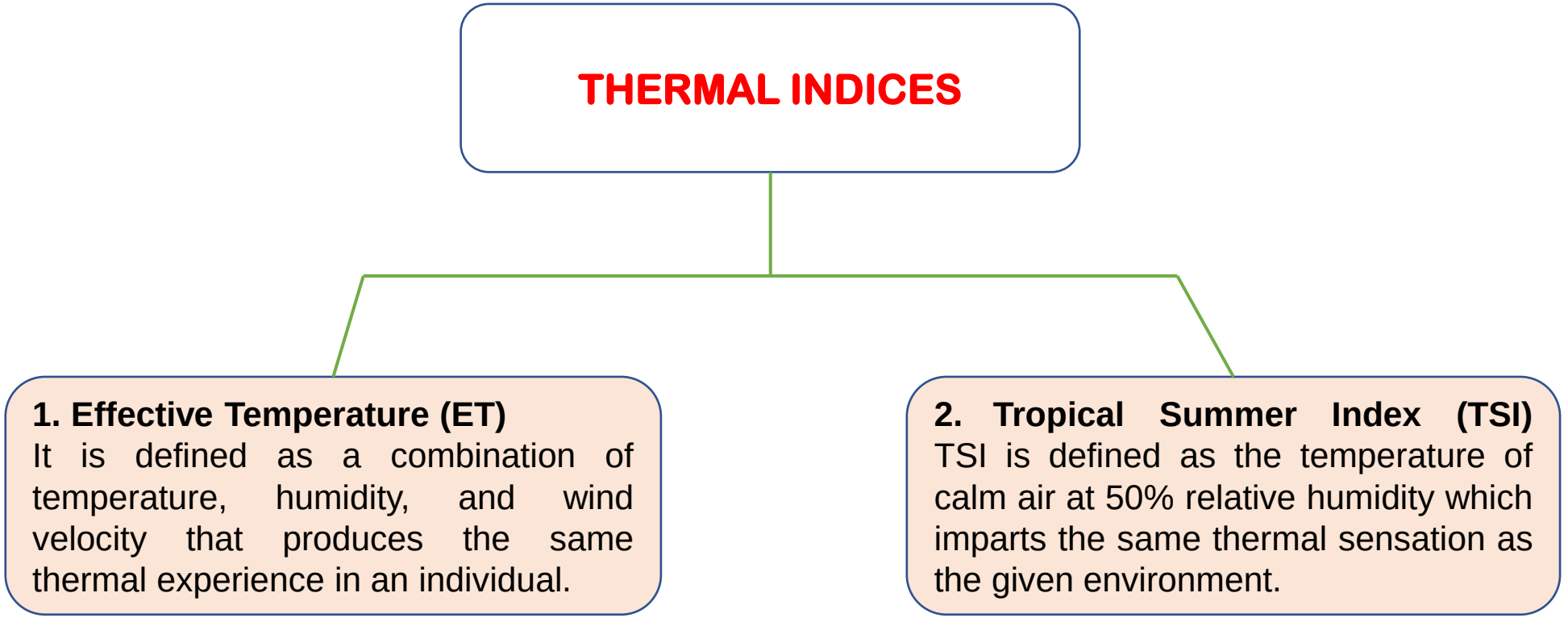
The rate at which chemical energy is converted into heat and mechanical effort by metabolic activities within an organism, commonly measured in units of total body surface area. People have different metabolic rates that can fluctuate due to activity level and environmental conditions.

Physiological factors & Metabolic rates

Parameters	Clothing	Clo	Activity	Met
Physio+Meta	T-shirts, shorts, Light socks, Sandals	0.30	Seated, Relaxed	1.0
Physio+Meta	Shirt, Trousers socks, Shoes	0.70	Sedentary Activity (office, dwelling, school, laboratory)	1.2
Physio+Meta	Jacket, Blouse, Long skirt, stockings	1.00	Standing, Light Activity (shopping, laboratory, light industry)	1.6
Physio+Meta	Trousers, Vest, Jacket Coat, Socks Shoes	1.50	Standing, Medium activity (shop assistant, domestic work, machine work)	2.0

Thermal Comfort Indices

Two of the thermal indices which find applications for hot environments are described as follows.



Thermal Comfort Indices

2 - Tropical Summer Index

Mathematically, TSI (°C) is expressed as

$$TSI = 0.308Tw + 0.745Tg - 2.06\sqrt{V + 0.841}$$

Where,	
Tw	Wet bulb temperature in °C
Tg	Globe temperature in °C
V	Air speed in m/s

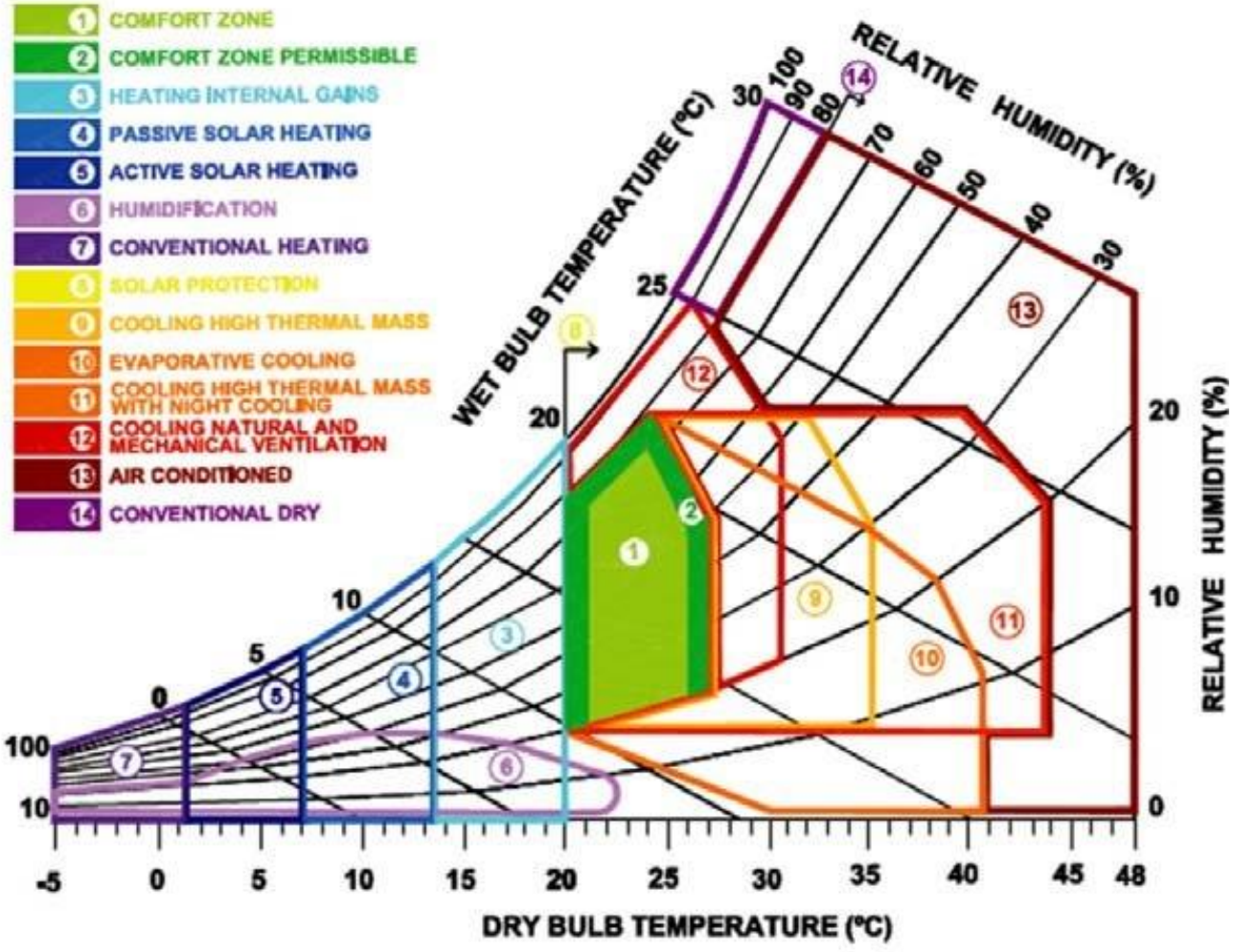
The thermal comfort of subjects was found to lie between TSI values of 25 and 30°C with optimum conditions at 27.5°C.

Thermal Comfort Indices

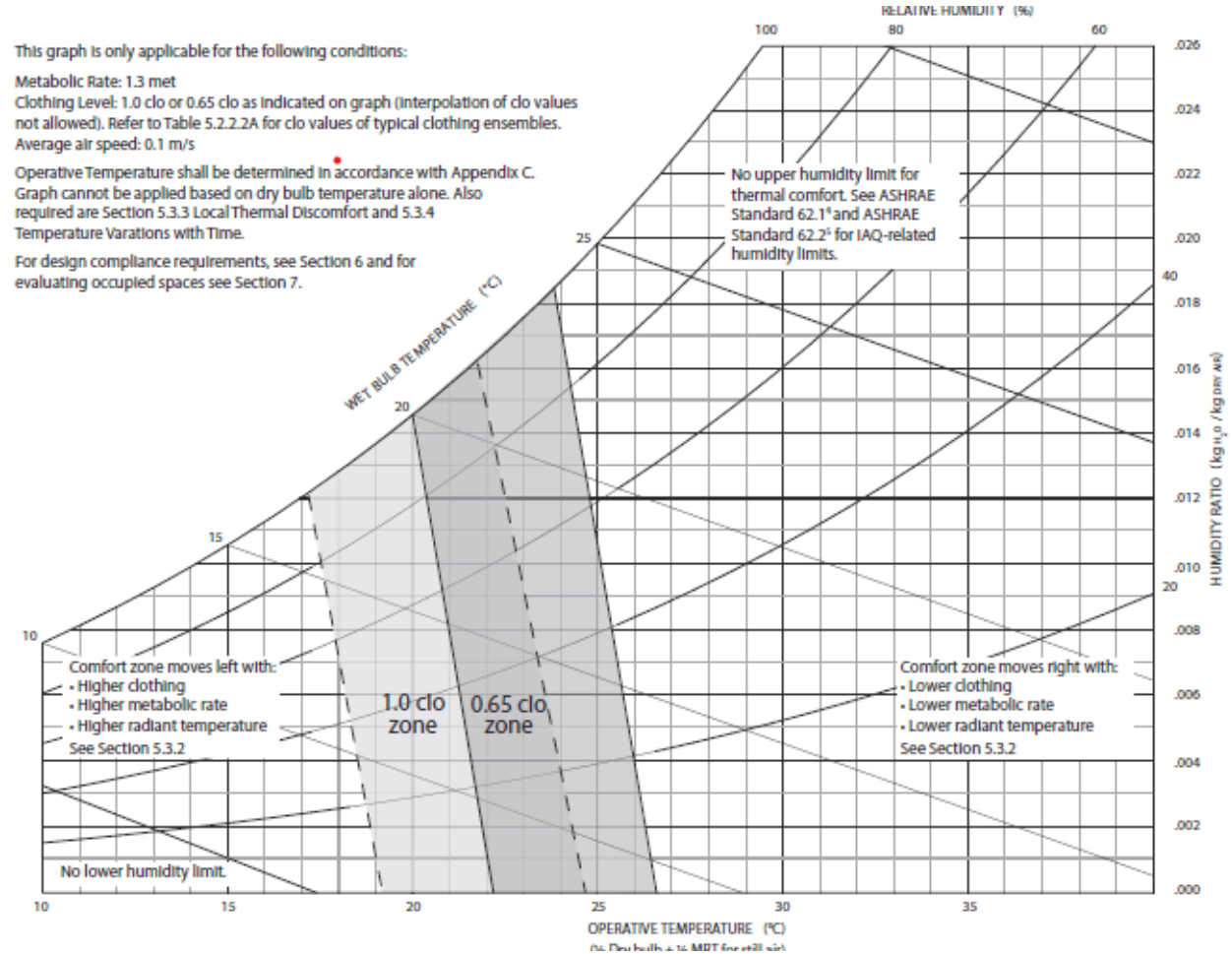
REDUCTION IN TSI VALUE FOR VARIOUS WIND SPEED	
Air Speed (m/s)	**Decrease in TSI (°C)**
0.5	1.4
1.0	2.0
1.5	2.5
2.0	2.8
2.5	3.2

The warmth of the environment was found tolerable between 30 and 34°C (TSI), and too hot above this limit. On the lower side, the coolness of the environment was found tolerable between 19 and 25°C (TSI) and below 19°C (TSI), it was found too cold.

Psychrometric Chart

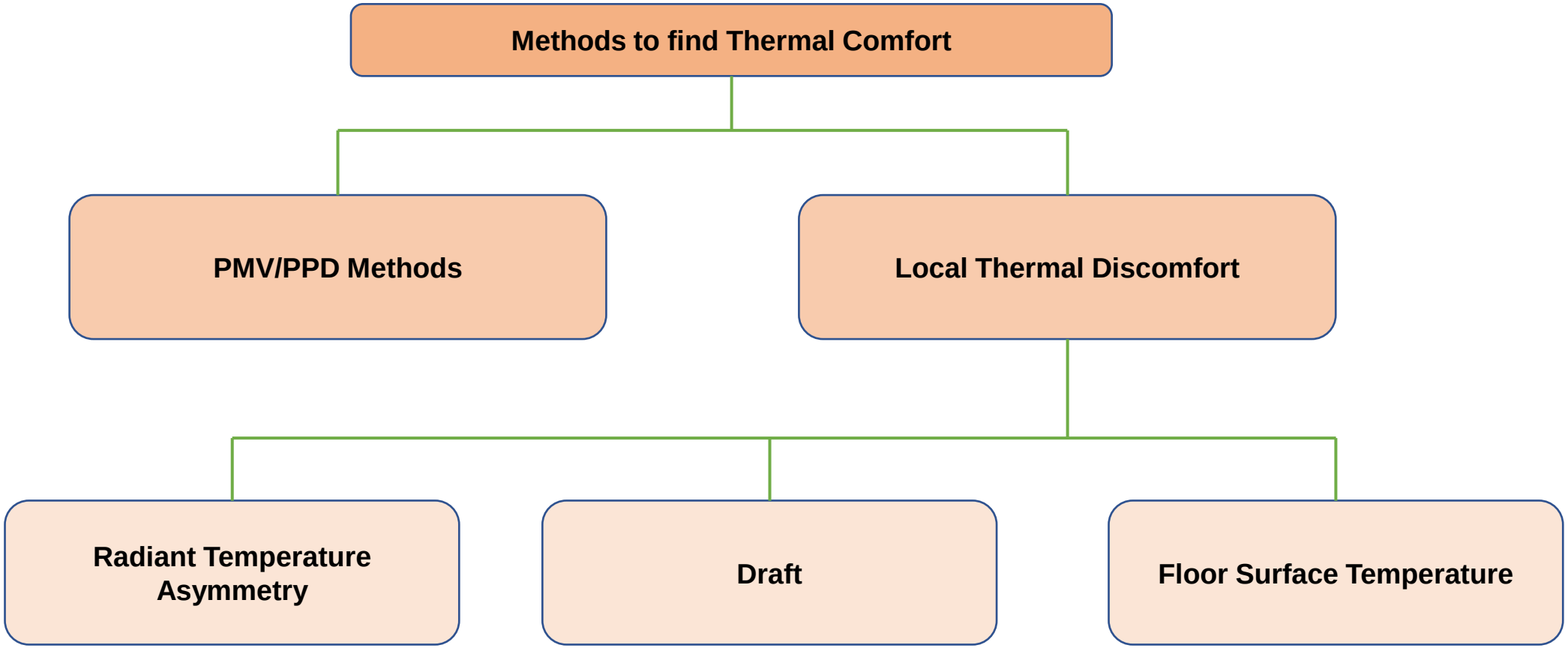


As per Giovani, 1992



As per ASHRAE 55 : 2017

Methods to find Thermal Comfort



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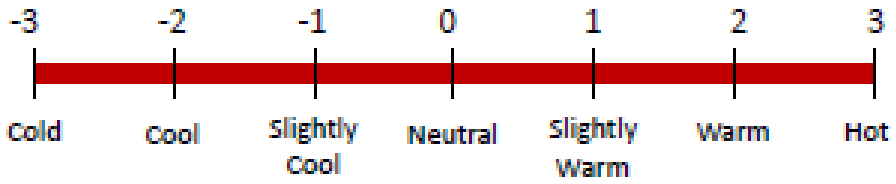
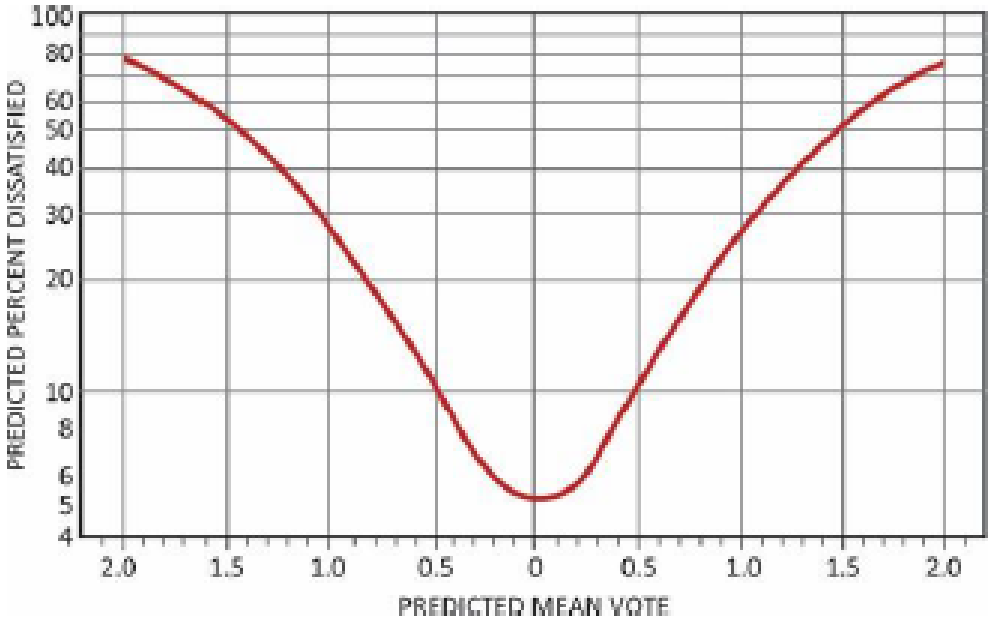
PMV / PPD Method





Reference : ASHRAE 55 - 2017

- Predicted Mean Vote / Predicted Percentage Dissatisfied Method shows level of comfort on a Thermal Scale.
- It was developed by Fanger and subsequently adopted as ISO Standard.
- Cold (-3) to Hot(+3).

Category	PMV	PPD (%)	DR (%)
A	< 6	-0.2 < PMV < +0.2	> 10
B	< 10	**-0.5 < PMV < +0.5**	> 20
C	< 15	-0.7 < PMV < +0.7	> 30

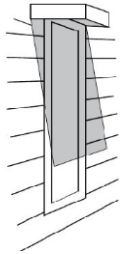
Note

1. According to ASHRAE 55 : 2017, Acceptable Thermal Environment for General Comfort is Category **B** in the above Table
2. DR means Drought Risk.

Thermal measures in Buildings

Measures to Improve Thermal Comfort

- **SHADING & GLAZING**



- **CONTROLLED VENTILATION**

- **INSULATION**

- **COOL ROOFS**

- **GREEN ROOFS**

Shading & Glazing

Shading reduces internal heat gain through coincident radiation.

VARIOUS METHODS TO SHADE WINDOWS			
Overhangs	Awnings	Louvers	Vertical Fins

These can reduce cooling energy consumption by 10-20%

Shading & Glazing

Thermal Comfort

SHADING

In combination with high-performance glass with low solar heat gain coefficient (SHGC), can reduce energy consumption.

GLAZING

Glazing of appropriate Heat transfer parameters (SHGC, VLT and U-value) is an integral part of Energy Efficient Buildings.

Natural / Controlled Ventilation

Designing windows and vents to dissipate warm air and allow the ingress of cool air can **reduce cooling energy consumption by 10-30%**

Air Velocity range between 0.5 to 1 m/s	**Drops temperature at about 3 ºC at 50% RH**
Natural Ventilation with Breeze Air	Works Best
Lesser scope for Natural Ventilation can be compensated by Fans	Fans can improve the air circulation and enhance comfort level.
Where intermittent ACs are required, circulation of Air is necessary	Mixed mode operation to achieve comfort level are Medium economy effort

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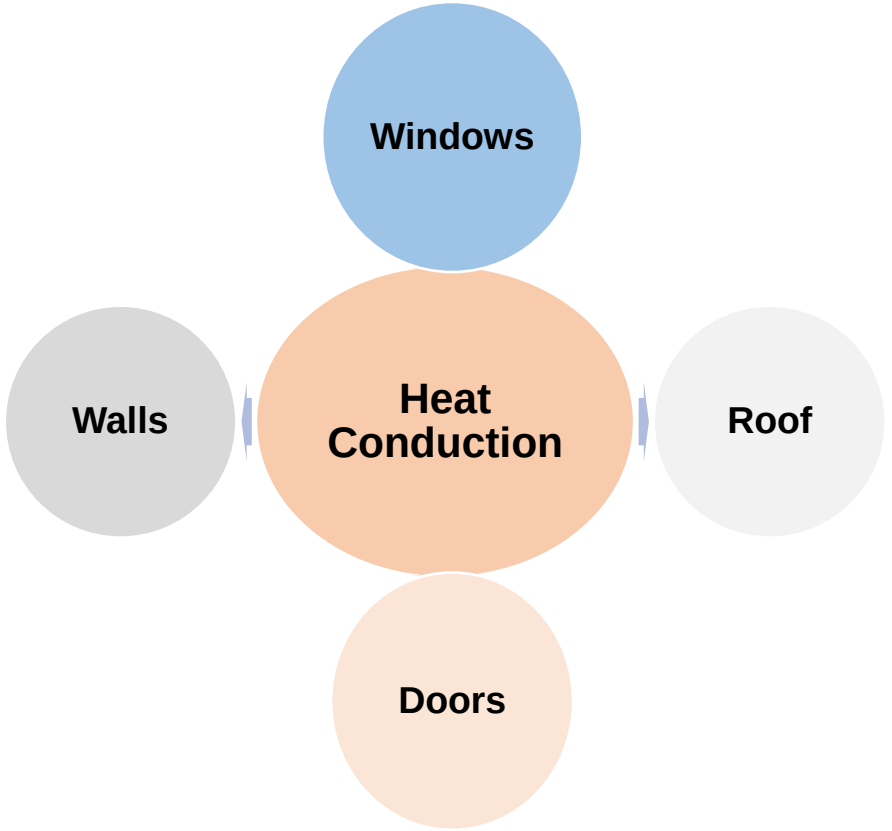
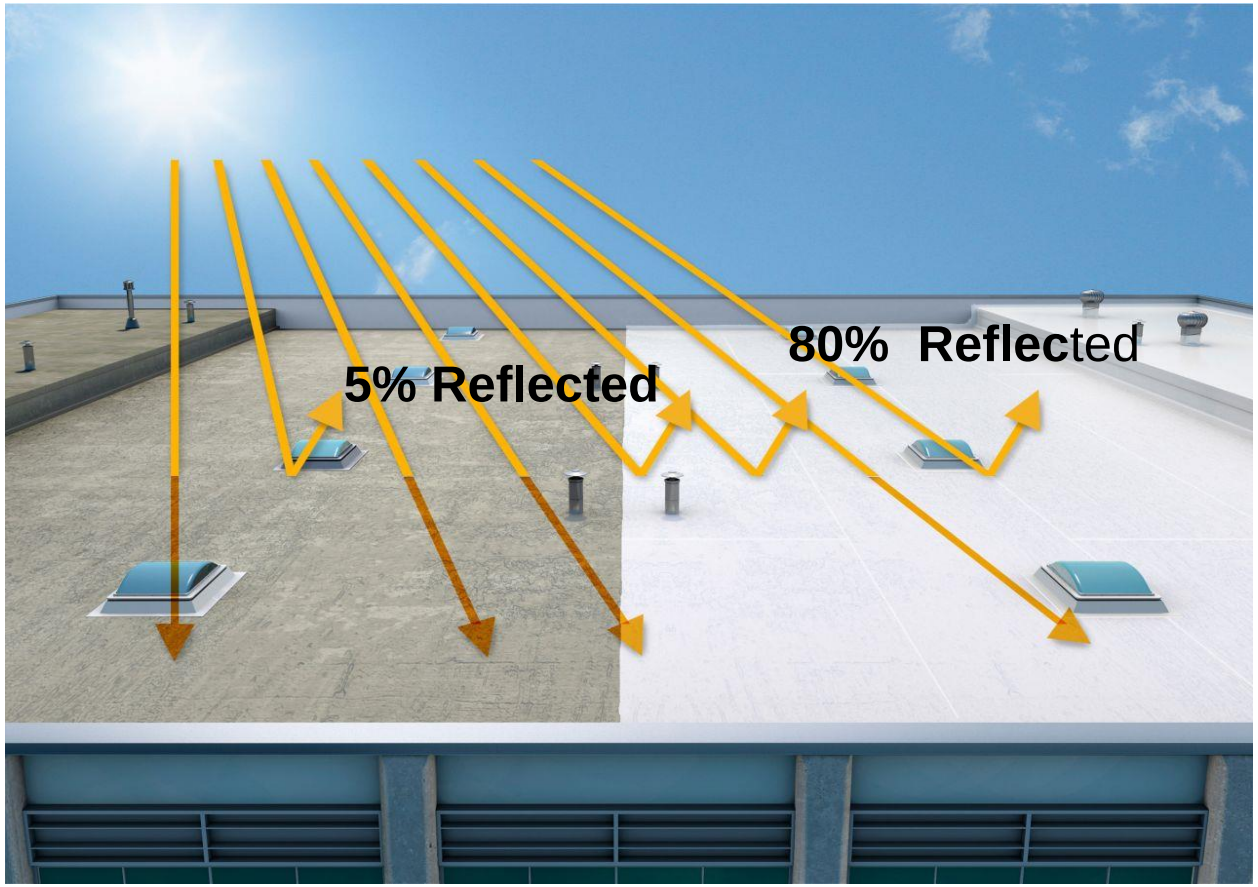
Insulation



An insulating material can resist heat transfer due to its low thermal conductivity. Insulating walls and the roof can reduce cooling energy loads up to considerable extent.

Cool Roofs

Cool roofs are one of the passive design options for reducing cooling loads in buildings. Cool roofs reflect most of the sunlight (about 80% on a clear day)



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Cool Roofs

- During summer, a typical cool roof surface temperature keeps 25-35°C cooler than a conventional roof, lowering the internal air temperature by roughly **3-5°C** and improving the **thermal performance**.
- The comfort of the inhabitants is improved, and the **roof's lifespan** is extended.
- Cool roofs increase the durability of the roof itself by reducing thermal expansion and contraction.
- Apart from helping enhance the thermal comfort in the top floor and helping **reduce air-conditioning load**, cool or white roof or pavements also offer significant reduction in urban heat island effect

In Arab countries, buildings are painted white for maximum reflection of Solar radiation

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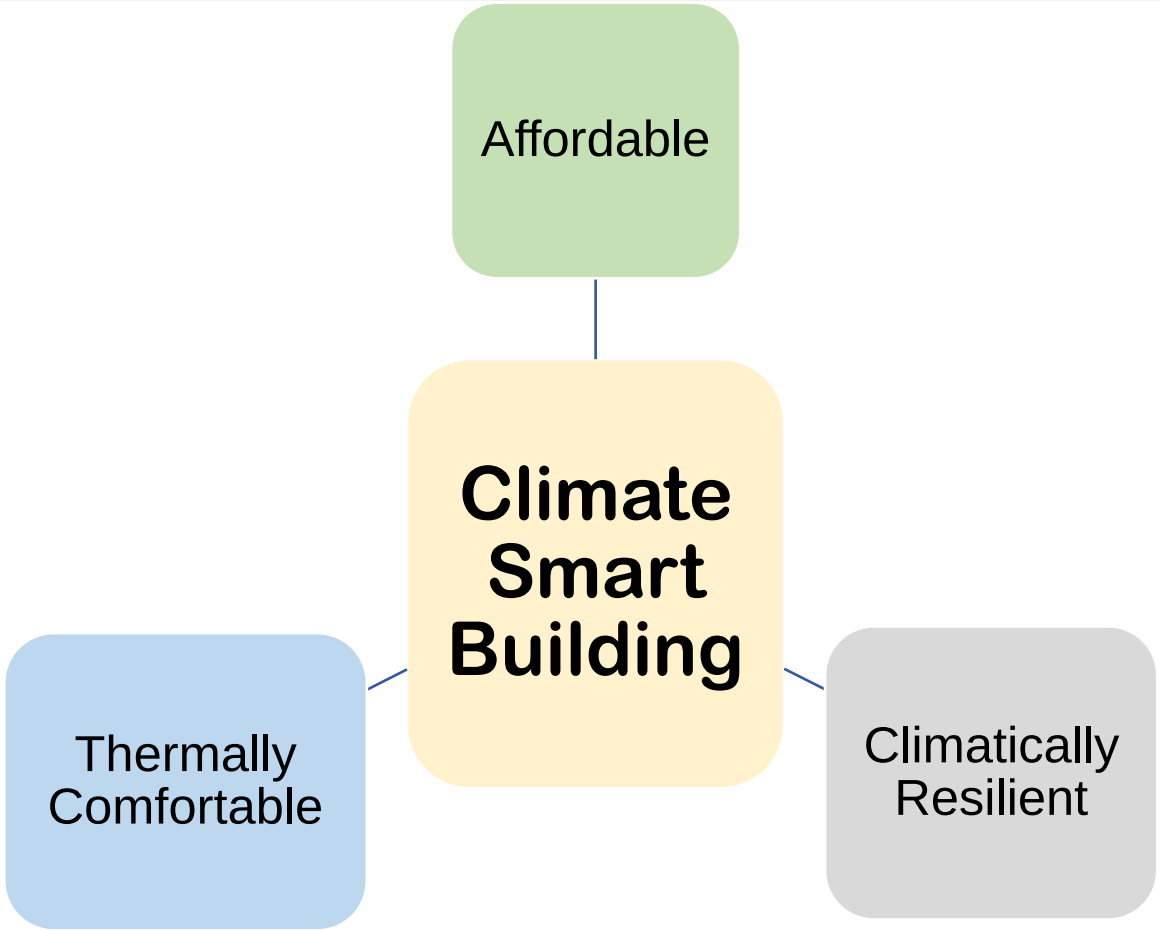
Green Roofs

A green roof is a roof of a building that is partially or completely covered with vegetation

GREEN ROOF'S FUNCTIONS

- Absorbing Rain Water
- Providing Insulation
- Helping lower Building air temperatures
- Mitigating the Urban Heat Island effect

Thermal Comfort in Affordable Housing

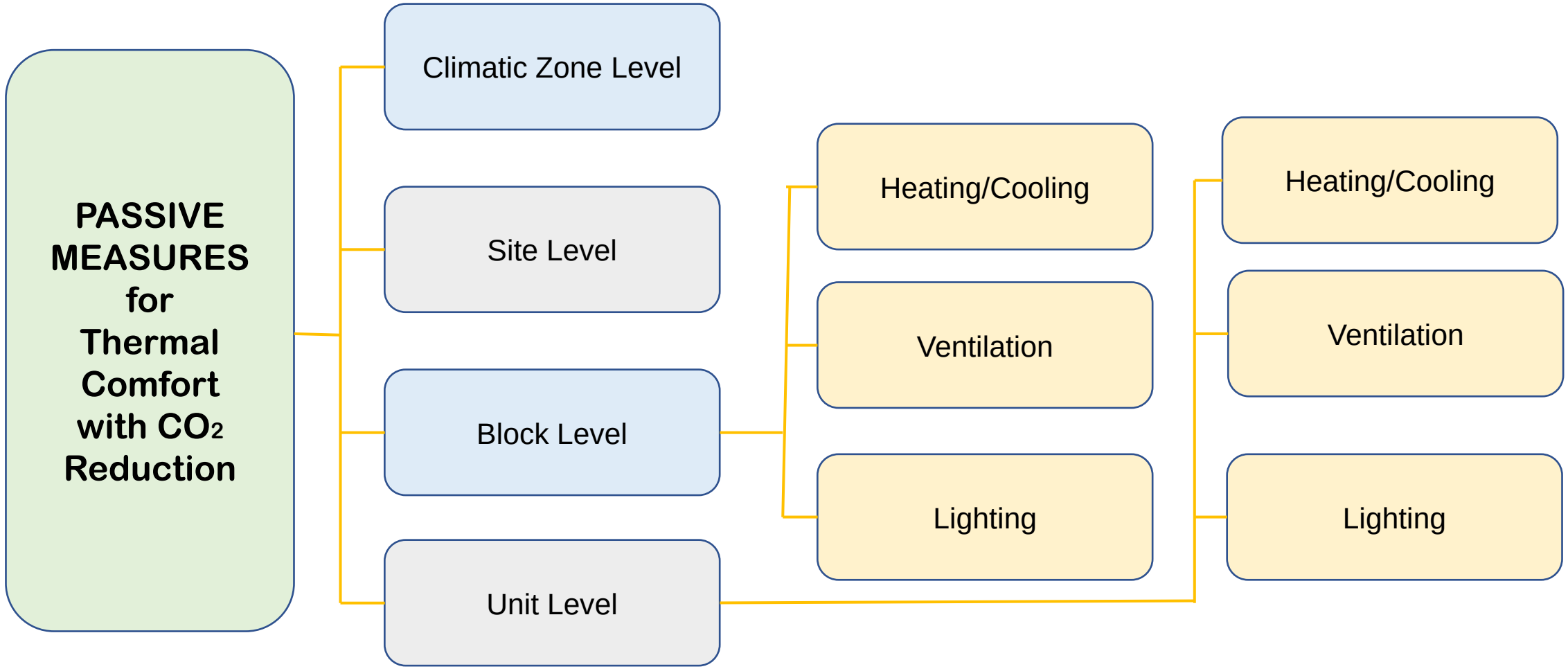


Thermal Comfort in Affordable Housing

TC in AH is having numerous positive impacts

- **Lower operational costs**
- **Sustainable Technology and Material market**
- **Better performance by Dwellers in all areas in life**
- **COP 21 and COP 26 Target achievement**
- **Health and Well being of Dwellers**

Passive Strategies & Building Physics



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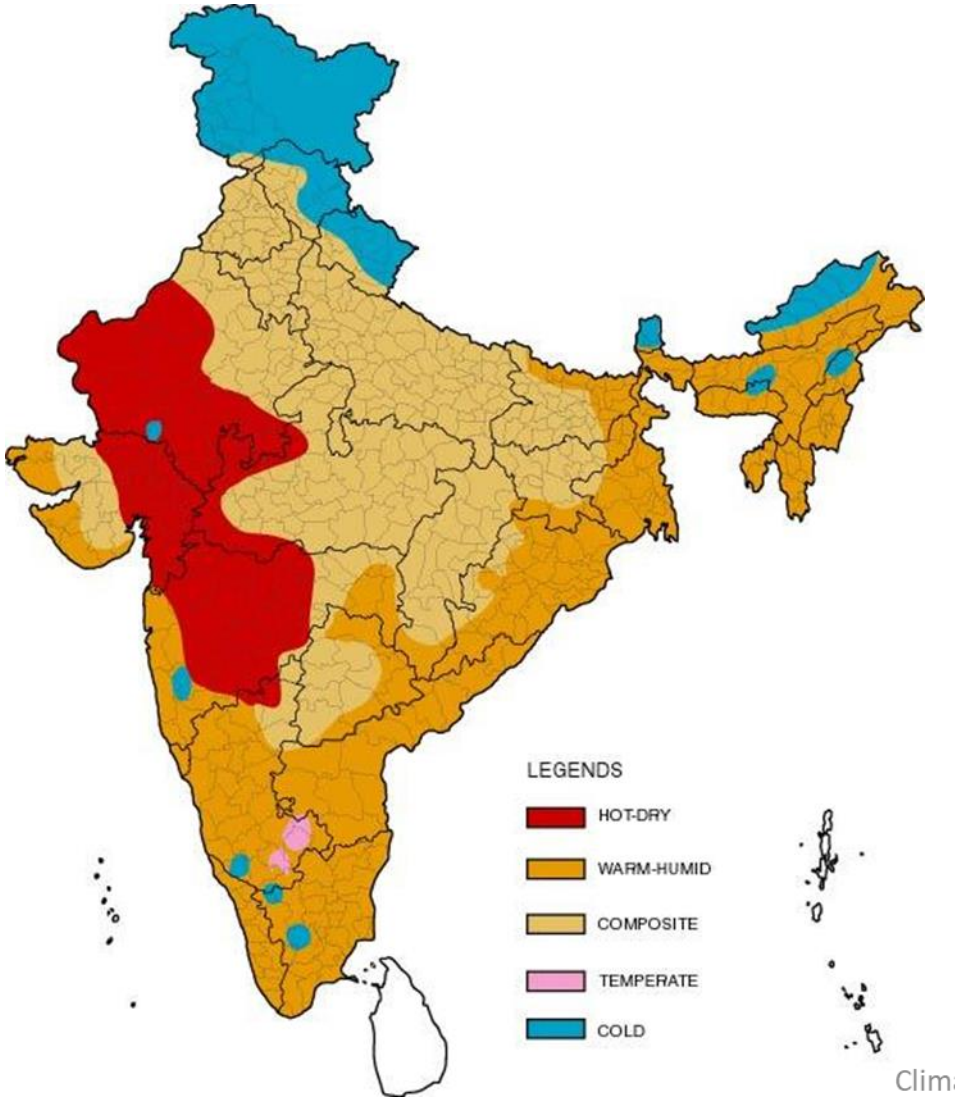
Passive Measures : Climatic Zone Level



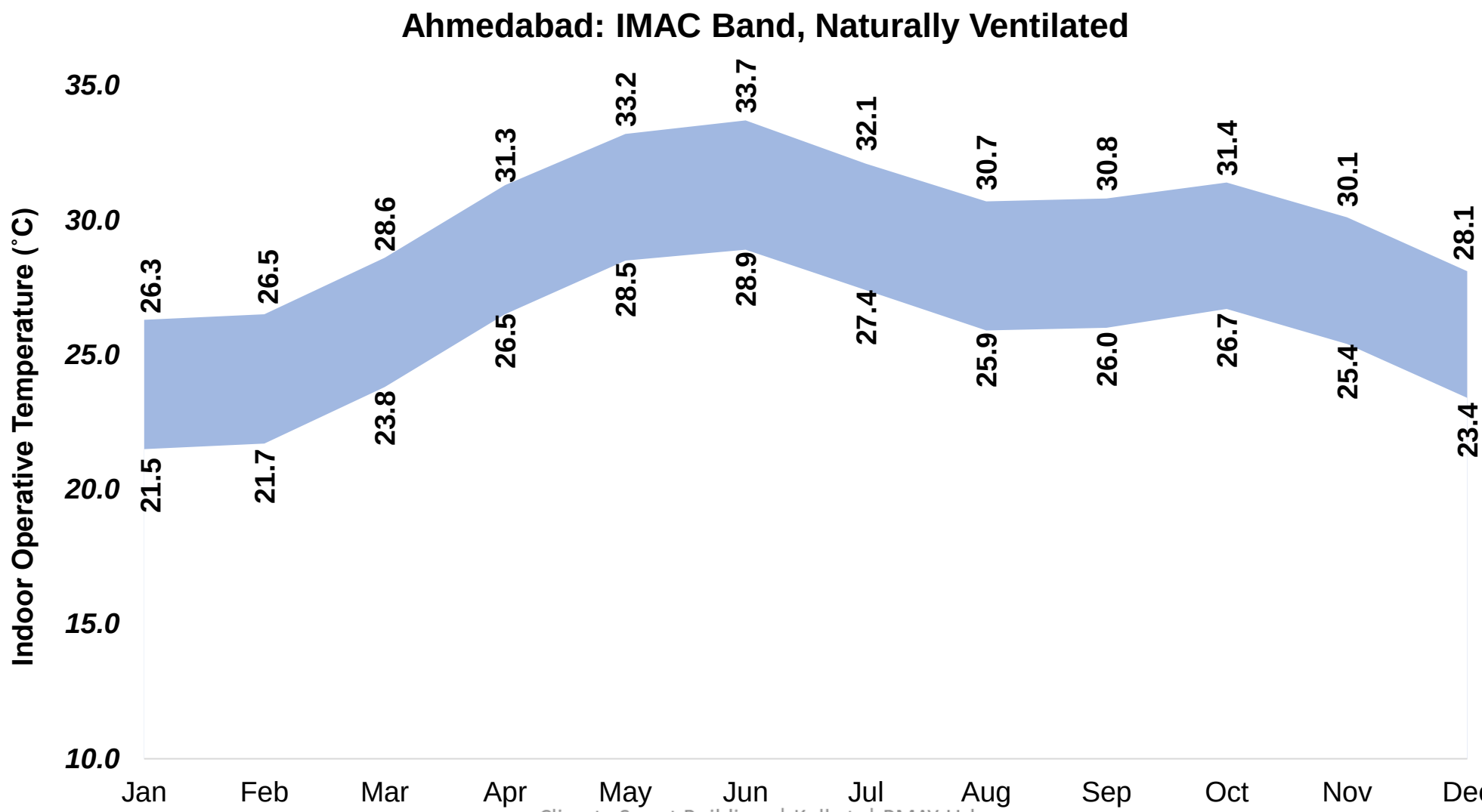
Standard of adaptive thermal comfort based on Indian specific model guideline (currently for office / commercial buildings)

Applicable for air conditioned, naturally ventilated and mixed-mode buildings

Includes the wide temperature ranges in all Indian climate zones

Shows 90% and 80% acceptability bands

Hot & Dry Climate



Composite Climate

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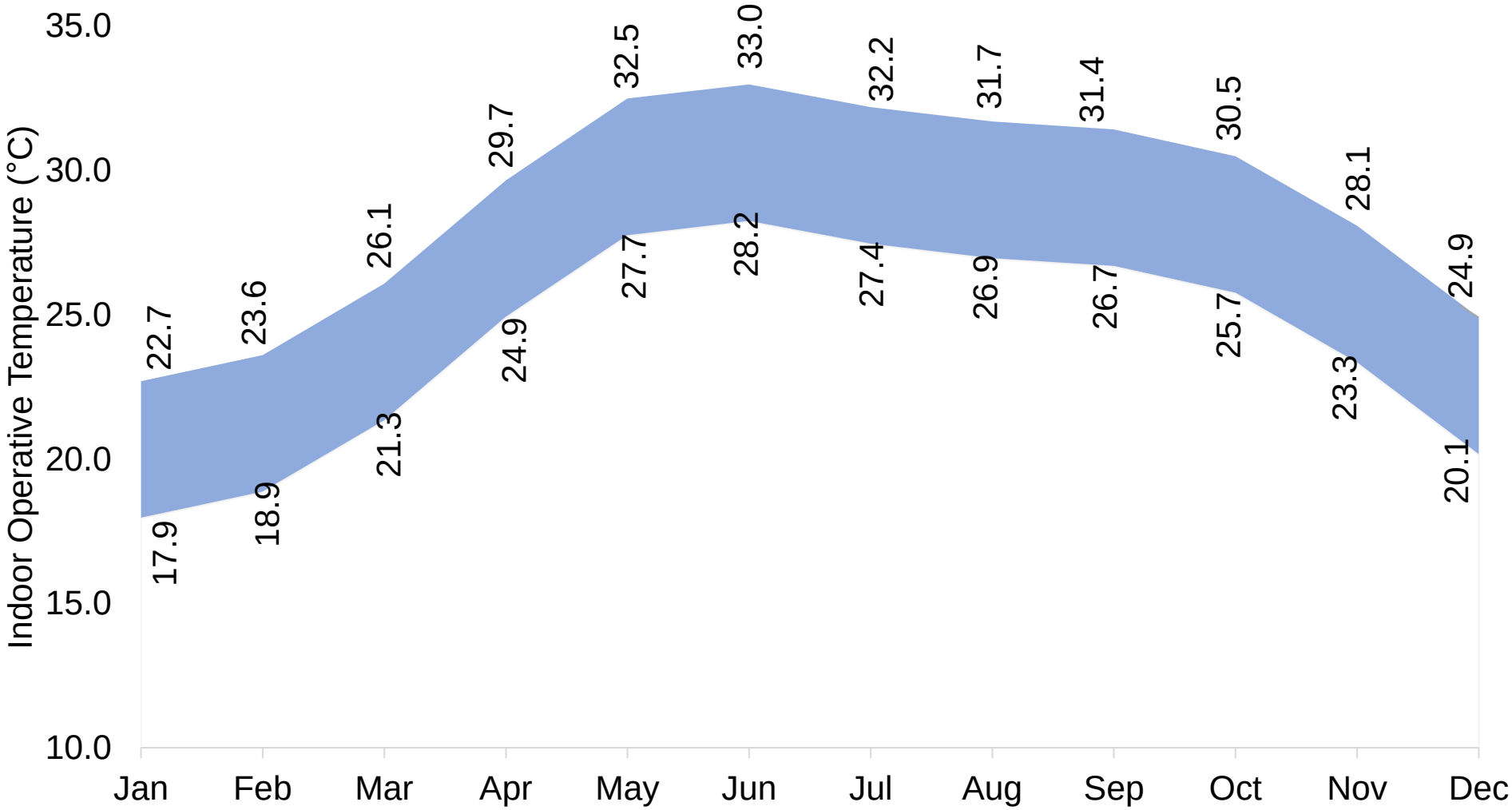
Delhi: IMAC Band, Naturally Ventilated



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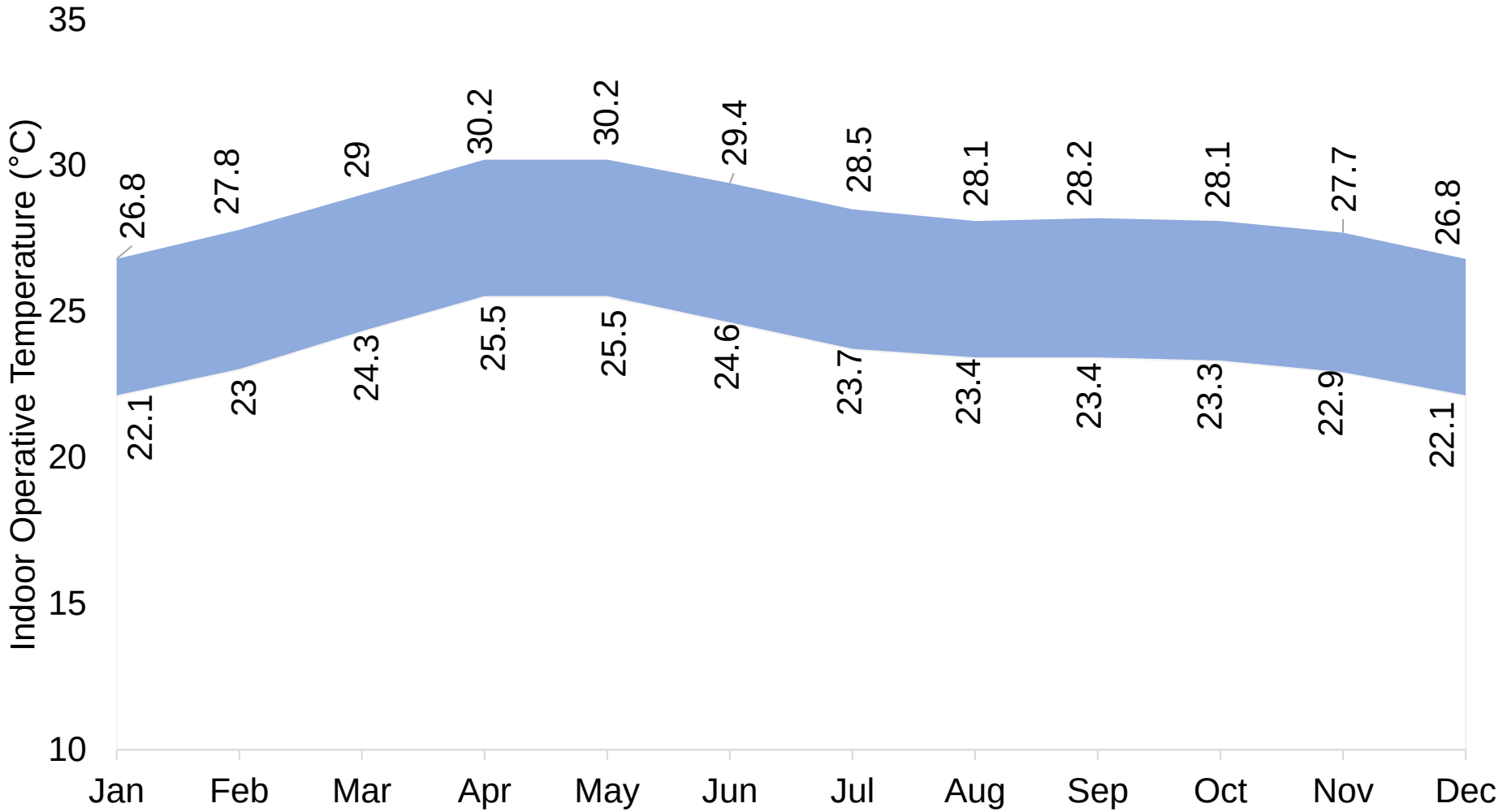
Temperate Climate

Bangalore: IMAC Band, Naturally Ventilated



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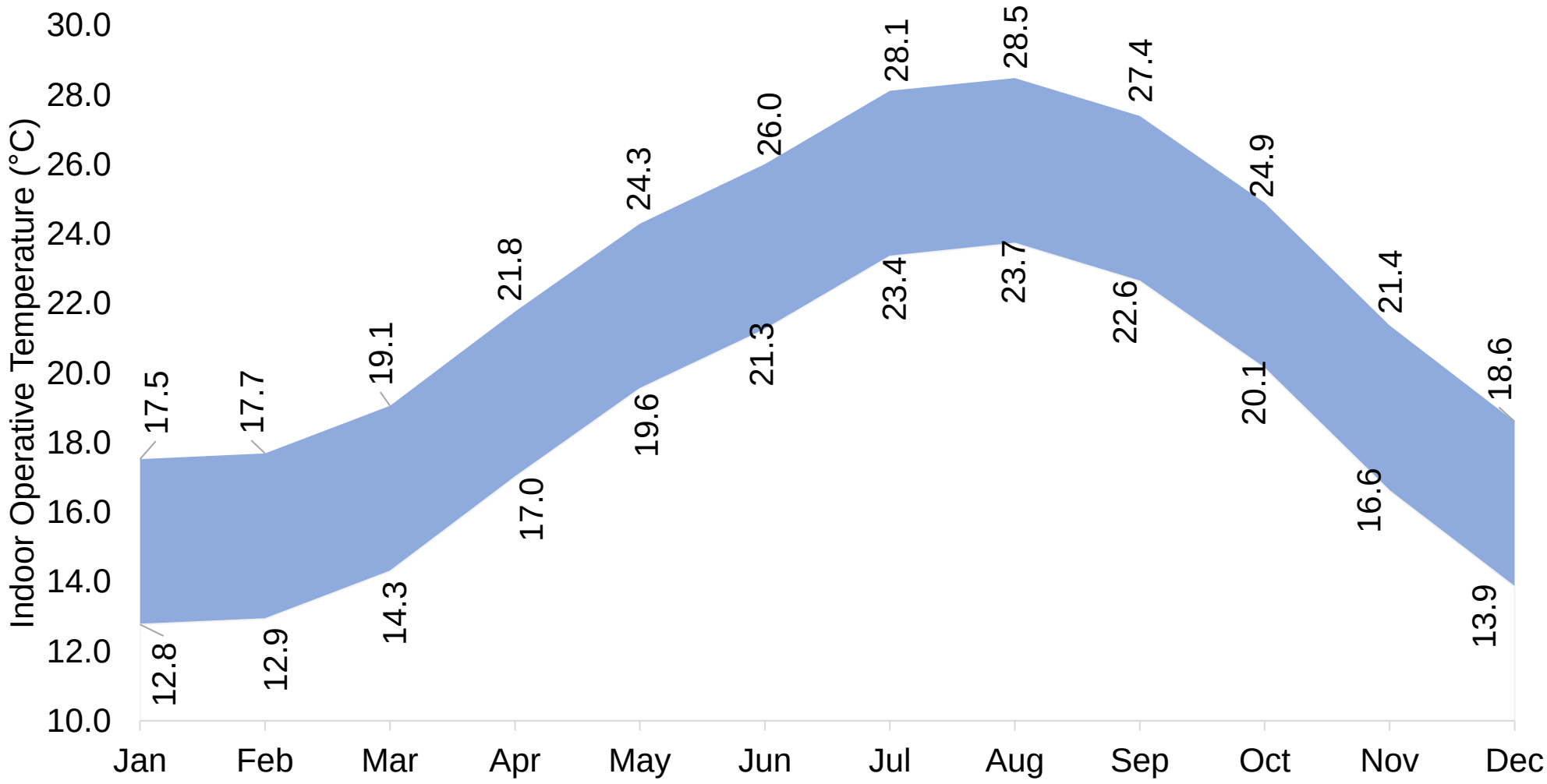
Cold Climate

Srinagar: IMAC Band, Naturally Ventilated



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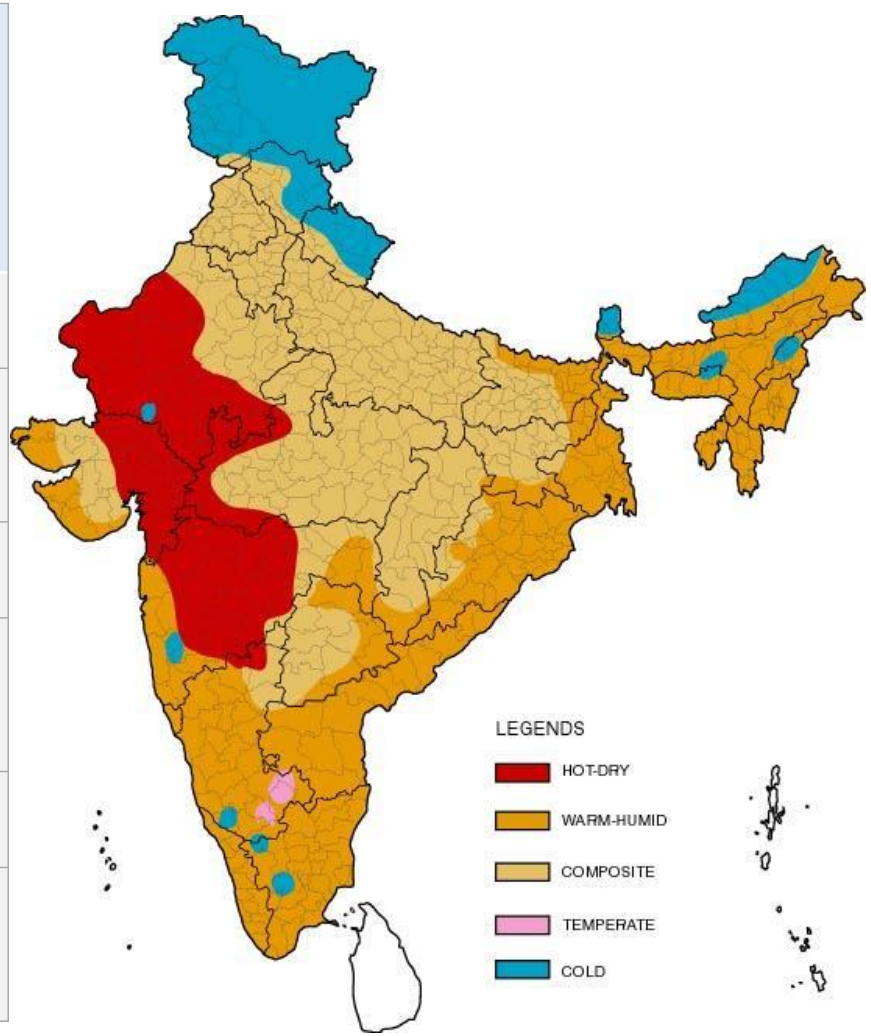
Indian Climatic Zones

Sr. No.	Climatic Zone	Mean Monthly Temperature (°C)	Relative Humidity (%)
i)	Hot-Dry	above 30	below 55
ii)	Warm-Humid	above 30	above 55
		above 25	above 75
iii)	Temperate	between 25-30	below 75
iv)	Cold	below 25	All values
v)	Composite	Not following any of the above	



Composite & Hot-dry, Warm-humid, Temperate:

- Cooling dominated climates, and responsible for fast growth in air-conditioning electricity requirement;
- accounts for >96% of the population and new construction

Cold:

- Heating dominated climate

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Passive Strategies for CSB

ORIENTATION:

- Buildings can be orientated in relation to the prevailing wind direction at angles ranging from 0° to 30°.
- In buildings with a courtyard, positioning the courtyard 45 degrees from the prevailing wind maximises wind flow into the courtyard and improves cross ventilation in the building (in climates where cooling is required).

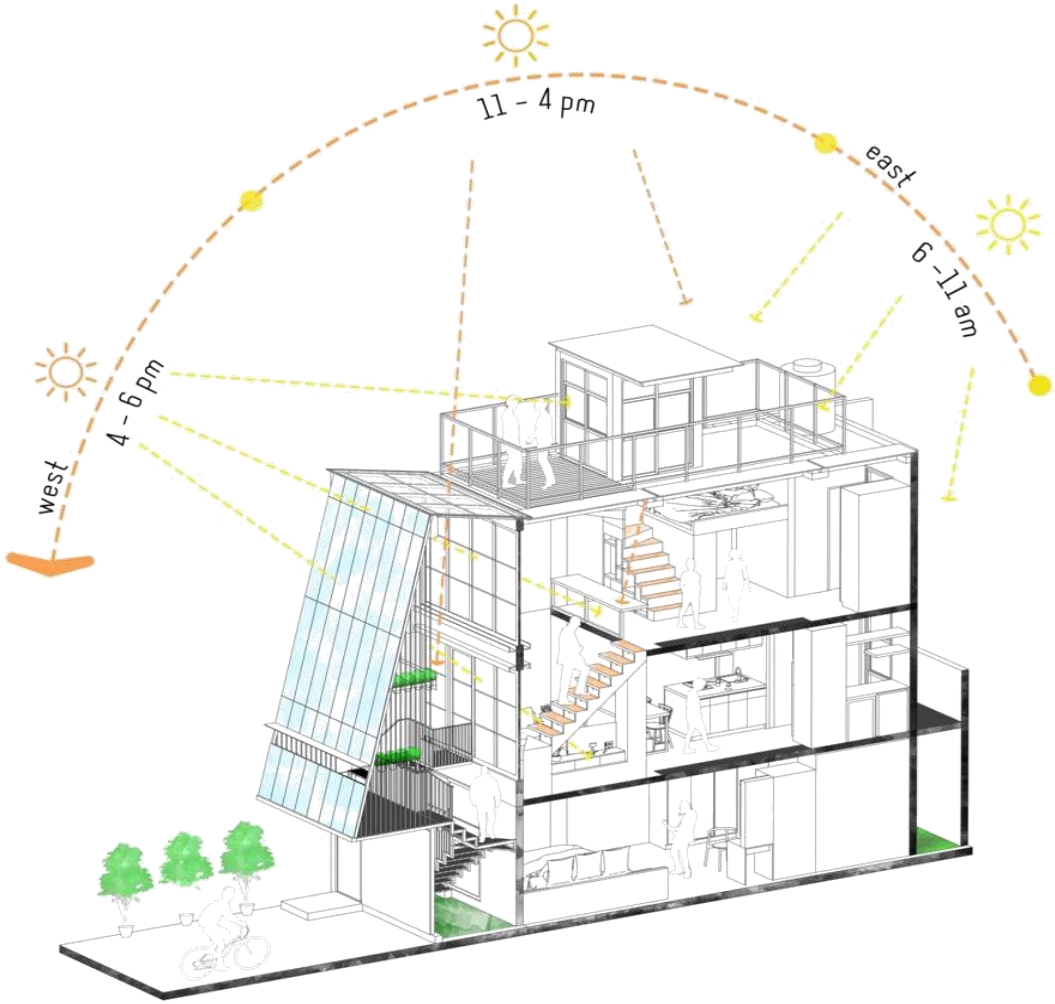
CREATING PRESSURE DIFFERENCES:

- A 'squeeze point' occurs when wind enters through a smaller opening and escapes through a larger opening. This generates a natural vacuum, which speeds up the wind.
- The total area of apertures should be at least 30% of the total floor space.
- The window-to-wall-ratio (WWR) should not exceed 60%.

VENTILATION

Passive Strategies for CSB : Orientation

- **Sun radiation** causes heat uptake and loss in a building and are affected by changes in solar route as per Cardinal directions.
- Buildings on Northern hemisphere are oriented differently than those at Southern hemisphere.
- If planned and situated on the East and, especially, the West end of the structure, non-habitable rooms (stores, bathrooms, etc.) can act as efficient thermal barriers.



HEATING / COOLING

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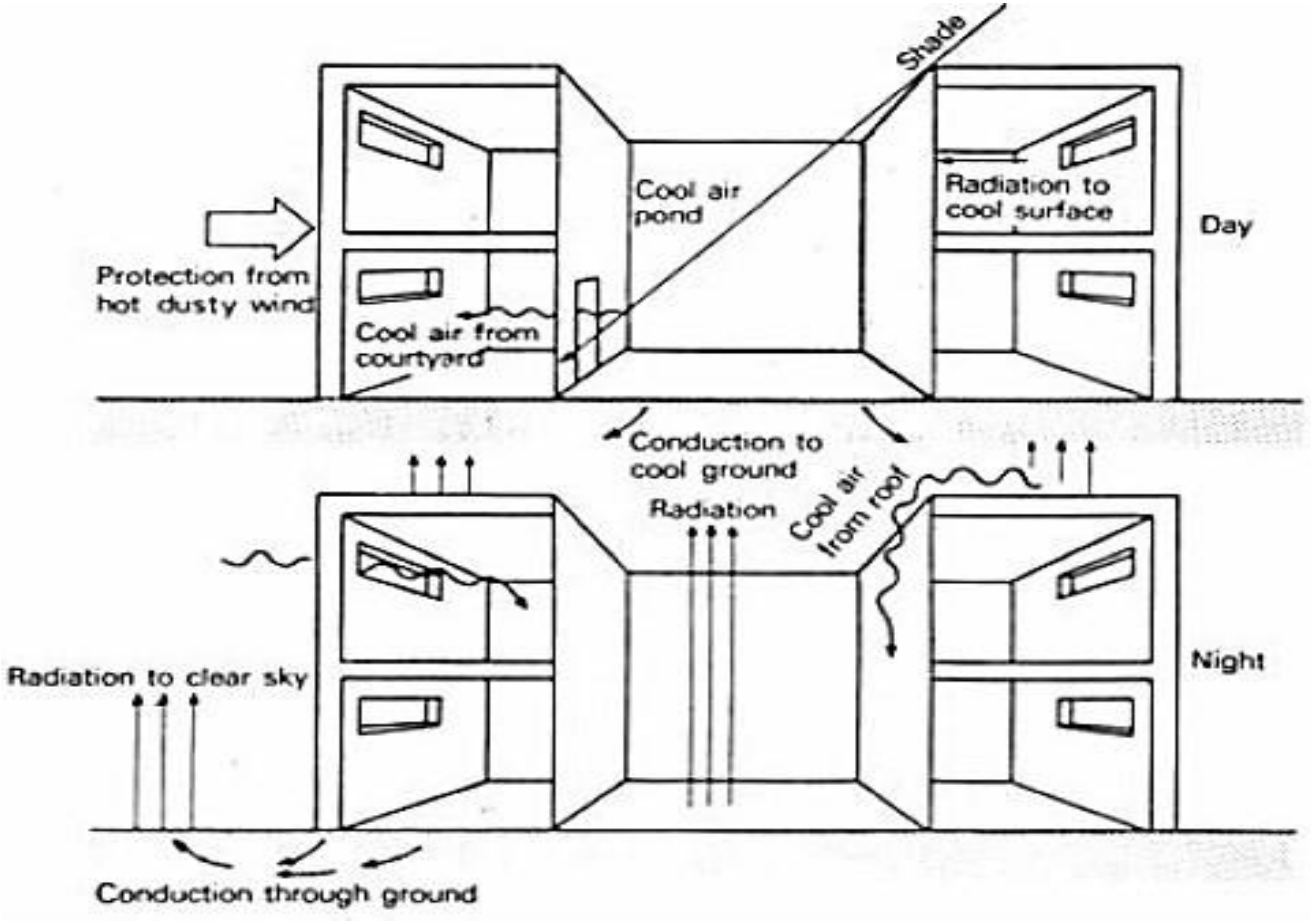
Passive Strategies for CSB : Forms and Orientation

- High walls block the sun, resulting in significant portions of the inner surfaces and courtyard floor being shaded during the day.
- Night cooling is effected through Re-radiation of heat from the exposed surfaces in and around the form.



HEATING / COOLING

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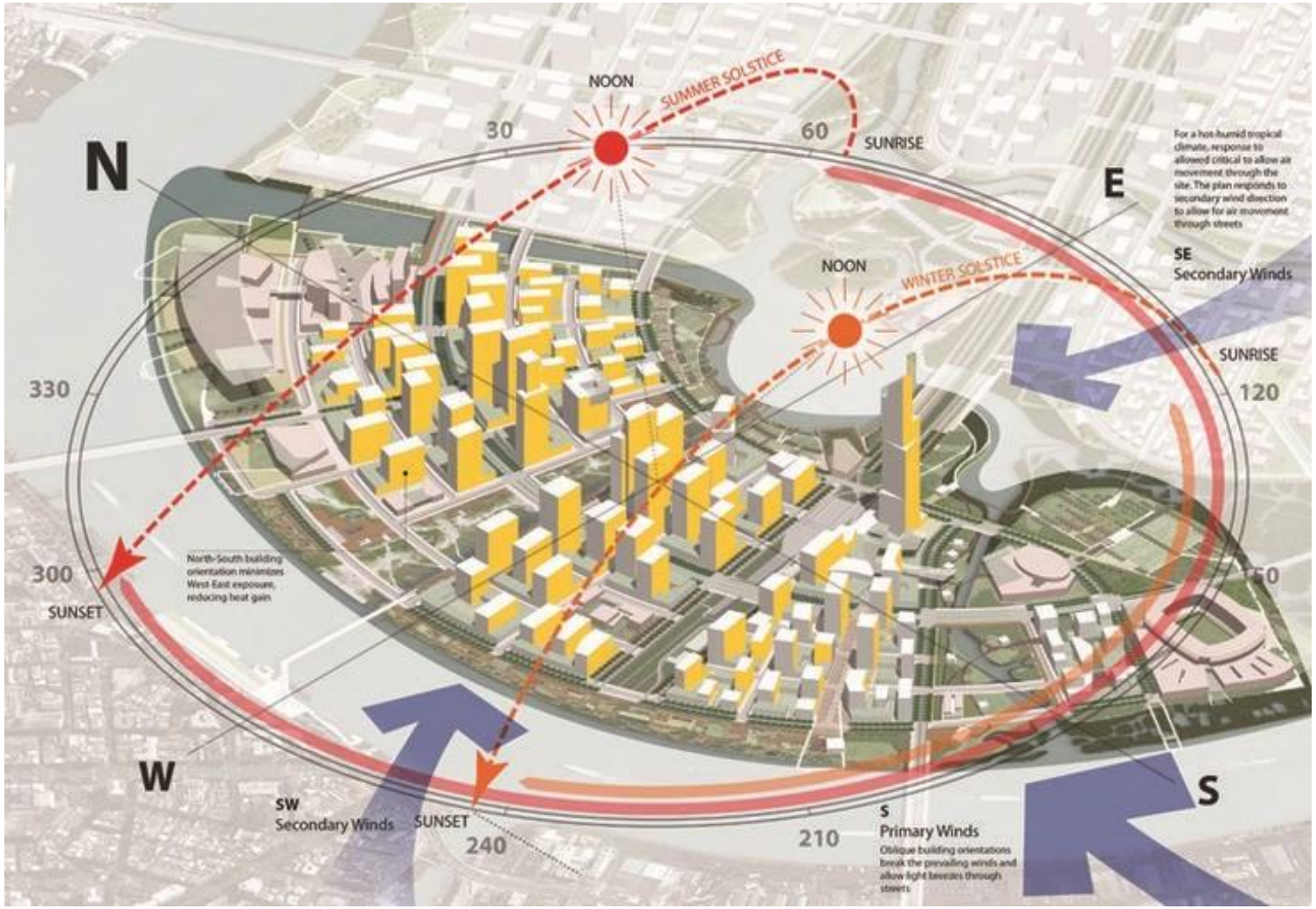
Passive Strategies for CSB : Site Level

Heat Island effect reduction strategies

- Choice of appropriate colour
- Taking advantage of block mutual shading
- Using site massing to create wind passageways
- Reducing the area of hard paving to allow for water absorption
- Using complementary vegetation to manage the amount of sunlight that gets through as the seasons change



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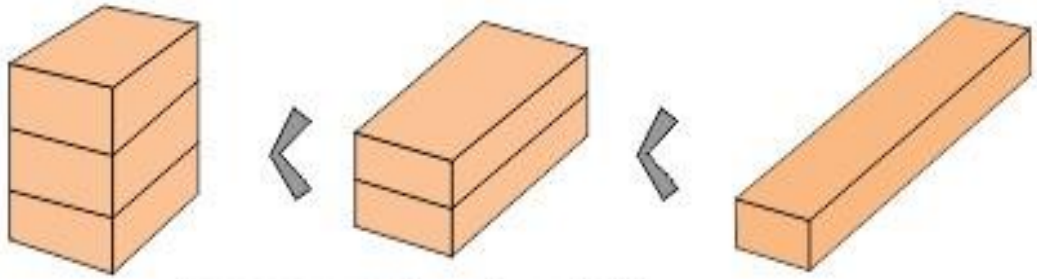
Passive Strategies for CSB : Surface Area, Volume, Perimeter

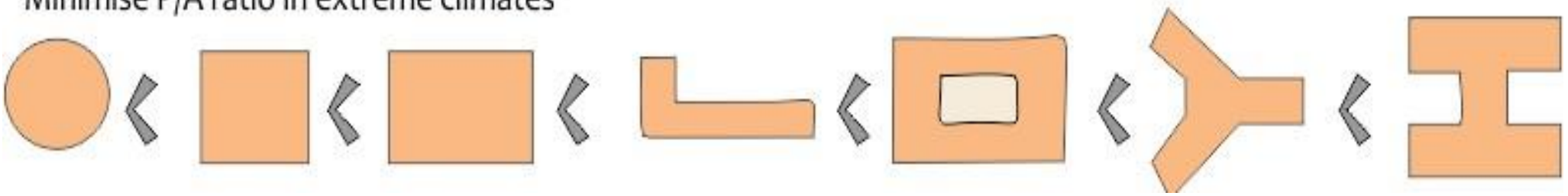
HEATING/COOLING

Minimise S/V ratio in extreme climates



increase compactness by reducing surface area for the same volume

Minimise P/A ratio in extreme climates



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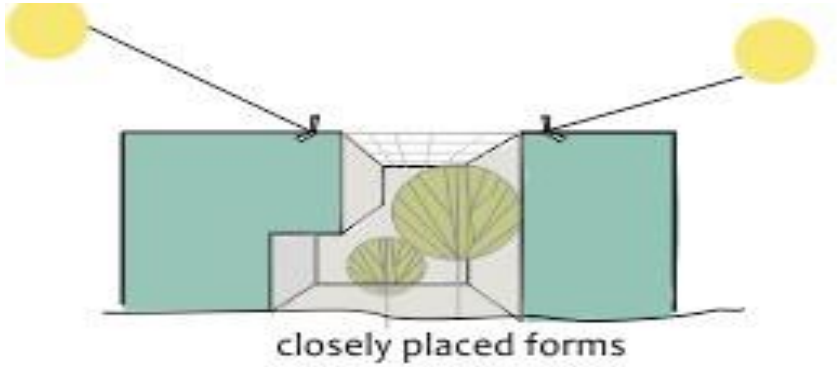
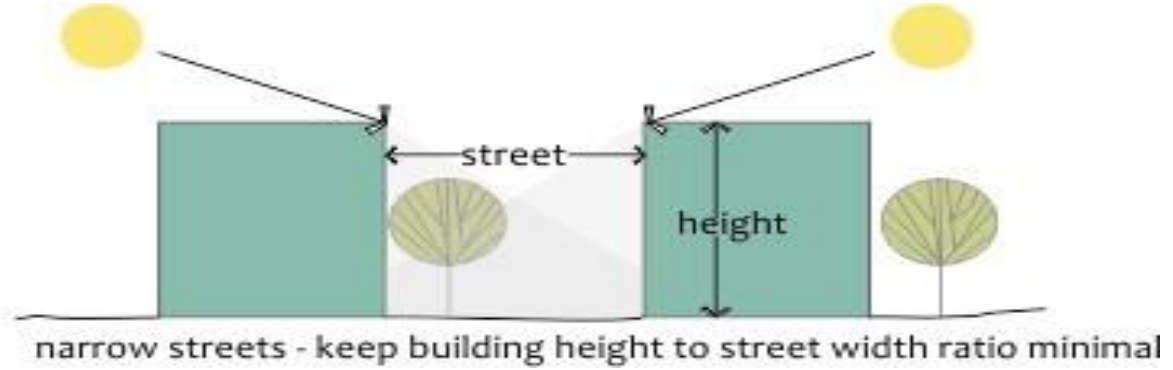
Passive Strategies for CSB : Mutual Shading at Block Level

Arrange the blocks so that mutual shade is obtained, avoiding solar heat build up throughout the summer.

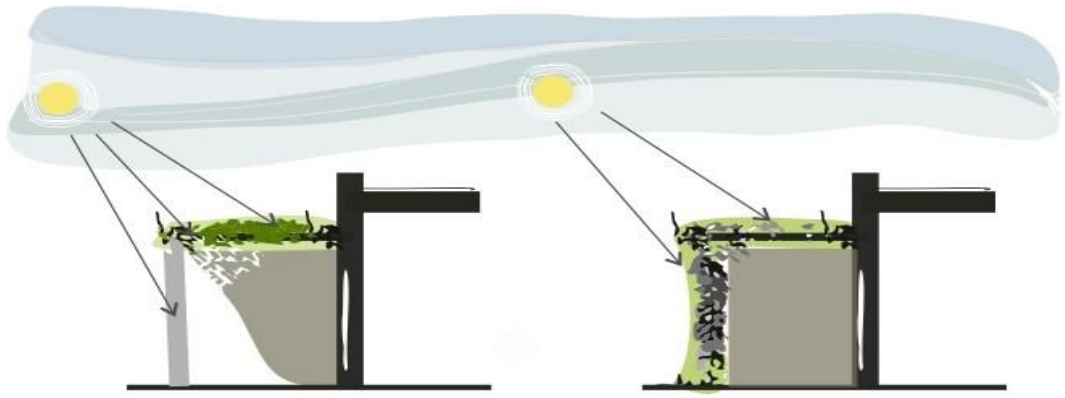


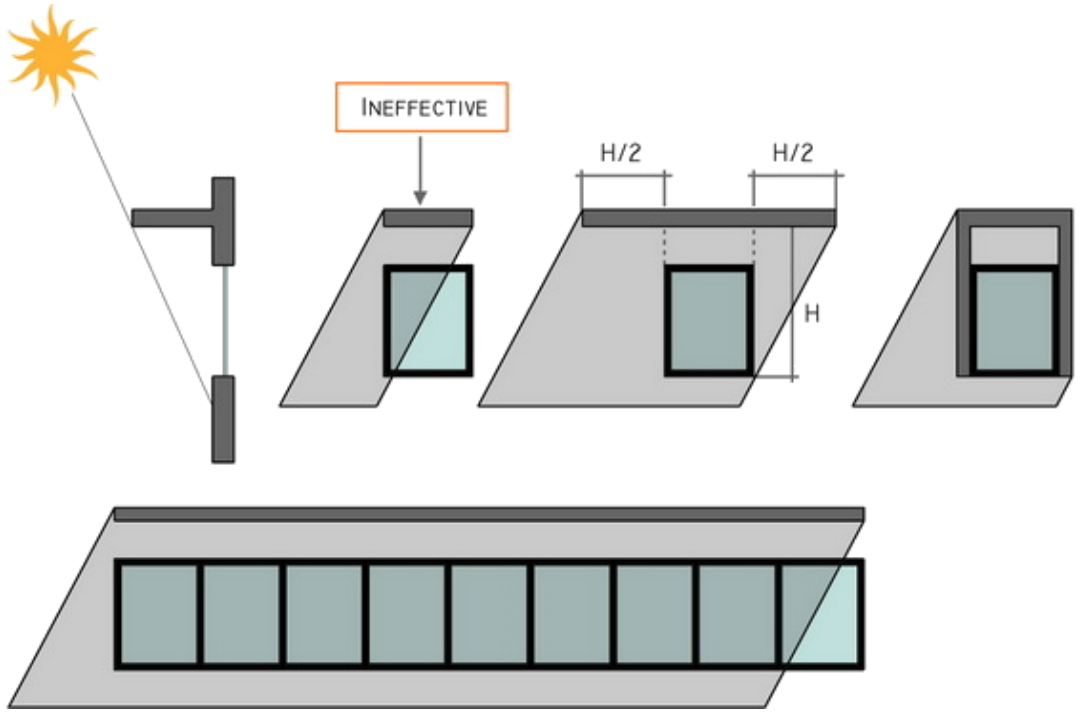


HEATING/COOLING

Passive Strategies for CSB : Shading

- Different creepers, can be used effectively for Shading purpose.
- Fenestrations with designed chajjas can block / allow Solar radiation as per Orientation.



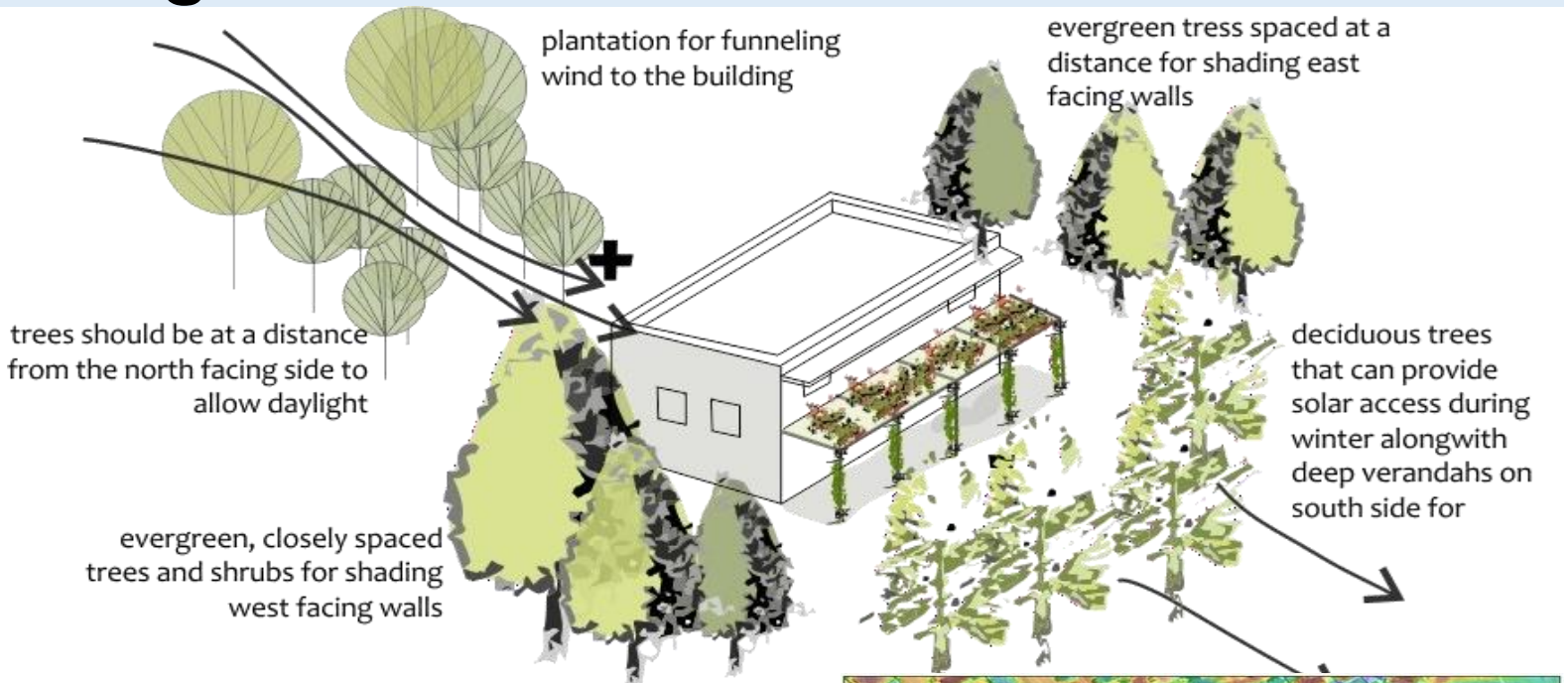


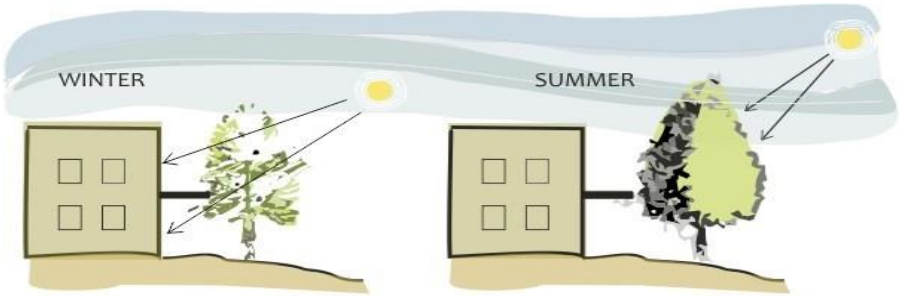
HEATING / COOLING

Passive Strategies for CSB : Tree Plantation

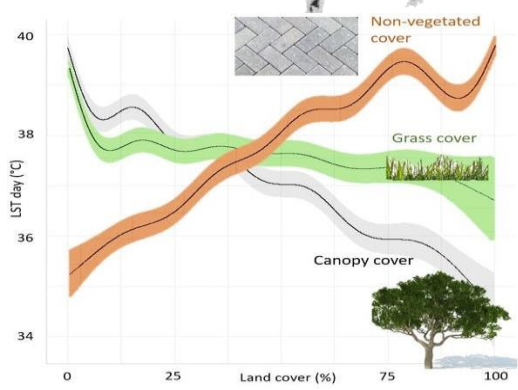
Planting trees in the appropriate position can provide Shade and Cooling effect.

It has been observed that the temperature may be reduced up to 6°C.

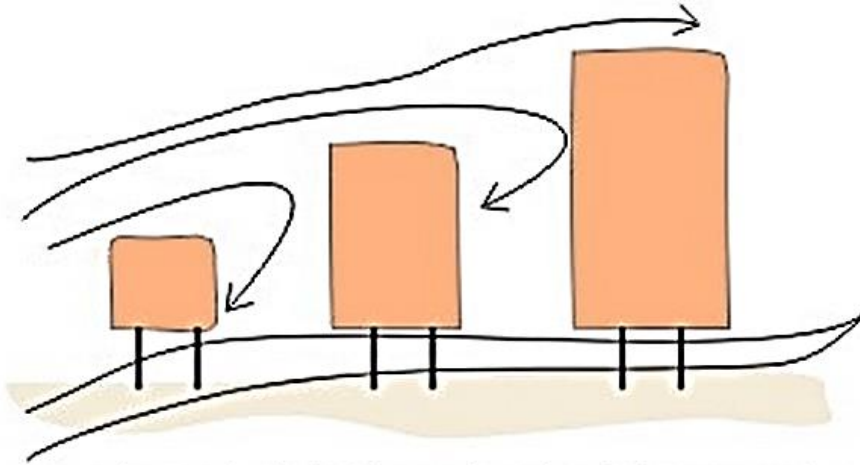




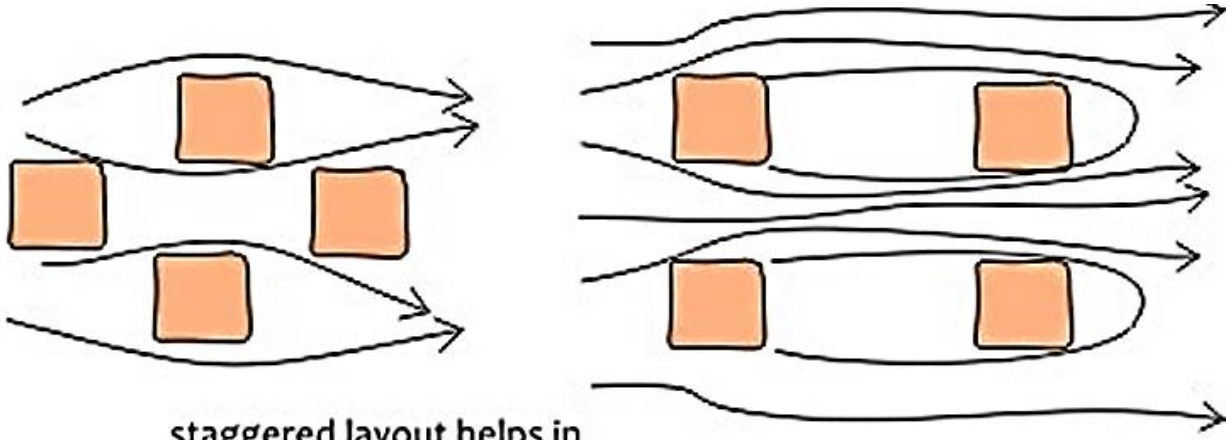
deciduous trees allow sun penetration in winter and block sun access during summer



Passive Strategies for CSB : Wind movement



if a site has multiple buildings, they should be arranged in ascending order of their heights and be built on stilts to allow ventilation



staggered layout helps in accentuating wind movement

WIND

Passive Measures – Vernacular Architecture

Vernacular typologies respond to the region's distinct environment are exemplified.

- In Ladakh, earth architecture with thick walls and limited windows provides optimal insulation.

- In Rajasthan, courtyard havelis take advantage of pressure differences and reciprocal shading to provide natural cooling and ventilation.

- In Kerala, sloping roofs are used to guard against severe rains.

CASE STUDY 1

Performance of naturally ventilated buildings in a warm-humid climate : a case study of Golconde Dormitories in South India

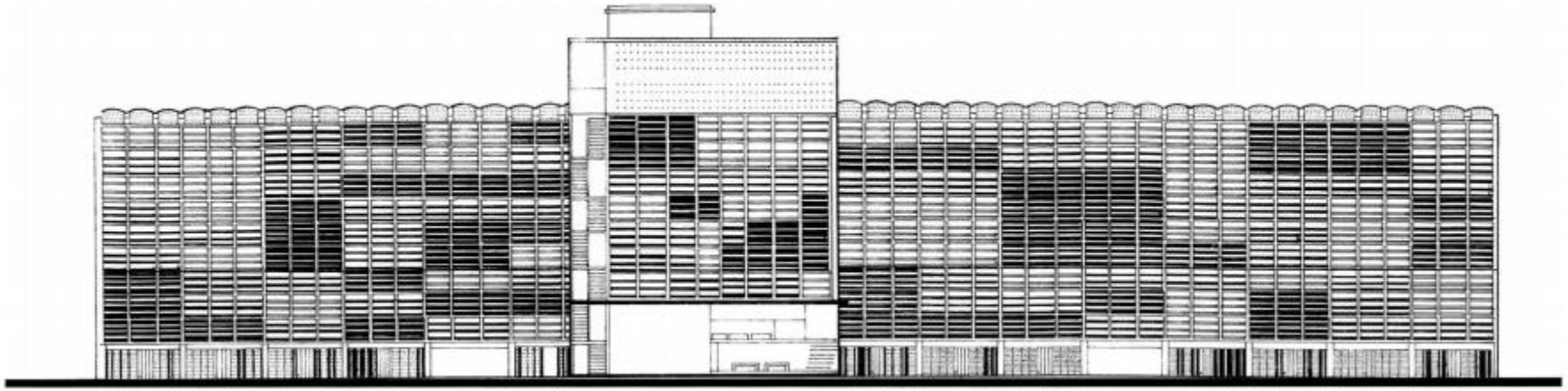
The Trainer would like to express his sincere gratitude to Ms.Mona Doctor – Pingel, the Corresponding Author of the above titled paper, published in Architectural Science Review (2017) , 60:3, 205-214 for her kind consent to use the salient features in this Training.

Golconde Dormitories of Shri Aurobindo Ashram was built eight decades ago and was first modern reinforced concrete building in India.

The building is in an urban setting within the old city precinct in Pondicherry, India (11N, 80E).

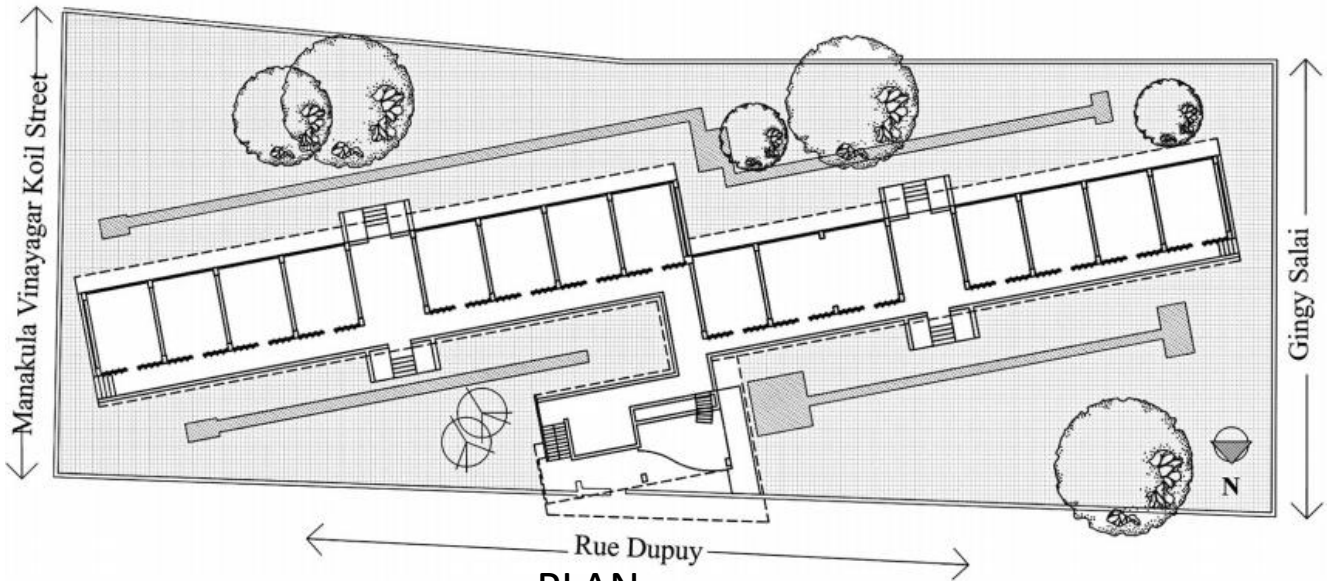
Features of the Golconde Building

- The temperature in Pondicherry ranges from about 16–40°C throughout the year, with temperatures above 28°C most of the year. The pre-monsoon (July–September) is seen with high humidity and occasional thunder showers and the North-East Monsoon(October – December) season tends to have higher temperatures (averaging 30°C.
- By using various passive strategies, this building has been designed eight decades ago to ensure thermal comfort without the use of mechanical ventilation or cooling system.
- It has 51 rooms across 3 floors and a semi-basement. The framed reinforced cement concrete (RCC) structure has been left un-plastered, while the walls which are made of burnt brick (210 × 100 × 55 mm) have a special ‘Chettinad’ lime plaster, which is still in its original state. The East and West walls contain little or no openings to reduce the solar heat gain. The floor is made of polished black Cuddapah stones of 63.5 × 63.5 cm with 5 mm butt joints. The ventilated double roof consists of an RCC slab covered with precast concrete shell and a ventilated air gap of about 10–30 cm in between.
- A simple landscaping strategy to transform the indoor and the surrounding environmental conditions were planned by the Architects, which are delivering the intended results till date.



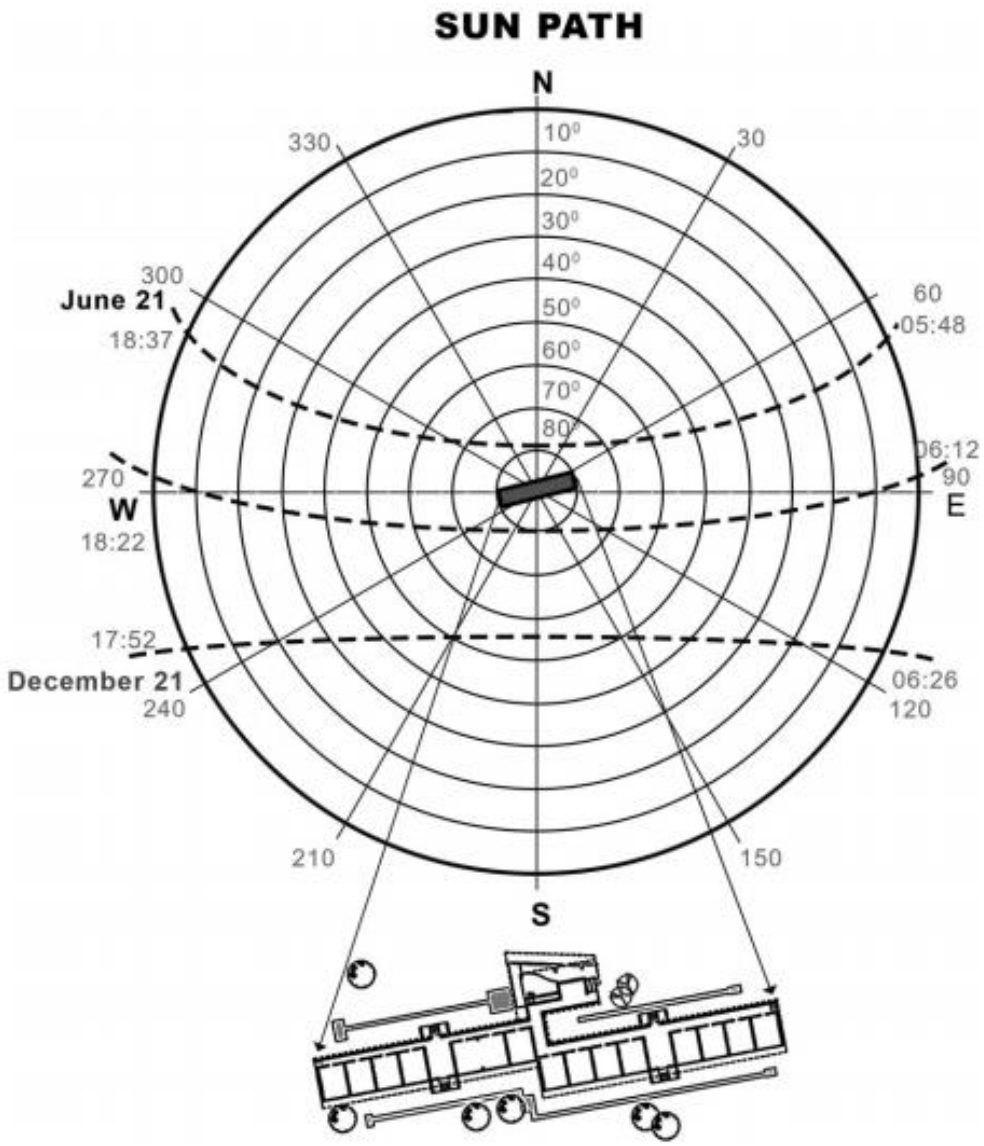
NORTH SIDE ELEVATION

The building is oriented with its longer axis facing North-South, with a tilt of 20oE,S. This is done as Pondicherry lies on latitude 11 degrees North, thus ensuring alignment with ideal East-West Cardinal axis facing due North and South.



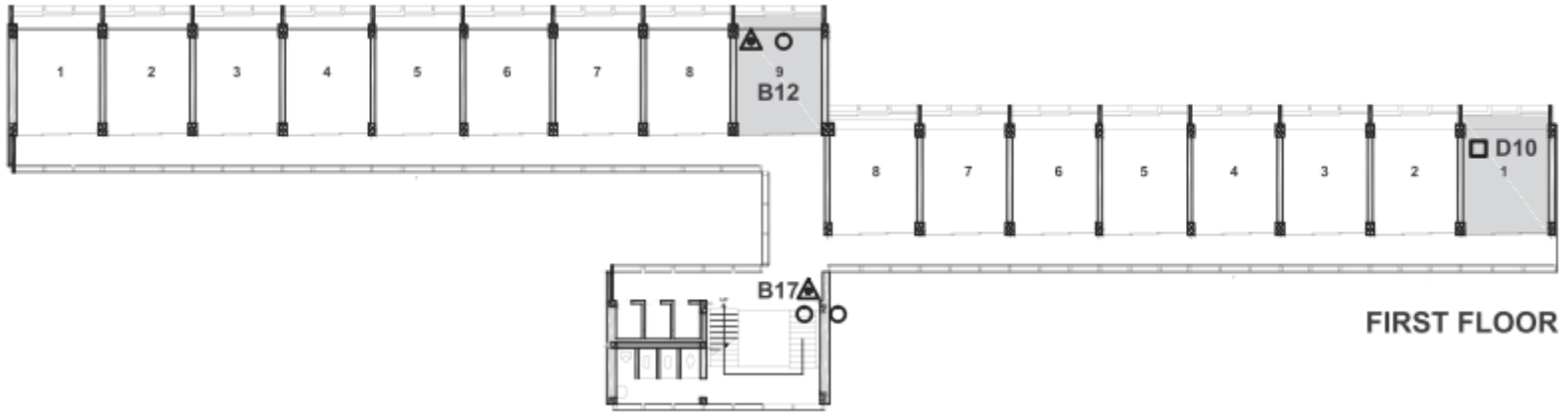
PLAN

Dr. Avijit Ghosh 2015-2022



The Orientation minimizes the Solar exposure on the East and West side where the Sun is the Lowest.

Both the North and South facades are equipped with individually operating horizontal asbestos cement louvres which provide protection from the Sun, Wind and Rain, while allowing for Ventilation, ensuring the best combination between natural daylight and solar heat gain. Since it is an occupied building, the louvres are manually operated as per the user's needs, mostly being closed during the day and open during the night. Access to the rooms is through a continuous corridor along the Northern side of the building which also acts as a thermal buffer to the internal spaces. Rooms are separated from the corridor by teak wood sliding doors with staggered slots which enhance the thermal performance.



Influence of Landscaping

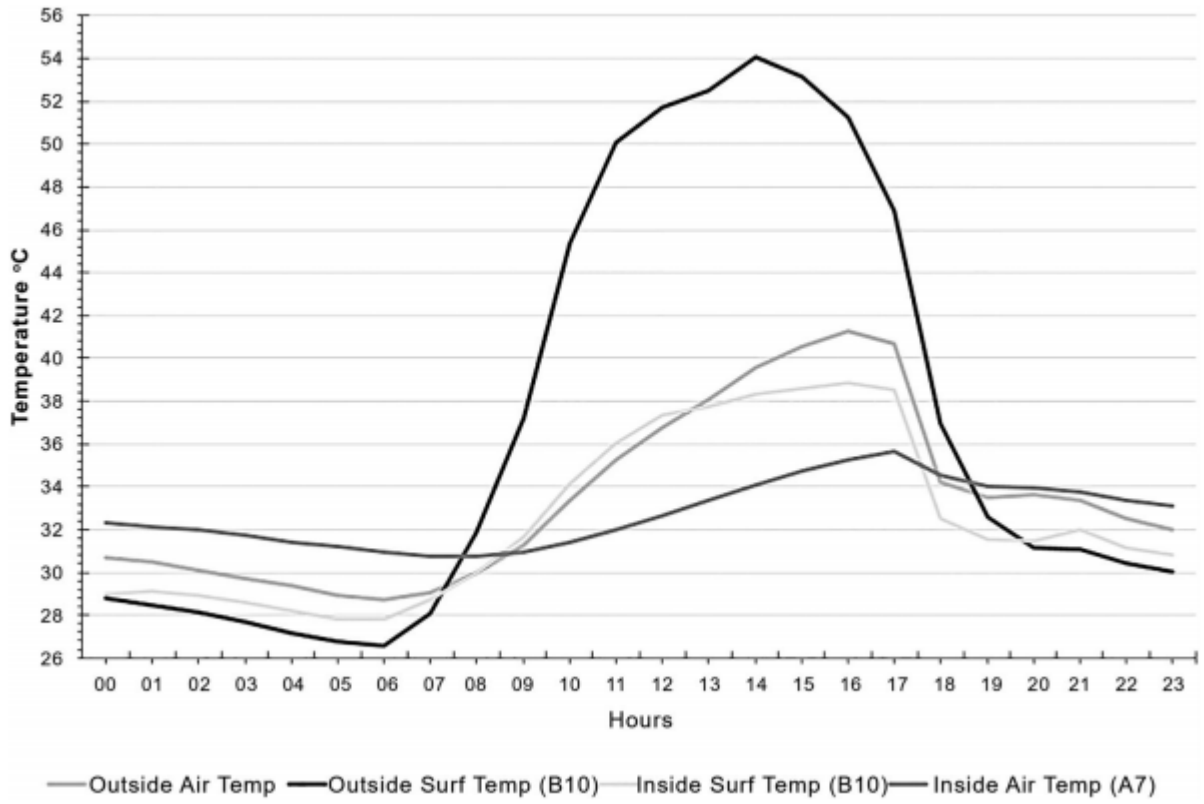
The North garden has been deliberately designed with sparse vegetation, resulting in lighter and dryer air while the South garden has more dense foliage with large tree cover. These tropical evergreen trees of the South garden increase natural shading of the building façade, making the air more dense and moist.

North Garden

These gardens are essential to reduce the radiation reflected from the ground (albedo) and prevent hot air from penetrating the building.

South Garden

Ventilated double roof



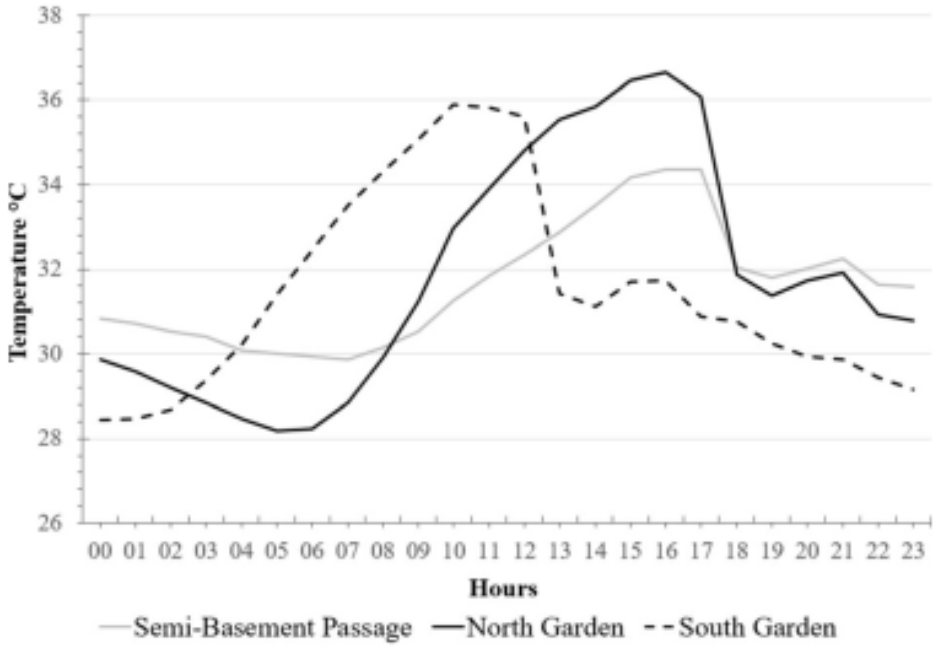
Golconde's unique ventilated double roof consists of a RCC slab covered with precast concrete shells with an air gap of 10–30 cm in between. The efficiency of this ventilated roof allows a reduction by 18°C between the outside and inside surface temperature, occurring under warm and radiant conditions.

Dr. Arijit Ghosh 20-5-2022

Cool Areas

North Corridor

Garden and Semi Basement Passage



Air temperature in Garden and Semi Basement

Conclusion : **Golconde has an effective passive and natural control system which is found responsible for providing a comfortable thermal environment indoors, during the Summer.**

CASE STUDY 2

Dr. Avijit Ghosh 20-5-2022

Thermal comfort perception in naturally ventilated affordable housing

Background

- The coastal city of Mumbai spread across 603 square kilometres is located in the south western part of India. The city falls within warm–humid climate according to NBC. Mumbai has three distinct seasons: Monsoon, Winter and Summer and experiences an average annual temperature of 27.2°C and average annual precipitation of 245.7 cm.

- Two Government-provided affordable housing - a slum rehabilitation housing and an institutional staff housing, situated in administrative ward M and ward S, respectively, were selected as the field study locations. More than half of the population of selected wards M and S consist of low-income people and thus these wards are representative of the city's low-income population

Citation of this article : Jeetika Mullick and Ronita Bardhan, Thermal comfort perception in naturally ventilated affordable housing of India, Advances in Building Energy Research(2021), https://doi.org/10.1080/17512549.2021.1907224

Ward M

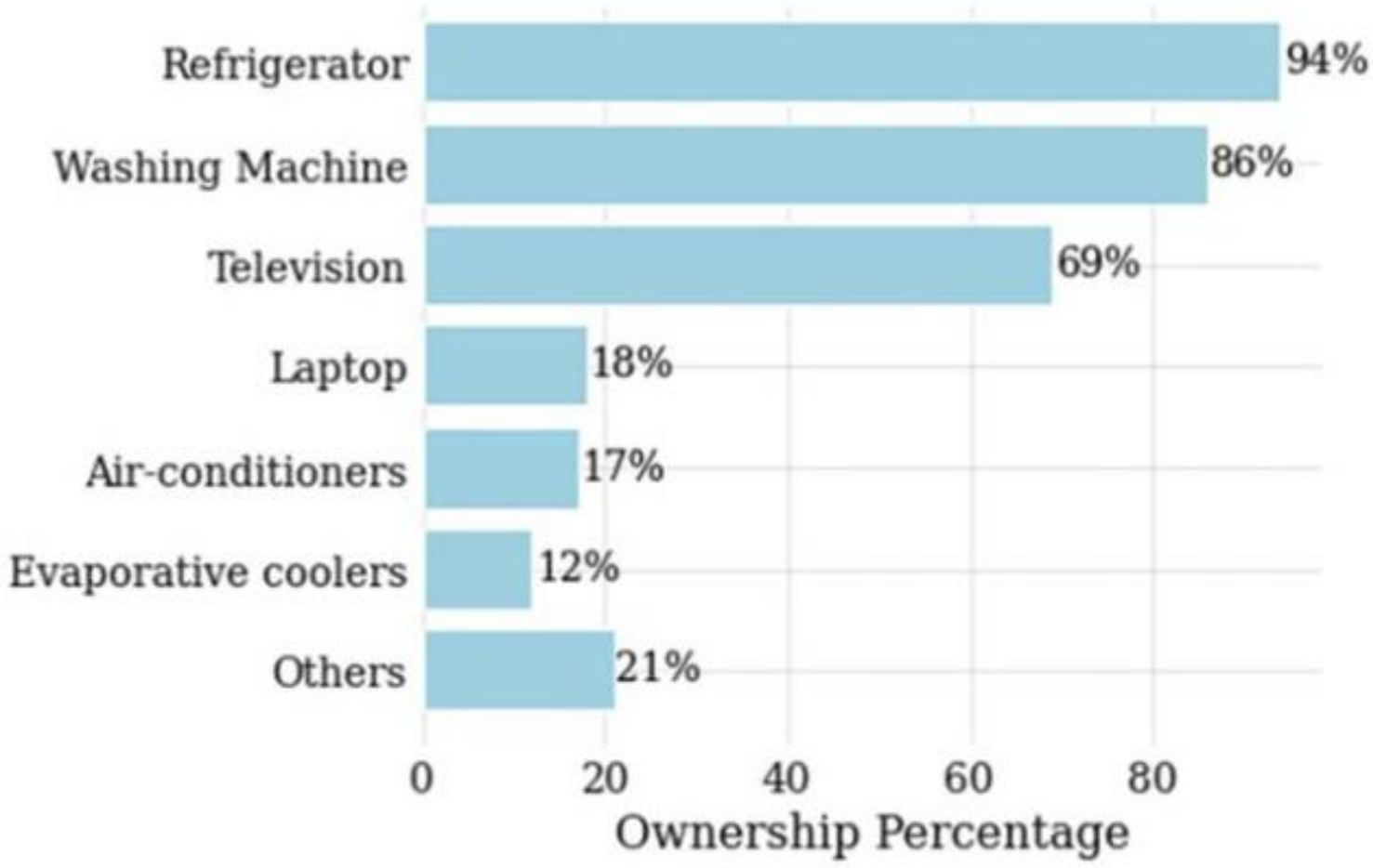
Ward S

Building Features	Ward M Buildings	Ward S Buildings
No. of Floors	G+7	3 Storied
Unit Area (Sq.M)	22	26
External Walls	Fired Bricks	Fired Bricks
Roof	Un-insulated RCC	Un-insulated RCC
Floor	Un-insulated RCC	Un-insulated RCC
Windows	UPVC frame with single glazed clear glass panel	Wooden frame with clear glass panel and mild steel grill

Occupant Survey sample size distribution w.r.t. Season, Gender and Time of the day

Description		Total		Phase I Monsoon		Phase II Winter		Phase III Summer	
		N=705		N=277		N=253		N=175	
		Sample Size	Percent	Sample Size	Percent	Sample Size	Percent	Sample Size	Percent
Gender	Female	537	76	215	78	196	77	126	72
	Male	168	23	62	22	57	23	49	28
Time slots	Morning	120	17	37	13	45	18	38	22
	Afternoon	288	41	105	38	97	38	86	49
	Evening	297	42	135	49	111	44	51	29

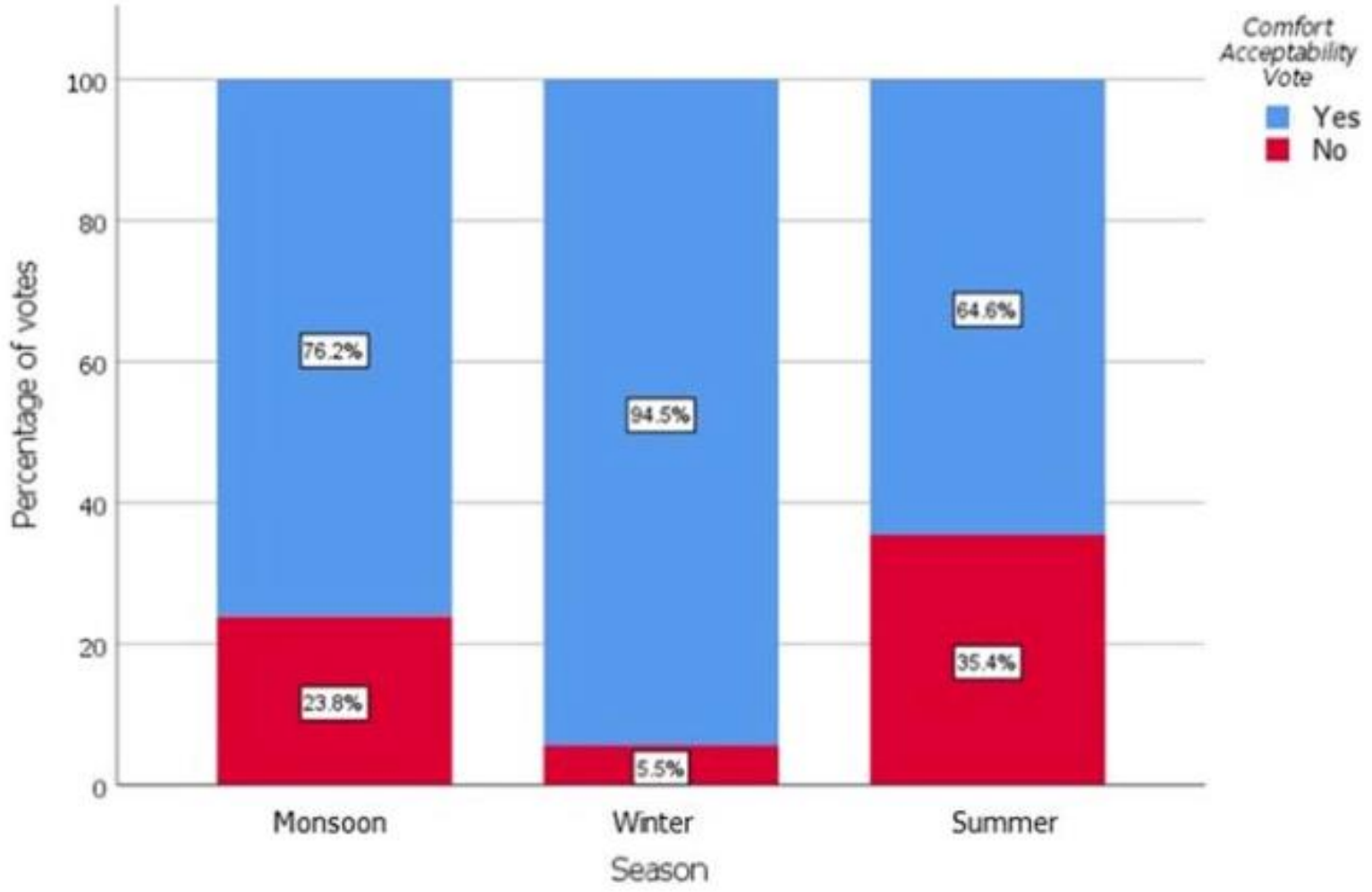
Appliance ownership percentage



Recorded Inside Outside Environmental data

Environmental Variable	Unit	Season 1 : Monsoon			Season 2 : Winter			Season 3 : Summer		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Daily Mean Outdoor Temperature, T_{out}	Deg.C	26.1	24.3	28.3	24.9	23.1	27.5	29.7	29.1	31.4
Daily Mean Outdoor Air relative Humidity, Rh_{out}	%	82.2	76.6	86.3	51.4	39.0	66.7	69.0	66.7	75.4
Air Temperature, T_{air}	Deg.C	28.4	27.0	30.5	27.0	24.2	30.6	31.2	28.1	34.2
Globe Temperature, T_g	Deg.C	28.5	26.9	30.5	27.4	24.8	30.8	31.8	29.4	33.8
Indoor Air Relative Humidity, Rh_{in}	%	78.0	61.3	87.4	50.8	26.6	70.3	62.9	54.2	79.0
Indoor Air Velocity, V_a	m/s	0.5	0.0	2.9	0.1	0.0	1.0	0.4	0.0	1.3
Ambient Carbon-di-oxide, CO_2	ppm	594	431	1522	664	457	1494	575	447	1005

Seasonal distribution of CA votes



Comfort Acceptability (CA) was prepared with the assimilation of Thermal Sensation Vote (TSV), Humidity Sensation Vote (HSV) and Air Sensation Vote (ASV). Fan assisted cooling only considered during the survey.

Study Report

A longitudinal field study was conducted in low-income affordable housing units during three seasons of Mumbai India. Two government-provided residential neighbourhoods operating in the free-running mode were investigated yielding 705 sets of thermal comfort data. The major findings drawn from this study are as follows:

(1) Most of the occupants reported comfortable on thermal, humidity and air movement sensation scales. Ninety per cent of TSV (Thermal Sensation Vote) were within the comfortable range, while HSV (Humidity Sensation Vote) and ASV (Air movement Sensation Vote) corresponding to comfortable conditions were 97% and 91%,respectively.Seventeen per cent of occupants experiencing neutral TSV preferred a cooler environment suggesting a natural desire for cooler environments.

(2) Eighty per cent of the participants reported an acceptable environment with a highest acceptability of 95% in the Winter season followed by the Monsoon and Summer season.

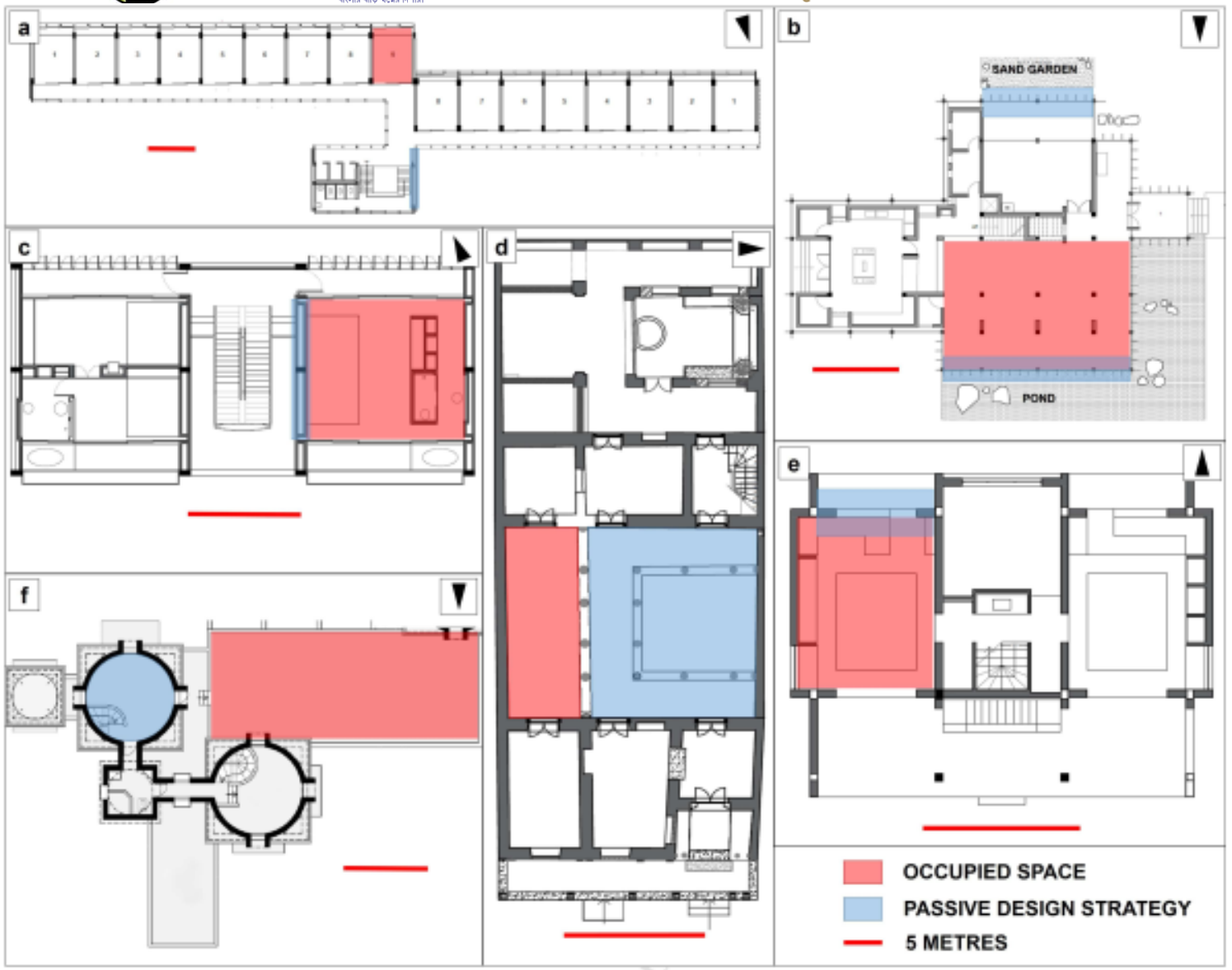
(3) Based on the linear regression analysis, a mean neutral temperature of 28.3°C was found with 80% of occupants voting comfortable within operative temperatures of 24.6–32.2°C.

Case Study 3

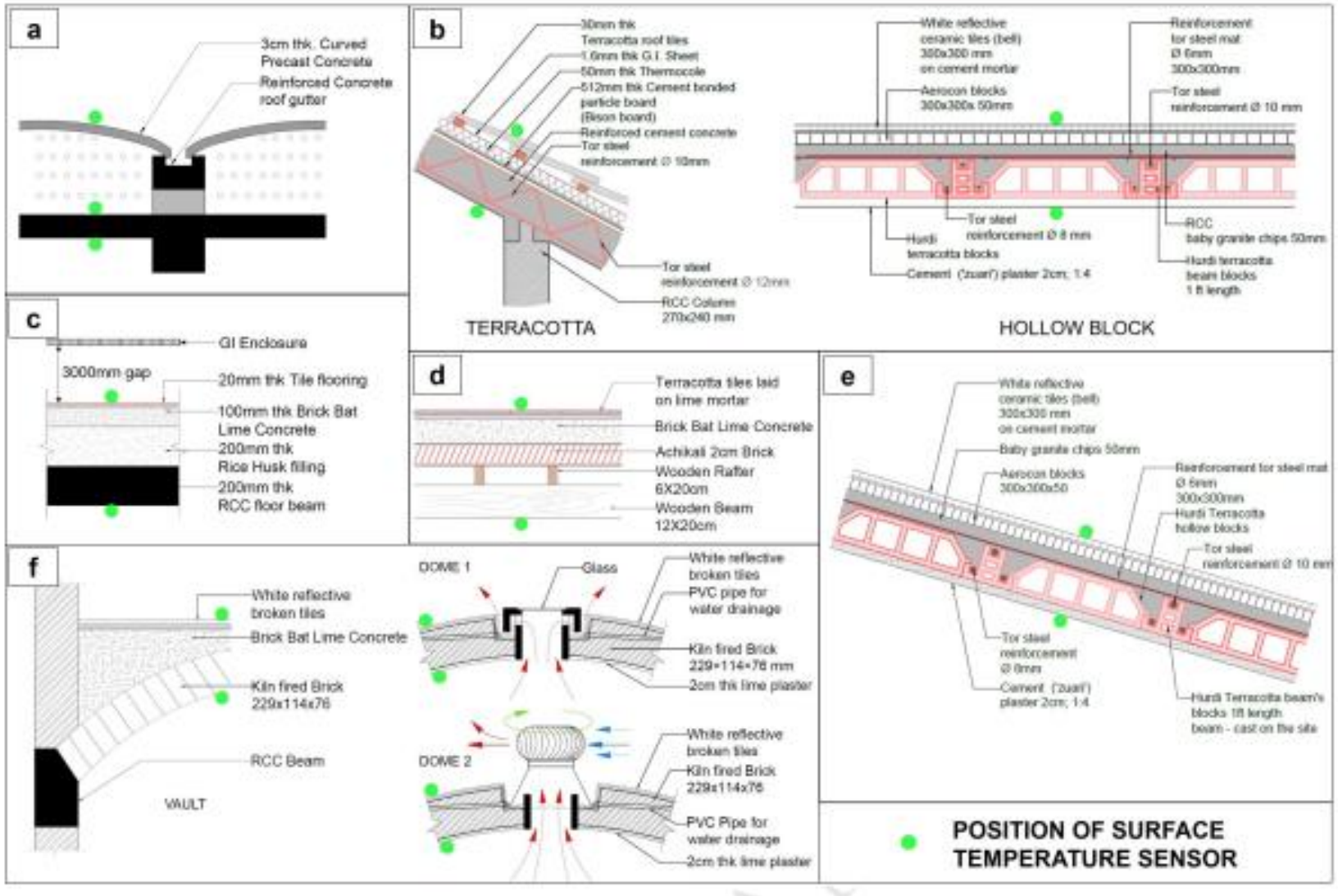
Six Naturally Ventilated Buildings in the vicinity of Aurovile were chosen on the basis of variety of functions, passive design strategies, and feasibility of monitoring. The design focus of all these buildings are Climate Responsiveness under Warm-Humid zone.

Citation of this article : Doctor-Pingel M, Vardhan V, Manu S, Brager G, Rawal R, A study of indoor thermal parameters for naturally ventilated occupied buildings in the warm-humid climate of southern India, *Building and Environment* (2019), doi: https://doi.org/10.1016/j.buildenv.2019.01.026

Buildings under study. (a) Golconde Dormitories. (b).Afsanah Guest House. (c). Luminosity Apartments. (d).INTACH Office. (e). Blessing House. (f). Mukuduvidu Residence.


a
b
SAND GARDEN
POND
c
d
e
f
OCCUPIED SPACE
PASSIVE DESIGN STRATEGY
5 METRES

Floor PLANs



Roof sections (a). Case1: Ventilated double roof. (b). Case2: Sloped terracotta and hollow block roofs. (c). Case3: Shaded, husk-insulated roof. (d). Case4: Traditional terracotta ‘Madras’ roof. (e). Case5: Sloped AAC block roof. (f). Case6: Lime plastered domes.

The six naturally ventilated buildings in the ‘warm and humid’ climate of Pondicherry and Auroville were monitored using long-term data loggers for a span of one year and analysed for Ta and RH across the most occupied zones, Ts across the roof and ceiling surfaces, and Ta/Ts across the passive design strategies . This study provided hourly averaged thermal readings for six tropical roofing strategies –

1. Ventilated double roof,
2. Terracotta cladded roof,
3. Hollow block roof with a sloped variant,
4. Traditional ‘madras’ roof,
5. Rice-husk-insulated shaded roof, and
6. Roof in the form of lime plastered domes and vaults.

- This study shows that the passive design strategies of *Exposed Cavity Wall, Night flushing, and Domes* are the most effective out of the studied strategies during tropical summers.
- The strategies of Central Courtyard, Landscaping of Sand Garden with Pond led to elevated indoor temperatures. The strategy of Indoor Cavity Wall was not found well suited to the climate too.

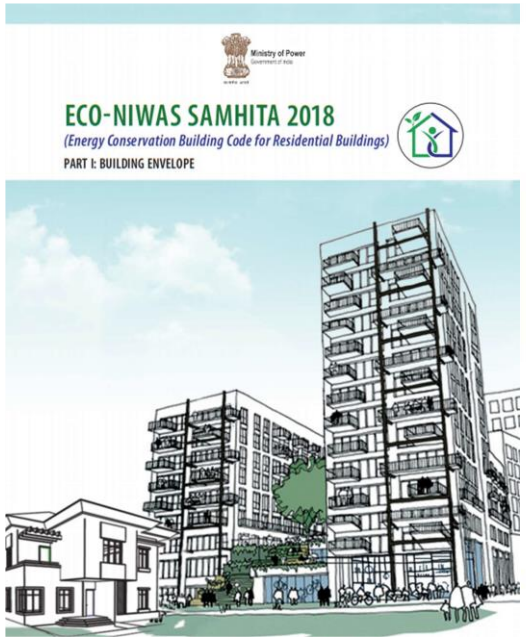
Thank you for your patient listening

02-A

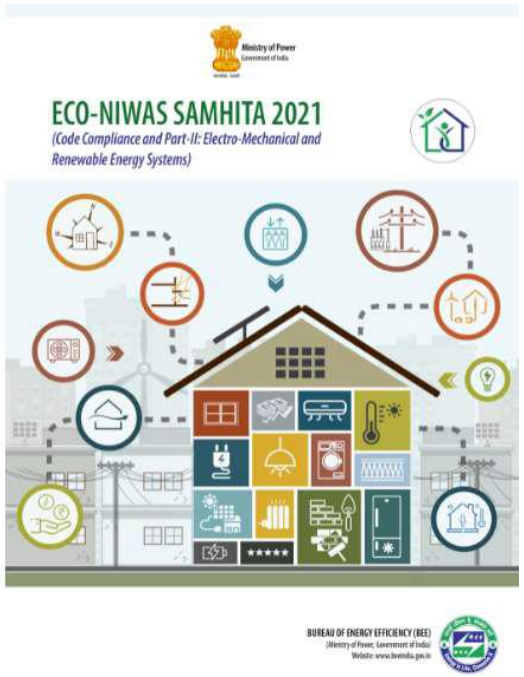
THERMAL COMFORT STANDARDS

Thermal Comfort Standards

- ASHRAE - 55
- National Building Code - 2016
- Handbook of Functional Requirements of Buildings 1987 by BIS
- Eco Niwas Samhita Part 1 and Part 2
- ISHRAE – Indoor Environmental Quality Standards 2018-19



EcoNiwas Samhita 2018
Part 1: Building Envelope



EcoNiwas Samhita 2021
Code Compliance and Part 2

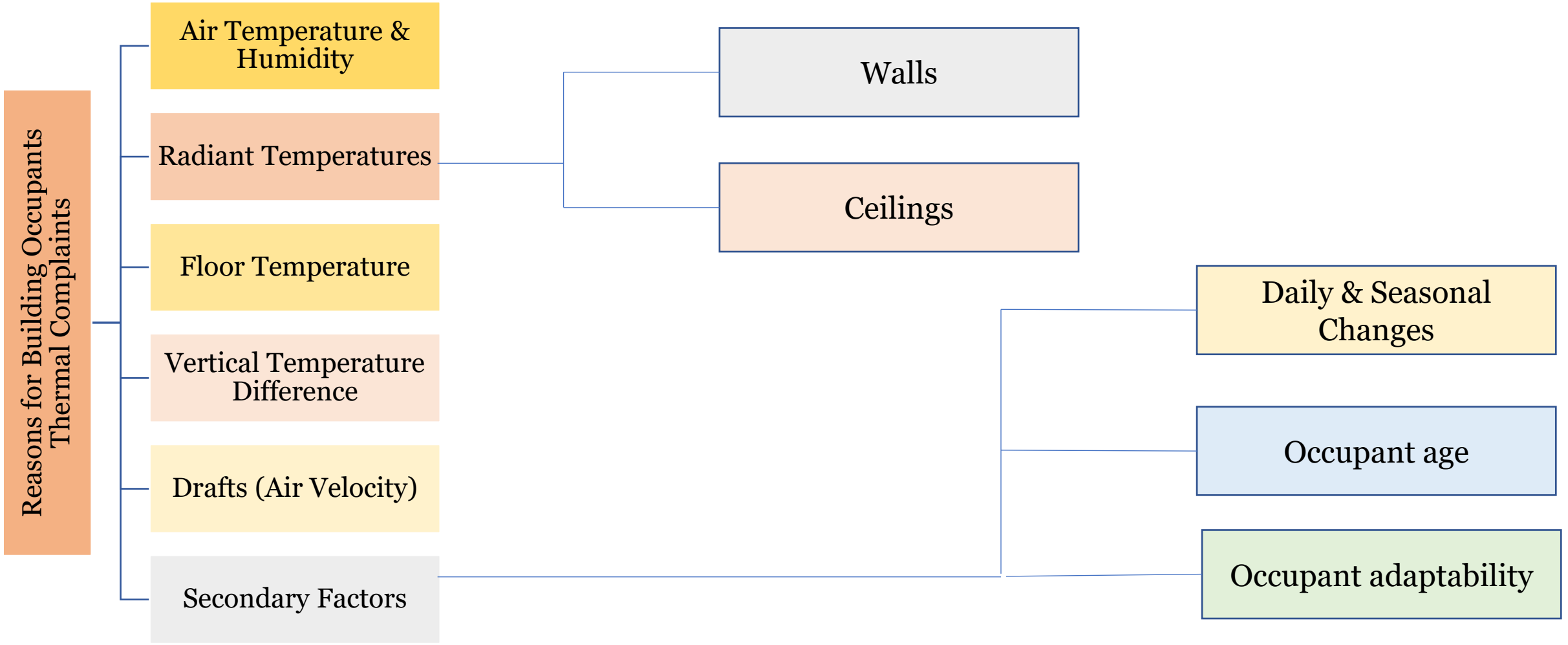
ASHRAE 55

Meeting the standards for Thermal Comfort

ASHRAE standard 55, Thermal Environmental condition for Human Occupancy

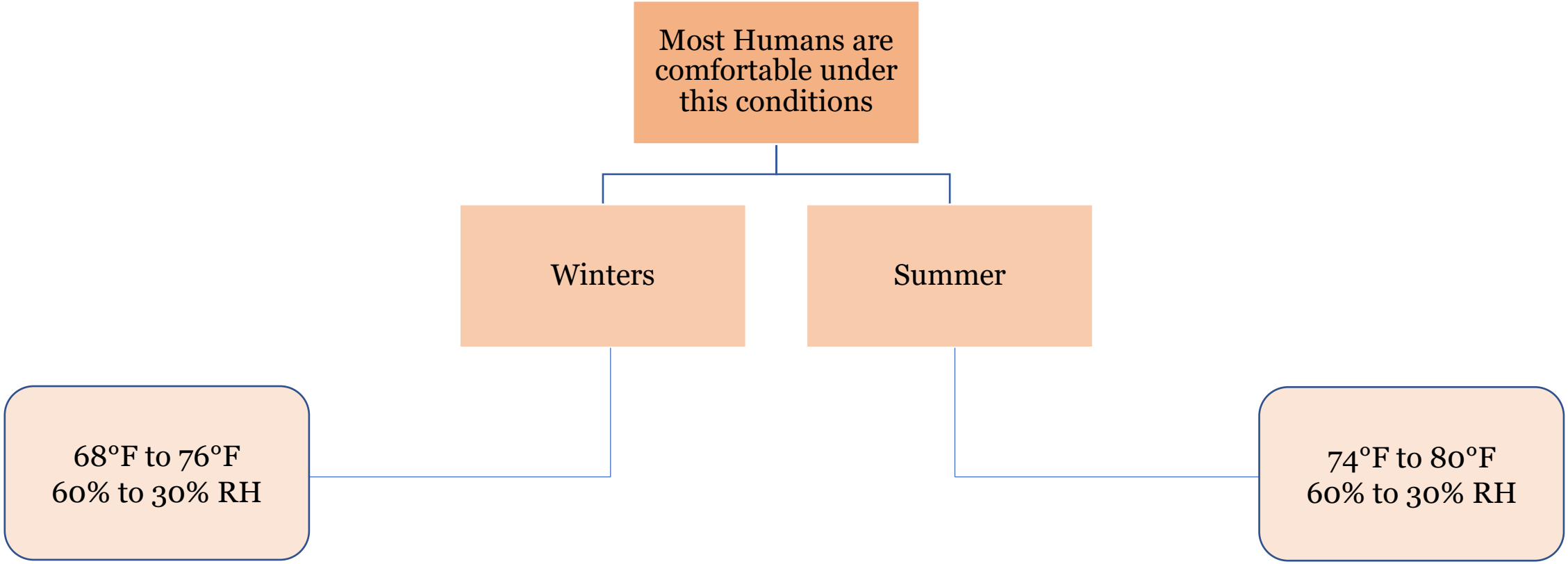
ISO 7726:1998	Ergonomics of the Thermal Environment – Instruments for measuring Physical quantities
ISO 7730:1994	Moderate Thermal Environments – Determination of the PMV and PPD Indices and specification of the conditions for Thermal Comfort

ASHRAE 55

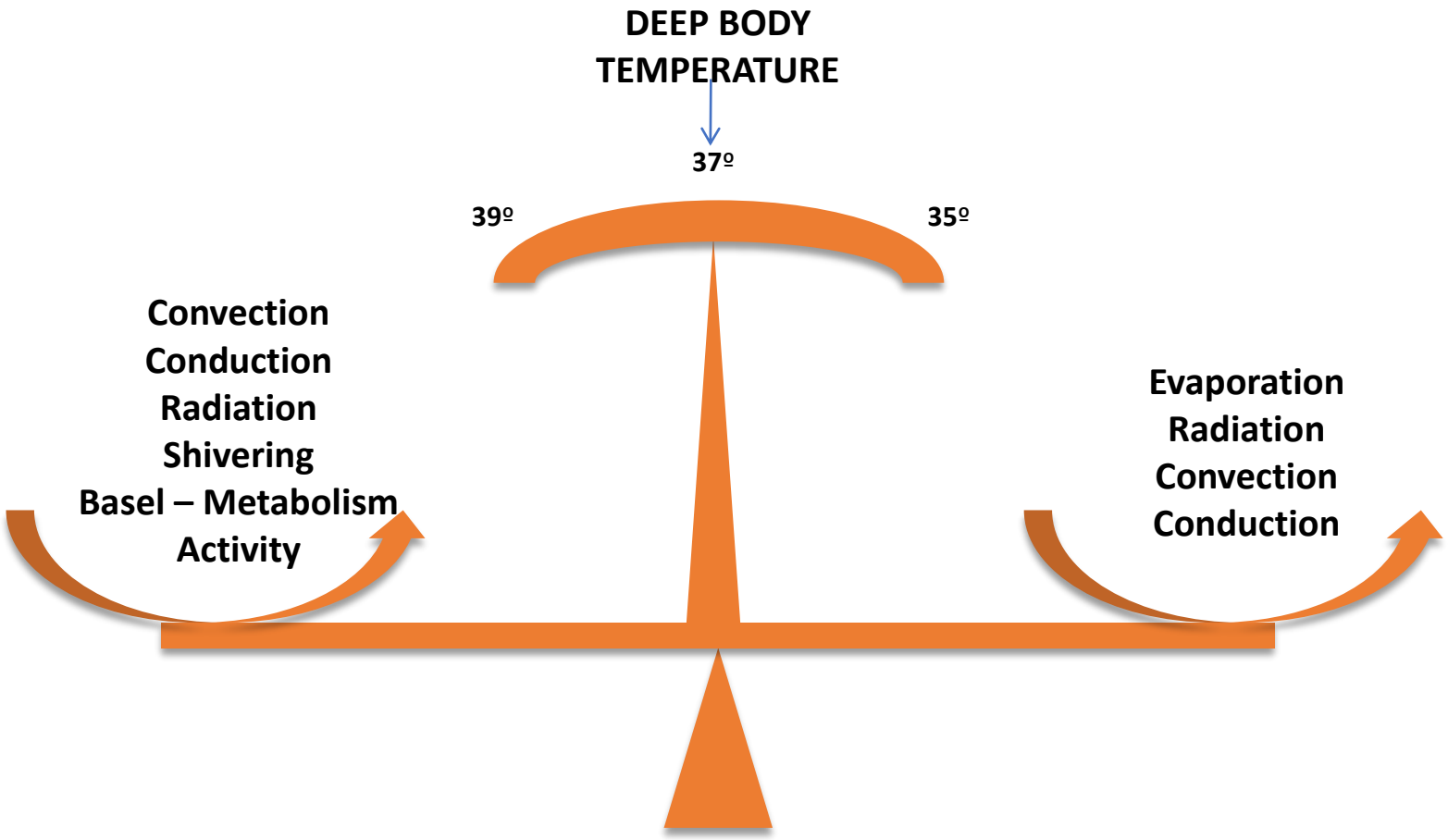

Reasons for Building Occupants Thermal Complaints
Air Temperature & Humidity
Radiant Temperatures
Floor Temperature
Vertical Temperature Difference
Drafts (Air Velocity)
Secondary Factors
Walls
Ceilings
Daily & Seasonal Changes
Occupant age
Occupant adaptability

ASHRAE 55

Human Comfort Range



Body Regularity Mechanism



Body Regularity Mechanism

The Thermal balance of the body can be shown by following equation, if the heat gain and lost factors are

Gain	Met = Metabolism (basel and muscular)
	Cnd = Conduction (contact with warm bodies)
	Cnv = Convection (if the air is warmer than skin)
	Red -= Radiation (from the sun, the sky and hot bodies)
Loss	Cnd = Conduction (contact with cold bodies)
	Cnv = Convection (if the air is cooler than the skin)
	Red = Radiation (to night sky and cold surface)
	Evp = Evaporation (of moisture and sweat)

Then Thermal Balance exist when:

$$Met - Evp + Cnd + Cnv + Red = 0$$

Body Thermal Balance

The body generates heat on a constant basis. The majority of the metabolic processes involved, such as tissue formation, energy conversion, and muscular effort, are all exothermic. Food ingestion and digestion provide the energy required, and metabolism refers to the process of converting food into living matter and usable energy.

METABOLIC HEAT PRODUCTION

BASEL METABOLISM	Heat Production of Vegetative, automatic process
MUSCULAR METABOLISM	Heat Production due to consciously controlled work

Body Thermal Balance

- Only 20% of the heat generated in the body is used, thus any excess heat must be evacuated.
- The mechanism by which the human body maintains its core internal temperature is known as thermoregulation.
- Homeostasis is the state of having a constant internal temperature. All thermoregulation systems aim to bring the body back to a state of homeostasis.
- The temperature range for a healthy safe temperature is between 98.6° F (37°C) and 100° F (37.8°C). The temperature on your skin is between 31° and 34°.

HUMAN BODY RELEASES HEAT TO THE ENVIRONMENT BY

EVAPORATION

RADIATION

CONVECTION

CONDUCTION

Body Thermal Balance – Heat Loss by Human Body

CONVECTION

- The heat from the body is transferred to the air in contact with the skin or clothing, which rises and is replaced by cooler air.
- Faster air movement, lower temperature, and a higher skin temperature all enhance the rate of convective heat loss.

RADIATION

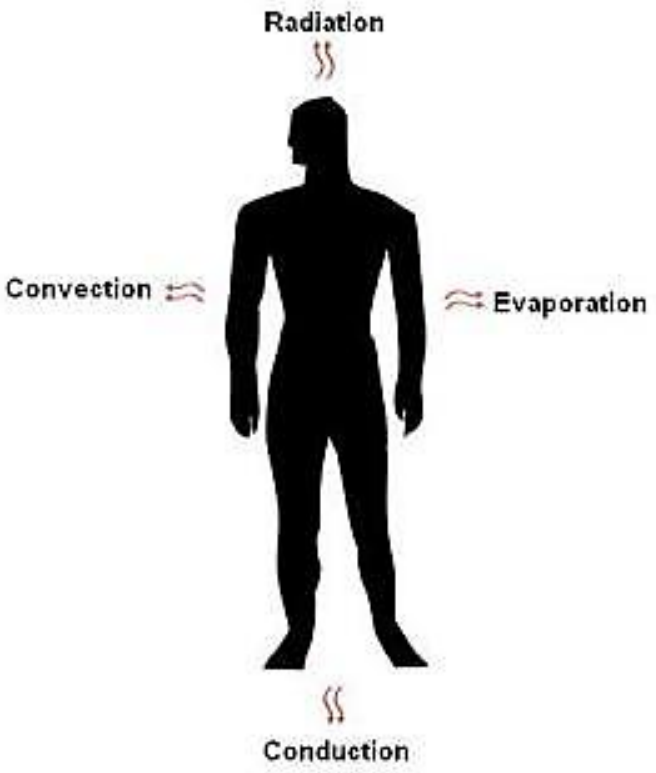
- The temperature of the body surface and the temperature of the opposing surface affects radiant heat loss.

CONDUCTION

- It is determined by the temperature difference between the body surface and the object with which the body is in direct touch.

EVAPORATION

- Is determined by evaporation rate, which is influenced by air humidity (the dryer the air, the faster the evaporation) and the amount of moisture available for evaporation.
- Perspiration and sweating cause evaporation, as does breathing in the lungs.



Body Thermal Balance – Heat Loss in Various Thermal Environment

CALM, WARM AIR, MODERATE HUMIDITY:

Air temperature is 18°.

In the indoors of temperature climate

Air velocity does not exceed 0.25 m/s and when humidity is 40% to 60%, a person engaged in sedentary work will easily dissipate heat as

By Radiation – 45%

By Convection – 30%

By Evaporation – 20%

If the temperature of bounding surface is same as air temperature

Body Thermal Balance – Heat Loss in Various Thermal Environment

HOT AIR AND CONSIDERABLE RADIATION

The Human body temperature is 37°. But skin temperature is 31-34°.

Body can gain substantial heat by radiation: Sun, radiator, bonfire.

Even if heat loss is small in the above scenario, evaporation can still occur if the air is suitably dry.

Heat loss via convection steadily declines as air temperature approaches skin temperature, and the body performs vasomotor adjustments to raise temperature to the higher limit (34°), but once the air temperature hits this point, there is no more heat loss by convection.

Body Thermal Balance – Heat Loss in Various Thermal Environment

HOT AIR, RADIATION AND APPRECIABLE AIR MOVEMENT

When the air is hot (equal to or above skin temperature), the surrounding objects are hot (no heat loss by radiation), and when the air is humid (less than 100% RH), air movement will speed up evaporation, even though the air temperature is higher than skin temperature. Moving air constantly replaces saturated air in the surrounding area.

Inadequately planned houses can generate a lethal condition in which the air is entirely saturated, there is no air flow, and the air is warmer than the skin, resulting in heat stroke.

Body Thermal Balance – Heat Loss in Various Thermal Environment

SATURATED STILL AIR, ABOVE BODY TEMPERATURE

Air is hot (over 34°.)

Unappreciable air movement (≤ 0.25 m/s)

Humidity is near 100%

This leads to profuse sweating and no evaluation and body temperature begins to rise.

At 45°, death is unavoidable.

At 41°, coma sets in and death is imminent

A body temperature of 40° will cause heat stroke. (Failure in circulation system, followed by rapid increase in body temperature)

At adverse situation

Measurements of Thermal Comfort

- Developed in parallel with ASHRAE 55
- Evaluate and measure the moderate Thermal Environment
- Extreme Environments
  - ✓ ISO 7243:2017
  - ✓ ISO 7933: 2004
  - ✓ ISO/TR 11079:1993

BS EN ISO 7730

Ergonomics of the Thermal Environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local Thermal comfort criteria

BS EN ISO 7726

Ergonomics of the Thermal Environment – Instruments for measuring Physical quantities

General Requirements & Standard Conditions of ASHRAE 55

- ASHRAE 55 specifies conditions for acceptable thermal environments and is intended for use in design, operation, and commissioning of buildings and other occupied spaces.
- specifies a certain percentage of occupants as acceptable, as well as the thermal environment values associated with that number.

ASHRAE 55 is oriented toward six factors:

- **metabolic rate,**
- **clothing insulation,**
- **air temperature,**
- **radiant temperature,**
- **air speed, and**
- **humidity**

Compliance with ASHRAE Standard 55

The comfort zone is regarded sufficient if at least 80% of its occupants are unlikely to object to the ambient state, implying that the majority are between -0.5 and 0.5 on the PMV scale.

Design conditions must maintain the spatial conditions within the acceptable range using one of the methodologies outlined in section 5 of the standard for building systems to comply with ASHRAE, including

- Natural ventilation systems
- Mechanical ventilation systems
- Combinations of these systems
- Control systems
- Thermal envelopes

They must also account for all expected conditions (summer and winter, although barring extremes), external and internal environmental elements, and any essential documents.

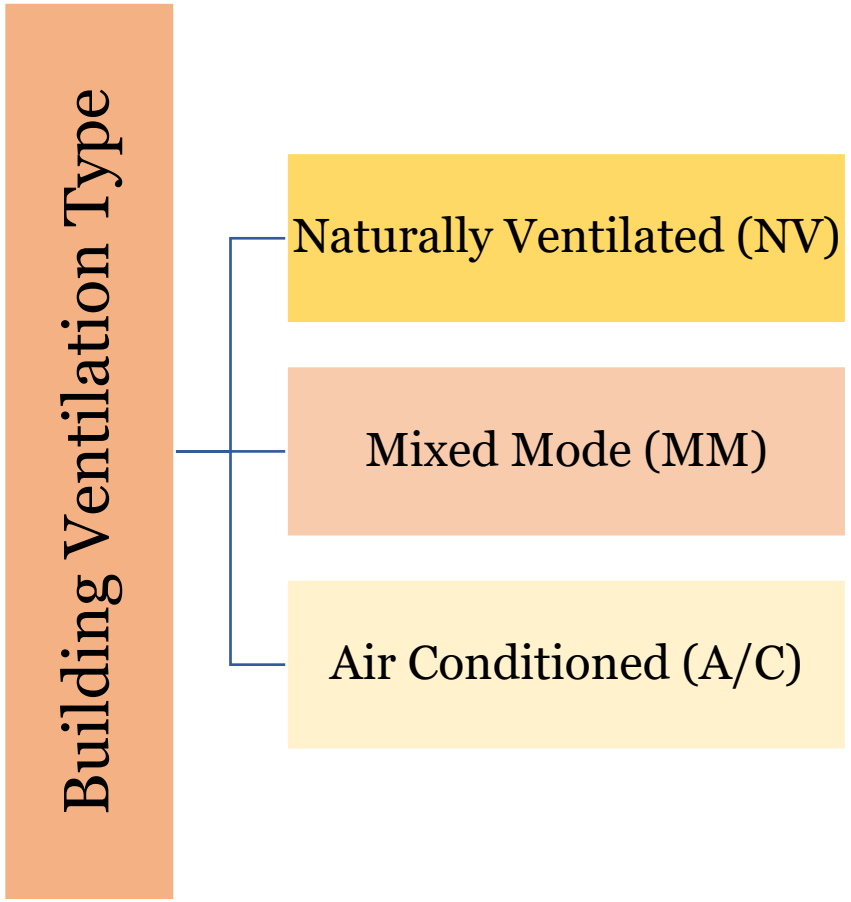
Needed Thermal Comfort Compliance Documentation

Except in the case of naturally ventilated areas, all of the following documentation is required to comply with ASHRAE:

1	The operative temperature, humidity, and total interior loads are all specified in the design.
2	The hours of each seasonal exceedance associated with the outdoor weather percent design conditions
3	The values assumed for comfort parameters (clothing insulation, metabolic rate, indoor airspeed, etc.) at the different assumed conditions (i.e., seasonal).
4	Local discomfort effects (i.e., if someone sits next to a radiator or right below a cooling vent this can lead to local discomfort although the entire space overall is in thermal equilibrium. These effects can easily be determined using thermal modeling tools)
5	The system input or output capacity needed to attain the design operative thermal conditions.

IMAC – Indian Model for Adaptive Comfort

- The adaptive thermal comfort model saves more energy in buildings that are naturally ventilated when compared to air-conditioned buildings as residents adjust to wider indoor temperatures than the peripheral thermal comfort zones determined by the PMV model.
- IMAC Classifies the Building Ventilation into three types based on their HVAC system ranging from naturally ventilated to complete Air Conditioning



IMAC – Indian Model for Adaptive Comfort

- The Standard Classification is based on the **ADAPTIVE Thermal Comfort model** which differentiate the thermal tolerance of occupants accustomed to monotonic temperature (such as air-conditioned places) and people habituated to variation in internal temperatures (such as naturally ventilated structures)

- The Indoor operative temperature values for different building types (NV, MM & A/C) are Pre – Calculated for most Indian cities

IMAC – Indian Model for Adaptive Comfort

Naturally Ventilated Buildings

- The Occupants in NV buildings are Thermally adapted to the outdoor temperature of their location.
- The Indoor Operative Temperature of the occupants to stay thermally comfortable is given by the belove equation.

Indoor Operative Temperature (°C) = **0.54 x Mean Monthly Outdoor DBT + 12.83**

Acceptability range for naturally ventilated buildings is **±2.38°C**

IMAC – Indian Model for Adaptive Comfort

Mixed Mode Ventilated Buildings

- The MM Ventilated buildings takes into consideration the combination of natural ventilation and the availability of air-conditioning when necessary.
- The Occupants in MMV Buildings thermally adapt to the outdoor temperature more than the A/C buildings & somewhat less adaptive to NV building
- The Indoor Operative temperature for the occupants to stay thermally comfortable is given by the below equation.

Indoor Operative Temperature (°C) = **0.28 x Mean Monthly Outdoor DBT + 17.87**

Acceptability range for Mixed Mode ventilated buildings is **±3.46°C**

IMAC – Indian Model for Adaptive Comfort

AC Buildings – Air Temperature based Approach

Indoor Operative Temperature (°C) = **0.078 x Mean Monthly Outdoor DBT + 23.25**

Acceptability range for Air-Conditioned buildings is **±1.5°C**

02-B

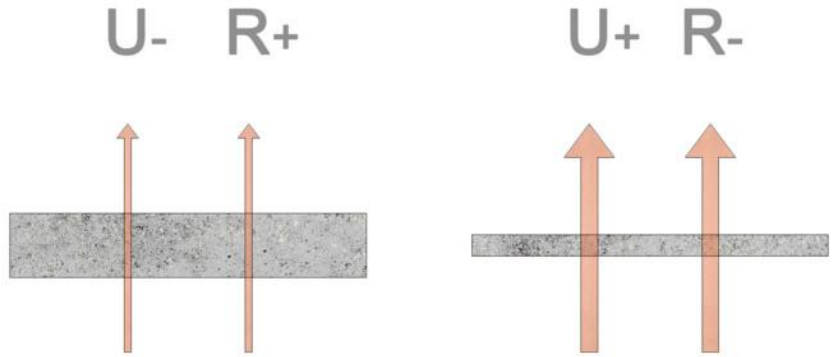
EFFECTS OF MATERIALS ON

THERMAL COMFORT

U-Value or Thermal Transmittance

U-Value or Thermal Transmittance (Reciprocal of R-Value)

Thermal performance is quantified in terms of heat loss and is often represented as a U-value or R-value in the building sector.
The rate of heat transfer through a structure (which can be a single material or a composite) divided by the temperature differential across that structure is known as thermal transmittance, also known as **U-value.**



- W/m²K is the unit of measurement.
- The lower the U-value, the better insulated the structure is.
- Workmanship and installation standards can have a significant impact on thermal transmission.
- The thermal transmittance can be much higher than desirable if insulation is installed improperly, with gaps and cold bridges.
- Thermal transmittance accounts for heat loss by conduction, convection, and radiation

U-Value Calculation

U-Value or Thermal Transmittance (Reciprocal of R-Value)

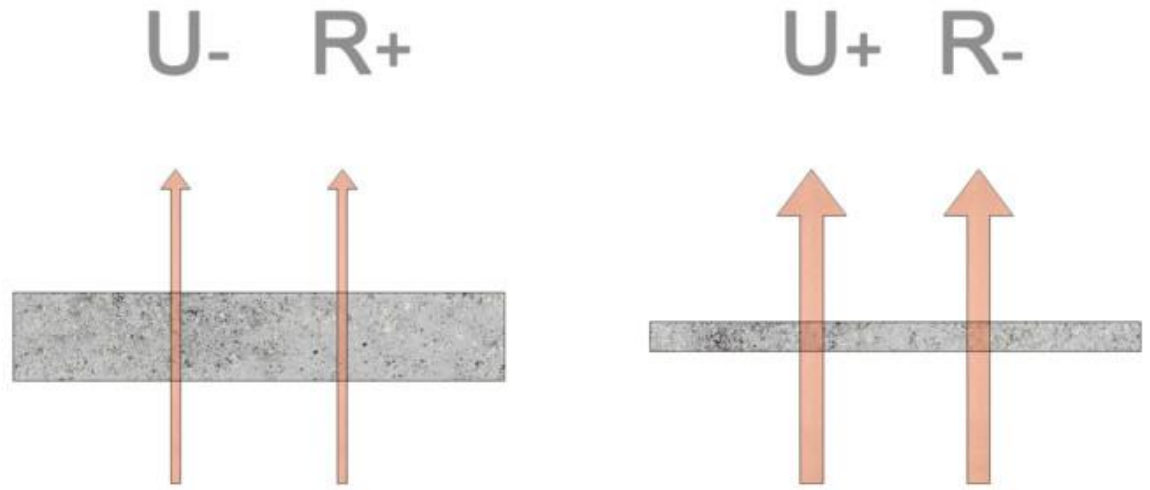
Thermal transmittance is the rate of heat transfer through materials

Unit of U value is W/(m²K)

$$U = \frac{1}{Thermal\ Resistance\ of\ a\ material\ (R)}$$

Where $R = \frac{Thickness\ of\ material\ (t)}{Conductivity\ (k)}$

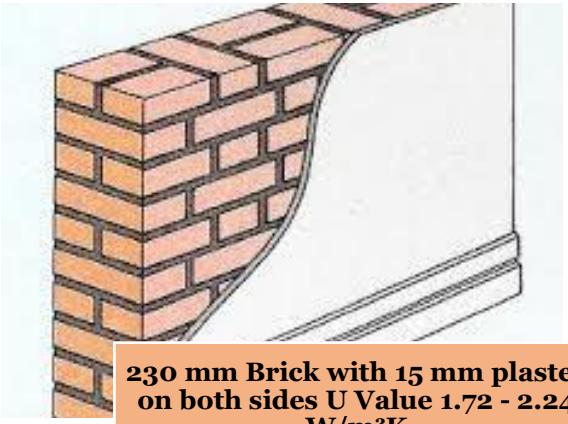
Conductivity (k) is the rate at which heat is transferred by conduction though material



Comparative in terms of U-Value

150 mm RCC (No plaster) – U Value 3.77 W/m²K

200 mm Solid Concrete Block with 15 mm plaster on both sides – U Value 2.8 W/m²K



230 mm Brick with 15 mm plaster on both sides U Value 1.72 - 2.24 W/m²K

200 mm Autoclaved Aerated Concrete (AAC) with 15 mm plaster on both side U Value 0.77 W/m²K

300 mm Autoclaved Aerated Concrete (AAC) with 15 mm plaster on both sides U Value 0.54 W/m²K

Conventional Materials vs Local Materials vs Materials used at LHP

Sr. No.	CONVENTIONAL MATERIALS		LOCAL MATERIALS		MATERIALS USED AT LHP	
	MATERIALS	U-VALUE	MATERILAS	U-VALUE	MATERIALS	U-VALUE
1	Red Bricks (230mm)	2.8 W/m²K	Concrete Block (200mm)	2.8 W/m²K	RCC Wall (150mm)	10.53 W/m²K
2	Fly Ash Bricks (200mm)	4.28 W/m²K	Sand Stone Blocks (200mm)	2.6 W/m²K	AAC Blocks (200mm)	0.77 W/m²K

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Pradhan Mantri Awas Yojana-Urban

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

bmtpc | giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

'Innovative Construction Technologies & Thermal Comfort for Affordable Housing'

Location: Kolkata | Date : 20th May 2022 , Friday | Time : 09:30 AM to 5:30 PM

प्रधान मंत्री आवास योजना-शहरी
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Light House Projects : Live Laboratories
Webinar Series

Emerging Construction Systems for Mass Housing

C N Jha, Dy Chief (S&PD), BMTPC

bmtpc

PMAY (U) Achievement (provisional)

[as on 17th May, 2022]

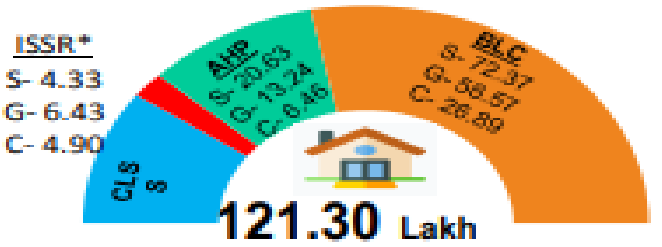
Overall Sanctions for 1.21 crore Houses

Construction of Houses (Nos in lakh)

Demand	Sanctioned	Grounded	Completed/ Delivered
112.24	121.30	99.01	59.02

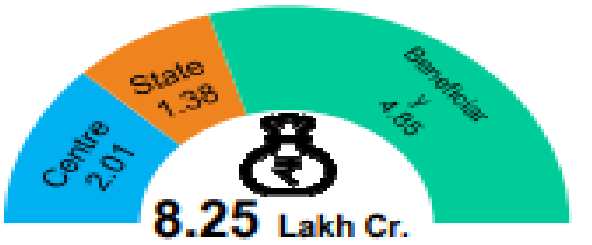
Financial Progress (₹ in Cr)

Committed	Released	Expenditure	UC Received
2,01,348	1,18,020	1,10,628	1,10,117

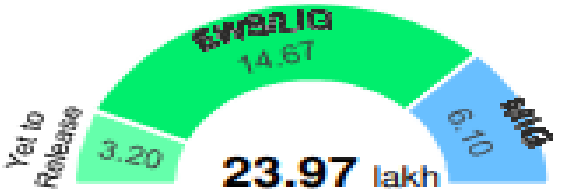


Houses in verticals (Nos in Lakh)

S- Sanctioned G- Grounded C- Completed



Investment Approved (Rs in Lakh Cr.)



Beneficiaries under CLSS (in lakh)

Interest Subsidy under CLSS (Rs in Cr.)

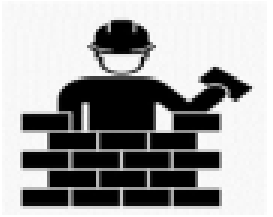
16 lakh houses are being constructed using New Technologies

PMAY (U) Achievement (provisional)

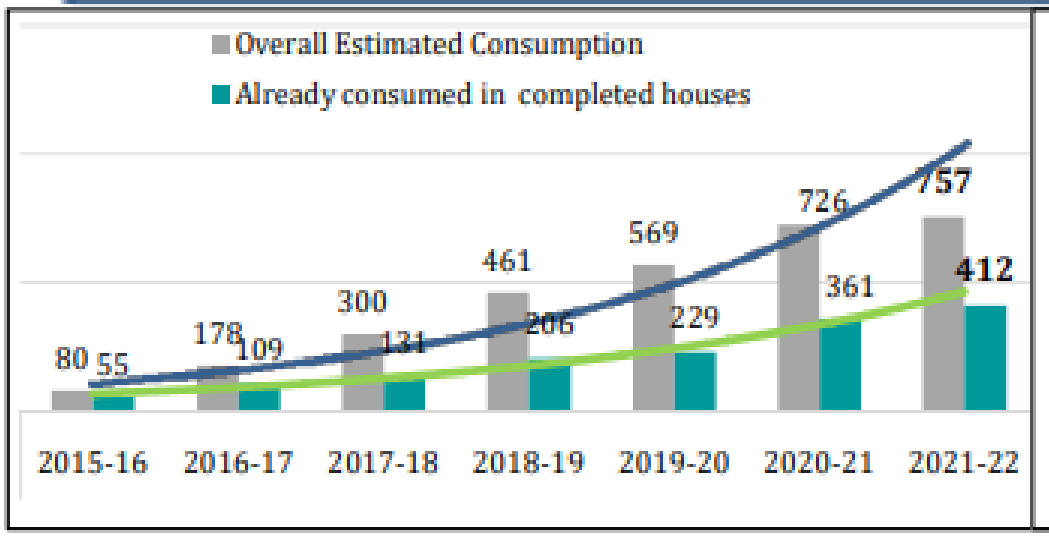
[as on 2nd May, 2022]

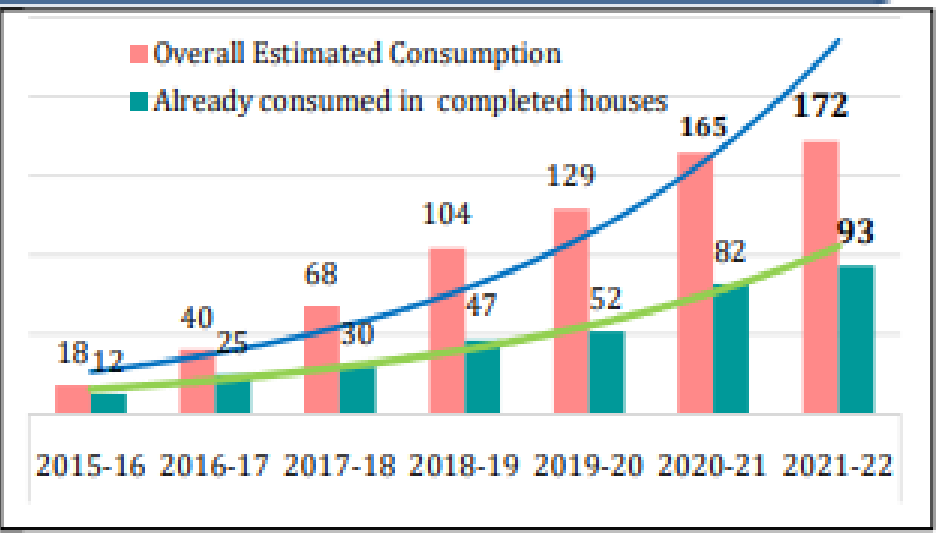
16 lakh houses are being constructed using New Technologies

Generation of Employment



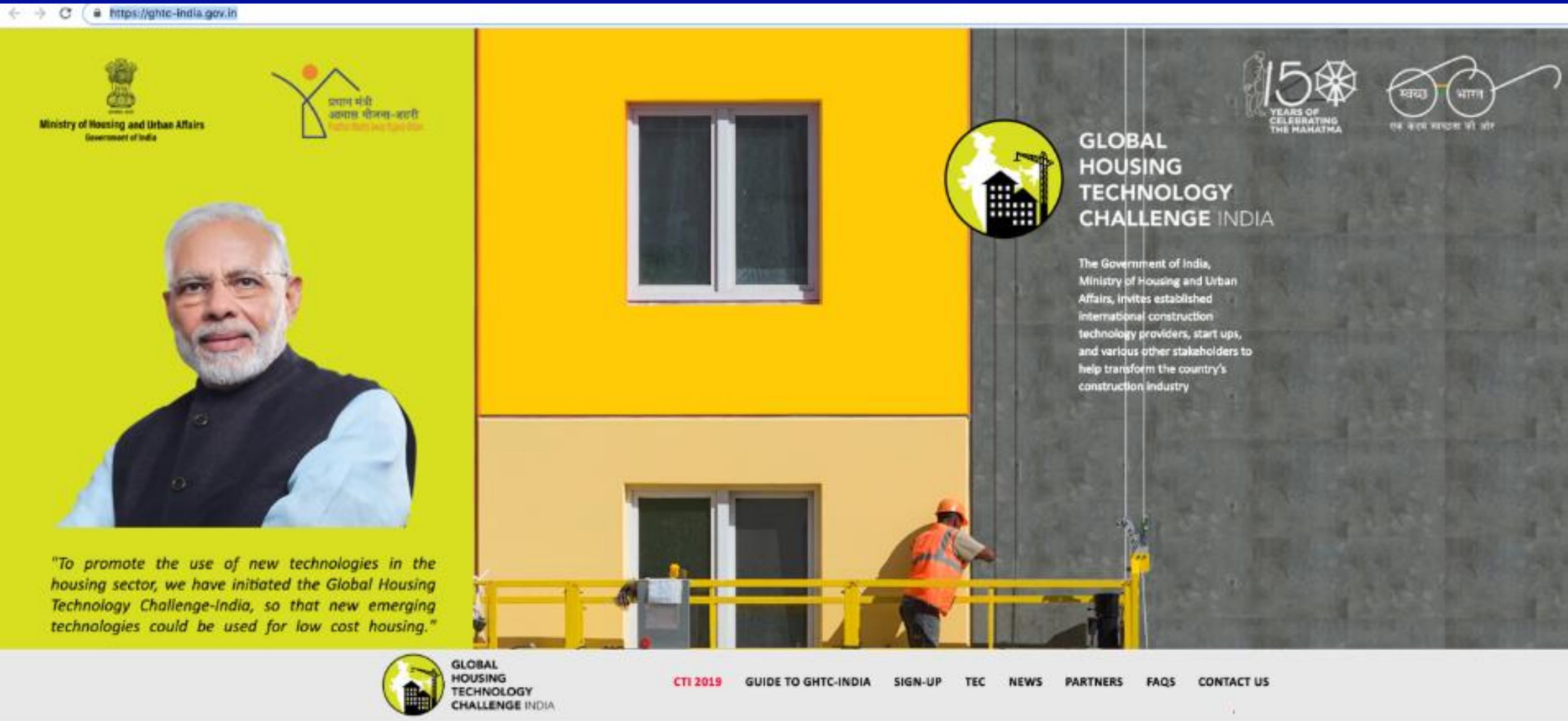
Details	Direct	Indirect	Total
Person days (Nos in Cr.)	212	474	**686**
Jobs (in lakh)	76	169	**245**





* *includes incomplete works of earlier NURM.*

Global Housing Technology Challenge - India (GHTC-I)



https://ghtc-india.gov.in/

Global Housing Technology Challenge - India (GHTC-I)

Categories	Technology	Tech. Providers
1	***Precast Concrete Construction System - 3D Precast volumetric***	4
2	***Precast Concrete Construction System – Precast components assembled at site***	8
3	***Light Gauge Steel Structural System & Pre-engineered Steel Structural System***	16
4	***Prefabricated Sandwich Panel System***	9
5	***Monolithic Concrete Construction***	9
6	***Stay In Place Formwork System***	8
	Total	**54**

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Ministry of Housing and Urban Affairs
Government of India

स्वच्छ भारत
एक कदम स्वच्छता की ओर

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

Light House Projects

Hon'ble Prime Minister laid the foundation stone of six LHPs on 01.01.2021

bmtpc

Conventional Construction Systems

business as usual approach

The prevalent construction systems in India are:

Load bearing Structure

In this system, walls are constructed using bricks/stone/block masonry and floor/roof slabs are of RCC/stone/composite or truss. It is cast in-situ system and called load bearing system as load of structure is transferred to foundation and then to ground through walls.

RCC Framed Structure

In this cast in-situ system, the skeleton of a structure is of RCC column and beam with RCC slab. The infill walls can be of bricks/blocks/stone /panels. The load of the structure is transferred through beam and column to the foundation.

Conventional Construction Systems	Alternate Construction Systems
Slow	Fast
Maximum Use of Natural Resources	Optimum use of Resources
Waste Generation	Minimum Waste
Air/Land/Water Pollution	Minimum Pollution
Labour Intensive	Industrialized System
Prescriptive Design	Cost-effective Design
Unhealthy Indoor Quality	Better health & Productivity
Regular Maintenance	Low Life Cycle Cost
Energy Intensive	Energy Efficient
Cast-in-situ Poor Quality	Factory Made Quality Products
High GHG Emissions	Low GHG Emissions
Unsustainable	Sustainable

Emerging construction systems help to build

SAFER structures

Sustainable Buildings

- 30%-50% reduction in energy use
- 40% reduction in water use
- 35% reduction in GHG emission
- 75% reduction in waste

E Economical - low life cycle cost, better quality

R Resilient - disaster-resistant, structurally superior

3D Precast Volumetric Construction

- Replacing cast in situ RCC structural frame with factory made structural components – 3D
- Customized factory made volumetric construction i.e. the entire module (room)

3D MONOLITHIC VOLUMETRIC Construction

Courtesy :

Global Housing Technology Challenge - India (GHTC-I)

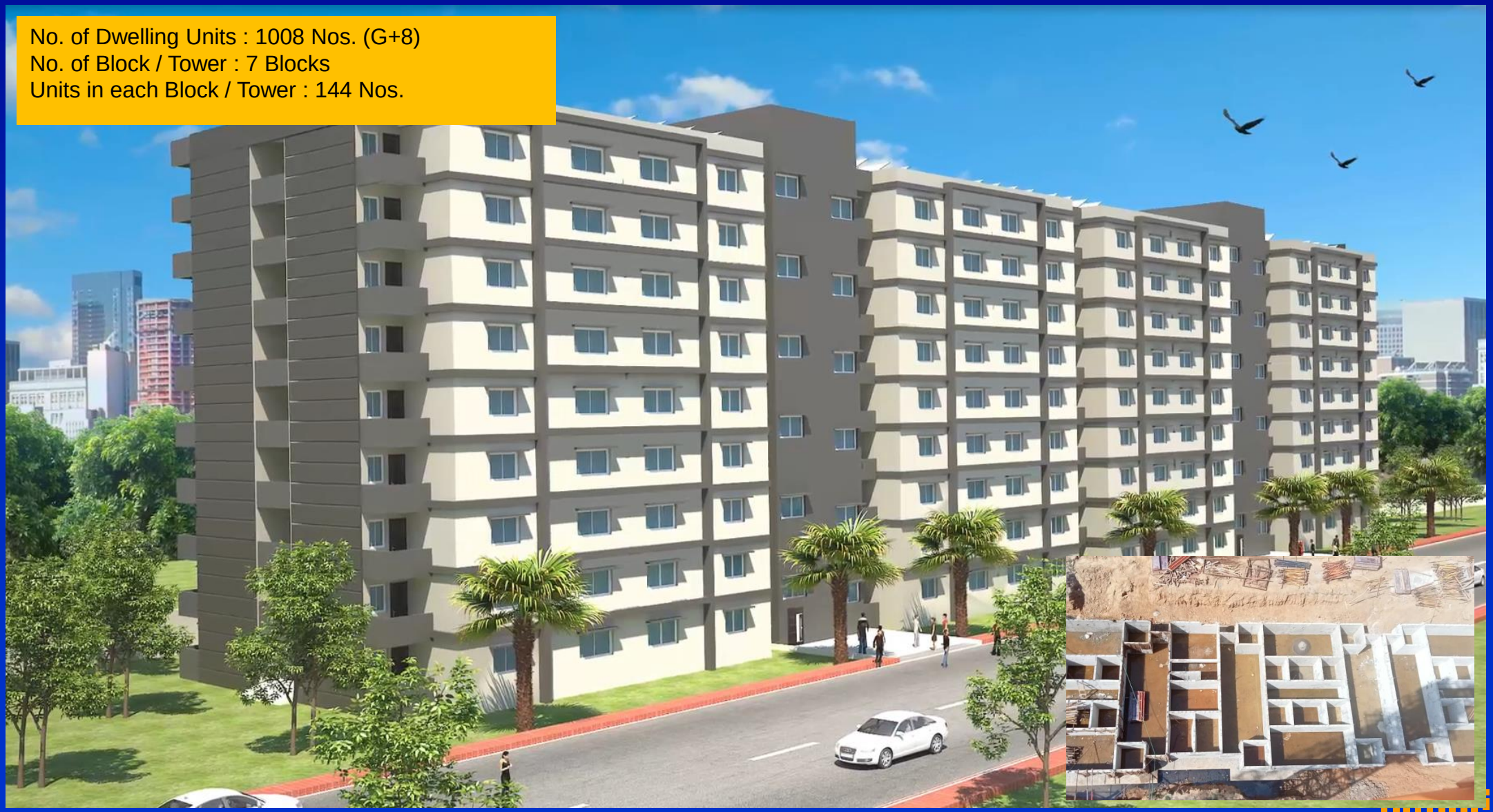
1 Precast Concrete Construction System – 3D Volumetric

1	Pre-cast concrete system with columns, beams, walls, slabs, hollow core slabs & also 3D Volumetric components	Katerra
2	Vertical structural modules cast in Plant/Casting yard are assembled together through casting of floor panel. The unit is transported & installed at site.	Moducast Pvt. Ltd
3	3D Modular casting using steel mould and high performance concrete of building modules in factory. These pods are transported to the construction site & assembled	Magicrete Building Solutions,
4	Modules with 3D Volumetric Precast concrete unit, various units make on house	Ultratech Cement Ltd,

Light House Project (LHP) at Ranchi, Jharkhand

(Technology: Precast Concrete Construction – 3D Volumetric Construction)

No. of Dwelling Units : 1008 Nos. (G+8)
No. of Block / Tower : 7 Blocks
Units in each Block / Tower : 144 Nos.



2D Precast Concrete Construction

- Replacing cast in situ RCC structural frame with factory made structural components – 2D planar elements
- Customized Factory made beams, columns, wall panels, slab/floors, staircases etc.

Concrete components prefabricated in precast yard or site and installed in the building during construction

Global Housing Technology Challenge - India (GHTC-I)

2

Precast Concrete Construction System – Precast components assembled at site

1	Precast Large Concrete Panel (PLCP) System with structural members (wall, slab etc.) cast in a factory/ casting yard and brought to the building site for erection & assembling	Larsen & Toubro
2	Pre-cast Concrete Structural system comprising of pre-cast column, beam, precast concrete / light weight slab, AAC blocks/ infill concrete walls.	B.G. Shirke Construction Technology Pvt. Ltd
3	Optimal Pre-cast concrete System through structural Analysis, design & equipment support	Elematic India,
4	Precast concrete construction system using precast walls with precast plank floor	PG Setty Construction Technology Pvt Ltd,
5	Precast components comprising of beams, coloumns, staircase, slab, hollow core slab etc. manufactured in plant & erected on site	Teemage
6	Pre-cast sandwich panel system & Light weight Pre cast Light Weight concrete slab	Nordicflex
7	Prefabricated Interlocking Technology (without mortar) with Roofing as Mechnized Precast R.C. Plank & Joist system	Adalakha Associates Pvt. Ltd
8	Large Hollow wall prefab concrete Panel (lightweight, interlocking, concrete panel) using factory produced large standard hollow interlocking concrete block	William Ling,

Light House Project (LHP) at Chennai, Tamil Nadu

(Technology: Precast Concrete Construction System-Precast Components)

No. of Dwelling Units : 1152 Nos. (G+5)
No. of Block / Tower : 12 Blocks
Units in each Block / Tower : 96 Nos.

PRE-ENGINEERED STEEL STRUCTURAL SYSTEM

- Replacing cast in situ RCC structural frame with factory made steel (hot rolled) structural system

Steel skeleton with Aerocon panel infills

LIGHT GAUGE STEEL STRUCTURAL SYSTEMS

- Replacing cast in situ RCC structural frame with factory made light gauge steel (cold rolled) structural system

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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3

Light Gauge Steel Structural System & Pre-engineered Steel Structural System

1	LGS Framing with various walling & roofing options	Mitsumi Housing Pvt. Ltd,
2	LGS Framing with various walling & roofing options	Everest Industries Ltd,
3	LGS Framing with various walling & roofing options	JSW Steel Ltd.,
4	LGS Framing with various walling & roofing options	Society for Development of Composites
5	LGS Framing with various walling & roofing options	Elemente Designer Homes
6	LGS Framing with various walling & roofing options	MGI Infra Pvt. Ltd.,
7	LGS Framing with various walling & roofing options	RCM Prefab Pvt. Ltd,
8	LGS Framing with various walling & roofing options	Nipani Infra and Industries Pvt. Ltd.,
9	LGS Framing with various walling & roofing options	Strawcture Eco
10	LGS Framing with various walling & roofing actions	Visakha Industries Ltd.
11	Prefabricated steel structural system with Dry wall system as AAC panels, PUF panels etc	RCC Infra Ventures Ltd.
12	Hot rolled steel frame with speed floor	Jindal Steel & Power Ltd.
13	Hot rolled steel section with AAC Panels as floor & slab	HIL Ltd.
14	AAC wall and roof panel system to provide integrated solution. AAC products are reinforced and used in both load and non-load bearing applications	Biltech Building Elements Ltd
15	AAC Panels are Wire mesh/ steel reinforced for use as wall & slab. Appears to be non load bearing panels to be used with structural framing.	SCG International India Pvt Ltd
16	Precast Light Weight Hollow-core wall Panel is a non-structural construction material with framed structures.	Pioneer Precast Solutions Private Limited

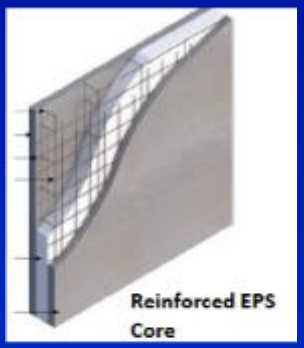
Light House Project (LHP) at Agartala, Tripura

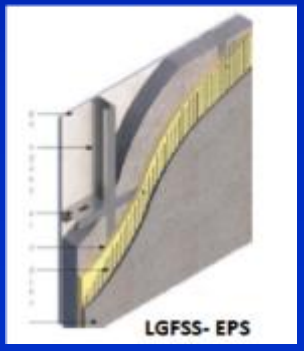
(Technology: Light Gauge Steel Structural System & Pre-Engineered Steel Structural System)

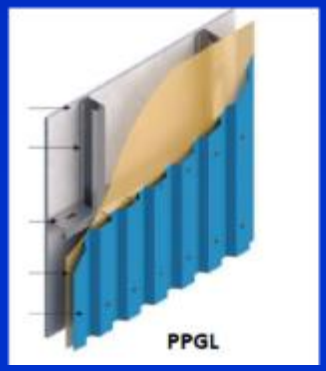
No. of Dwelling Units : 1000 Nos. (G+6)
No. of Block / Tower : 7 Blocks
Units in each Block / Tower : A(112), B(154), C(118), D(168), E(168), F(168) & G(112)

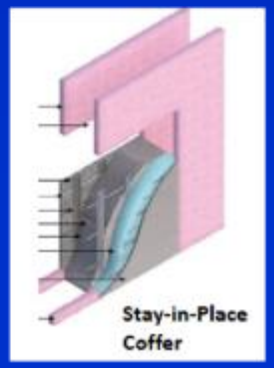
PREFABRICATED SANDWICH PANEL SYSTEMS

- **EPS Core Panel Systems**
- **Other Sandwich Panel Systems**
  - **Fibre cement board**
  - **MgO Board**
  - **AAC panels**









- **Replacing brick and mortar walls with dry customized walls made in factory**

SINGLE

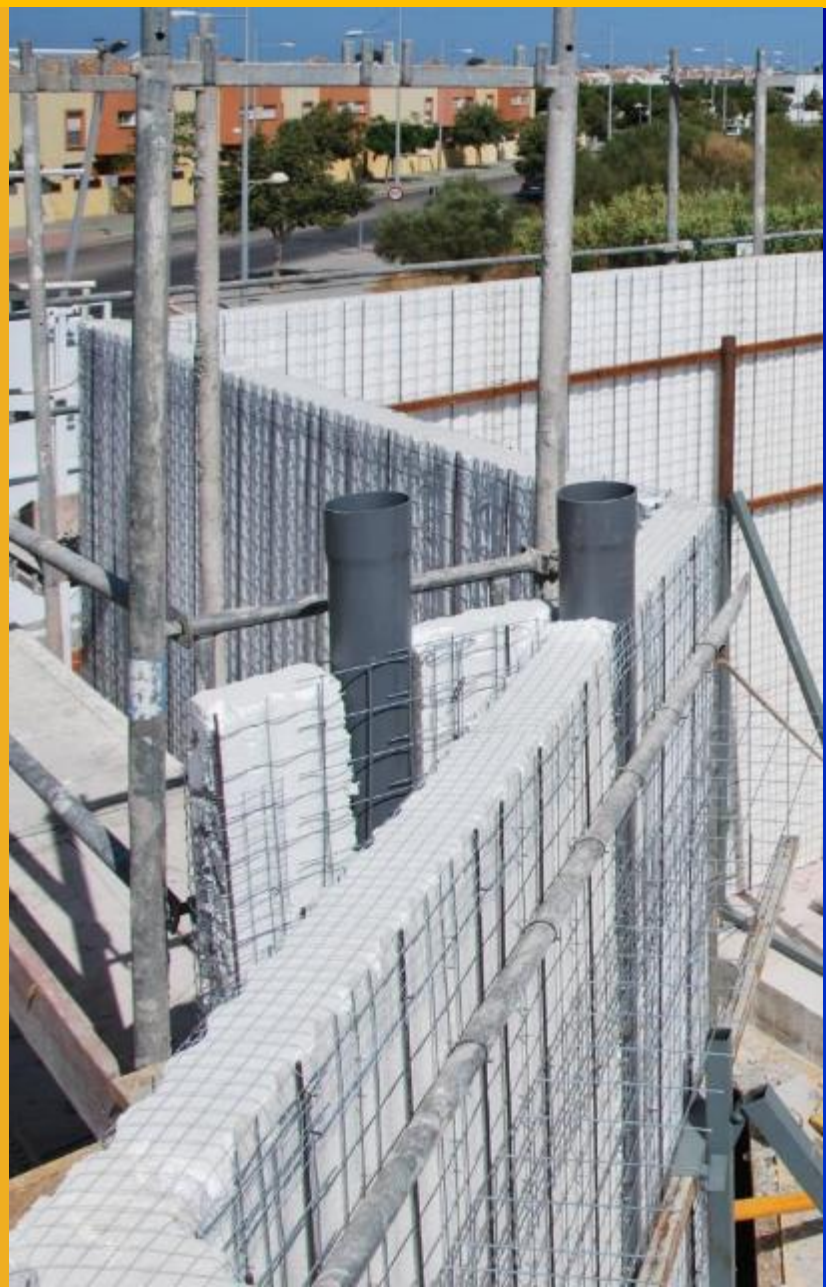
DOUBLE

Global Housing Technology Challenge - India (GHTC-I)

4

Prefabricated Sandwich Panel System

1	Reinforced Expanded Polystyrene sheet core Panel with sprayed concrete as wall & slab	Worldhaus
2	EPS Cement sandwich Panel: wall & slab with EPS Cement sandwich Panel to be used with RCC or Steel structural frame. Load bearing upto G+1 storey	Bhargav Infrastructure Pvt.Ltd
3	EPS Cement sandwich Panel: wall & slab with EPS Cement sandwich Panel to be used with RCC or Steel structural frame. Load bearing upto G+1 storey	Rising Japan Infra Private Limited
4	Reinforced Expanded Polystyrene sheet core Panel with sprayed concrete as wall & slab	Bau Panel Systems India Pvt Ltd,
5	Reinforced Expanded Polystyrene sheet core Panel with sprayed concrete as wall & slab	BK Chemtech Engineering
6	Reinforced Expanded Polystyrene sheet core Panel with sprayed concrete as wall & slab	MSN Construction
7	Reinforced Expanded Polystyrene sheet core Panel with sprayed concrete as wall & slab	Beardshell Ltd.
8	Pre-fab PIR (Poly-isocyanurate) based Dry Wall Panel System" as non-load bearing wall	Covestro India Pvt. Ltd.,
9	Sandwich panels as wall & slab	Project Etopia Group



Light House Project (LHP) at Indore, M.P.

(Technology: Prefabricated Sandwich Panel System & Pre-Engineered Steel Structural System)

No. of Dwelling Units : 1024 Nos. (S+8)
No. of Block / Tower : 8 Blocks
Units in each Block / Tower : 128 Nos.

Rising EPS (Beads) Cement Panels

- Rising EPS (Beads) Cement Panels are patented panels from M/s Rising Japan Infra Pvt. Ltd. These are lightweight composite wall, floor and roof sandwich panels made of thin fiber cement/calcium silicate board as outer and inner faces with a core of EPS granule balls, adhesive, cement, sand, fly ash and other bonding materials in mortar form.
- The core material in slurry state is pushed under pressure into preset molds. Once set, it shall be moved for curing and ready for use with RCC or steel framed structure.
- These panels were manufactured by the firm in China and now two plants at Nagpur & Pune are operational in India.

MONOLITHIC CONCRETE CONSTRUCTION

- Replacing cast-in-situ Formwork with factory made customized formwork systems
- Formwork material is Aluminium / composites / steel having 100 to 500 repetitions
- Assembly line construction i.e. placing the formwork, pouring the concrete, moving the formwork to upper level

Global Housing Technology Challenge - India (GHTC-I)

5

Monolithic Concrete Construction

1	Aluminium formwork system for Monolithic Concrete construction	Maini Scaffold Systems
2	Aluminium formwork system for Monolithic Concrete construction	KumkangKind India Pvt. Ltd
3	Aluminium formwork system for Monolithic Concrete construction	S-form India Pvt. Ltd.,
4	Aluminium formwork system for Monolithic Concrete construction	ATS Infrastructure Ltd.
5	Aluminium formwork system for Monolithic Concrete construction	Innovative housing & Infrastructure Pvt. Ltd
6	Aluminium formwork system for Monolithic Concrete construction	MFS formwork Systems Pvt. Ltd.
7	Aluminium formwork system for Monolithic Concrete construction	Knest Manufacturers LLP
8	'Tunnel form' construction technology, an cast in situ RCC system, based on the use of high-precision, re- usable, room-sized, steel forms or moulds for monolithic concrete construction	Outinord Formworks Pvt. Ltd.
9	Aluminium formwork system for Monolithic Concrete construction	Brilliant Etoile

Light House Project (LHP) at Rajkot, Gujarat

(Technology: Monolithic Concrete Construction System)

No. of Dwelling Units : 1144 Nos. (S+13)
No. of Block / Tower : 11 Blocks
Units in each Block / Tower : 104 Nos.

Modular Tunnel form

- Tunnel formwork is a mechanized system for cellular structures. It is based on two half shells which are placed together to form a room or cell. Several cells make an apartment. With tunnel forms, walls and slab are cast in a single day.
- The formwork is set up for the day's pour in the morning. The reinforcement and services are positioned and concrete is poured in the afternoon. Once reinforcement is placed, concrete for walls and Slabs shall be poured in one single operation. The formwork is stripped the early morning and positioned for the subsequent phase.
- Here the walls and slabs are cast in a form of a tunnel leaving two sides open whereas in monolithic concrete construction the entire room is cast in a single pour..

STAY-IN-PLACE FORMWORK SYSTEM

- Replacing cast-in-situ Formwork with factory made formwork systems
- It is sacrificial formwork or lost formwork means formwork is left in the structural system to later act as insulation or reinforcement cage

6

Stay In Place Formwork System

1	Expanded-Steel Panel reinforced with all- galvanised Steel Wire-Struts serving both as the load- bearing steel structure and as the stay-in-place steel formwork filled with EPS-alleviated concrete	JK Structure
2	Factory made prefab Glass fibre reinforced Gypsum cage panels suitable for wall & slab with reinforcement & concrete as infill as per the requirement	FACT-RCF Building Products Limited
3	Structural Stay In Place Galvanized Steel formwork system for walling with the same bottom single layer formwork for slabs/ in-situ slab	Coffor Construction Technology Pvt.Ltd
4	Factory produced PVC Stay in place formwork with concrete & reinforcement in walling units with cast insitu RCC Slab	Joseph Jebastin (Novel Assembler)
5	Fully load bearing walls with 150 mm monolithic concrete core sandwiched inside two layers of EPS as walling The forms are open ended hollow polystyrene interlocking blocks which fits together to form shuttering system	Reliable Insupack
6	Ready to use Stay in place polymer formwork, light weight, with flooring slab (combination of ferro cement and natural stone) placed on RCC precast joists)	Kalzen Realty Pvt. Ltd
7	Fast Bloc, Insulated Concrete Form (ICF), acts as formwork for concrete and rebar, Co1oumn/post and beam construction, creating an strong skeleton in the walls.	Fastbloc Building Systems
8	Formwork system "Plaswall with Two fibre cement boards (FCB) & HIMI (High Impact Molded Inserts) bonded between two sheets of FCB in situ and erected to produce a straight-to finish wall with in-situ concrete	FTS Buildtech Pvt.Ltd

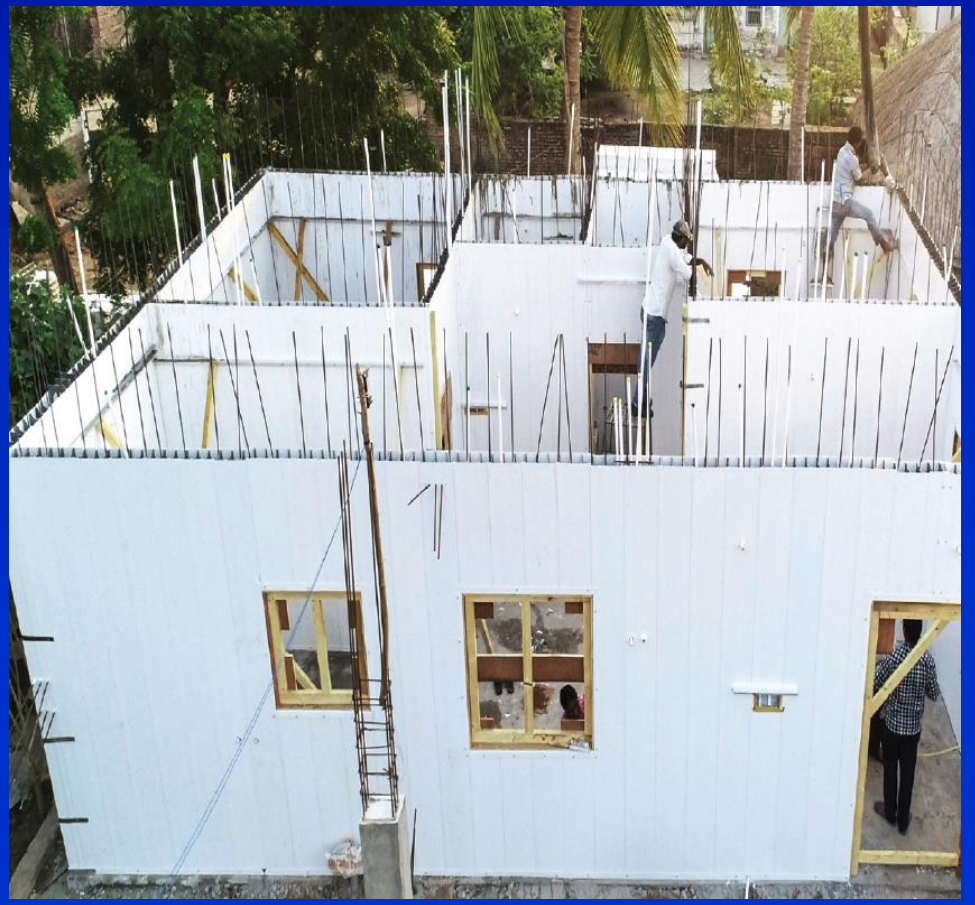
Light House Project (LHP) at Lucknow, U.P.

(Technology: Stay in-place Formwork System & Pre-Engineered Steel Structural System)

No. of Dwelling Units : 1040 Nos. (S+13)
No. of Block / Tower : 4 Blocks
Units in each Block / Tower : A(494), B(130), C(208) & D(208)

Stay-In-Place PVC Wall Forms

- This is a prefinished wall formwork from M/s Novel Assembler Pvt. Ltd. comprising of rigid Poly-Vinyl Chloride (PVC) based polymer components that serve as a permanent stay-in-place durable finished form-work for concrete walls.



- The extruded components slide and interlock together to create continuous formwork with the two faces of the wall connected together by continuous web members forming hollow rectangular components. The web members are punched with oval-shaped cores to allow easy flow of the poured concrete between the components.
- The hollow Novel Wall components are erected and filled with concrete, in situ, to provide a monolithic concrete wall.

Adoption of New Technologies by States

AHP houses in Pune, Maharashtra using Precast Construction Technology

- Around **16 Lakh houses** are being built using innovative technologies under PMAY(U) & other state schemes.

State	Technology
Andhra Pradesh	EPS, Monolithic and Steel Technology
Chhattisgarh	Monolithic and Precast Technology
Gujarat	Monolithic, Precast (Waffle-crete)
Kerala	Glass Fibre Reinforced Gypsum (GFRG)
Maharashtra	Precast (3S) & Monolithic Technology
Odisha	Precast concrete construction
Jharkhand	Global Tender floated
Tamil Nadu	Precast Concrete Technology
States like Assam, Karnataka, Madhya Pradesh, Telangana & Uttarakhand have also expressed interest in Technology neutral bidding process	

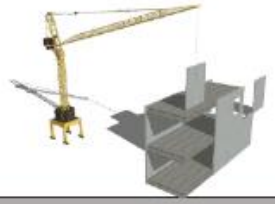
54
Alternate technologies Identified

54
technologies approved by CPWD

29
SoRs issued for alternate technologies by CPWD (22+7)

Looking Back / Rear view

Levels of Construction Technology

Level 0	Level 1	Level 2	Level 3	Level 4
				
MATERIAL	COMPONENTS	ELEMENTAL OR PLANAR SYSTEMS	VOLUMETRIC SYSTEM	COMPLETE BUILDING SYSTEMS
Basic materials for site-intensive construction ✓ Involves more Labour ✓ Time consuming	Manufactured components ✓ Fabricated in Factory ✓ Can't be build On-site ✓ Assist in construction speed & quality	Linear or 2D components ✓ Series of Pre fabricated elements assembled to form the shell ✓ Requires on-site work	3D components in the form of modules ✓ Volumetric, forms a completed part of the building ✓ Involves more than one trade in the factory	Modular components - fully finished and delivered to site ✓ Finished interior & exterior surfaces ✓ Less on-site work

Source: Gibb., A.G.F., *Off-site Fabrication—Pre-Assembly, Pre-Fabrication, and Modularization*

Courtesy : hoMission Abode All

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"Creating Enabling Environment for Affordable Housing for All"

Session 4

Eco-Niwas Samhita and Compliance

Avijit Ghosh, PhD (Engg.), FIE

Eco Niwas Samhita Part.1

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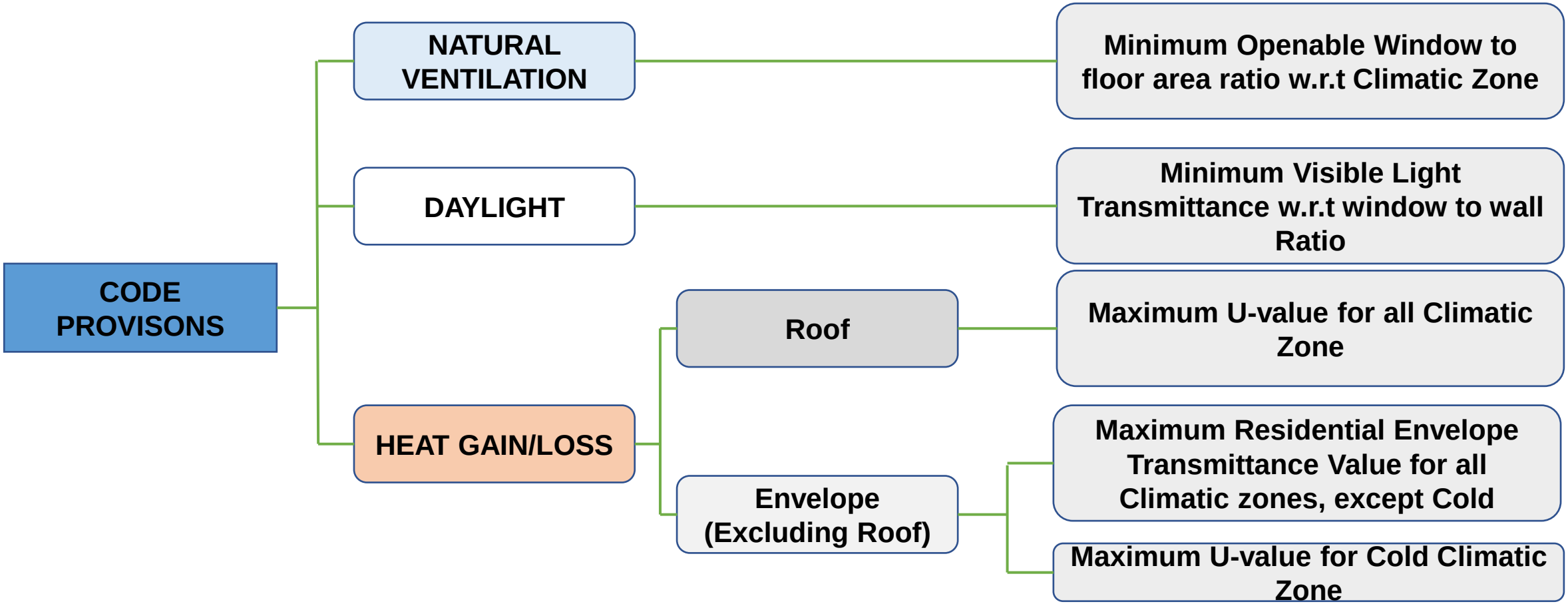
Code Provisions ENS 1



Openable window to floor area ratio (WFR): ENS Part 1

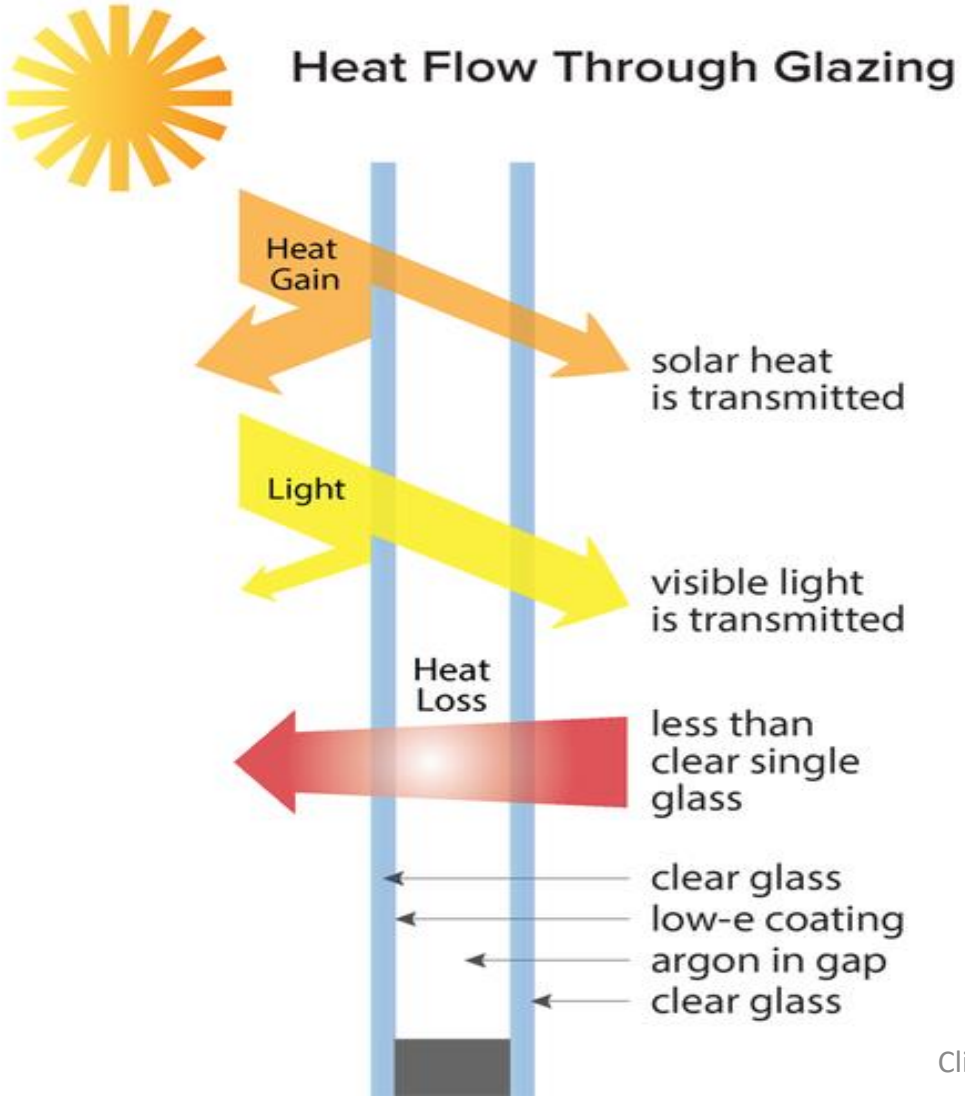
Openable Window-to-Floor Area Ratio (WFR) indicates the potential of using external air for ventilation. Ensuring minimum WFR helps in ventilation, improvement in thermal comfort, and reduction in Cooling energy demand.

The openable Window-to-Floor Area Ratio (WFR) shall not be less than the values given in Table. (Source : National Building Code of India 2016)

Climatic Zone	Minimum WFR
Composite	12.50
Hot-Dry	10.00
Warm-Humid	16.66
Temperate	12.50
Cold	8.33

Note : floor area means carpet area

VISIBLE LIGHT TRANSMITTANCE (VLT): ENS Part 1



Visible light transmittance (VLT) of non-opaque building envelope components (transparent/ translucent panels in windows, doors, ventilators, etc.), indicates the potential of using daylight to reduce the need for artificial lighting

The VLT requirement is dependent on the window-to-wall ratio (WWR) of the building.

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VLT w.r.t WWR: ENS Part 1

Window-to-wall Ratio (WWR)	Minimum VLT (%)
0 - 0.30	27
0.31 - 0.40	20
0.41 - 0.50	16
0.51 - 0.60	13
0.61 - 0.70	11

THERMAL TRANSMITTANCE OF ROOF : ENS Part 1

Thermal transmittance takes place through the roof of a building. Limiting the transmittance, helps in reducing heat gains or losses from the roof, and reducing the energy required. It is expressed as Overall heat Transfer Co-efficient or U-value.

Thermal transmittance of roof shall comply with the maximum U_{roof} value of 1.2 W/m^2 K.

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THERMAL TRANSMITTANCE OF ROOF : ENS Part 1

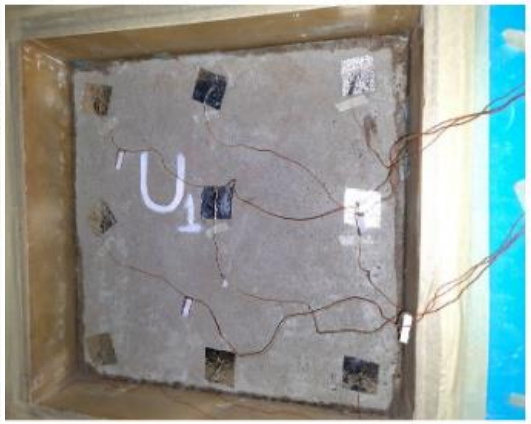
EQUATION FOR U_{roof}:

$$U_{roof} = \frac{1}{A_{roof}} \sum_{i=0}^{n} (Ui \times Ai)$$

U_{roof}	**Thermal Transmittance of Roof (W/M^2.K)**
A_{roof}	Total Area of the Roof (m^2)
U_i	Thermal Transmittance values of roof constructions by layers (W/m^2 .K)
A_i	Areas of different Roof Constructions (m^2)

U-value Test Set-up

Glass sample for U-value test



RESIDENTIAL ENVELOPE TRANSMITTANCE VALUE : ENS Part 1

Residential envelope heat transmittance (RETV) is the Net heat gain rate (over the cooling period) through the building envelope (excluding roof) divided by the area of the building envelope (excluding roof). Its unit is W/m^2.

Heat Conduction through opaque building envelope components (Wall, Opaque, panels in doors, windows, ventilators, etc.

Heat Conduction through non-opaque building, envelope components (transparent/translucent panels of windows, doors, ventilators, etc.)

Solar radiations through non-opaque building envelope components (transparent/translucent panel of windows , doors, ventilators, etc.)

RESIDENTIAL ENVELOPE TRANSMITTANCE VALUE : ENS Part 1

$$RETV = \frac{1}{A_{envelope}} \times [\{a \times \sum_{i=1}^{n} (Aopaque \times Uopaque \times \omega_i)\} + \{b \times \sum_{i=1}^{n} (Anon\_opaque \times Unon\_opaque \times \omega_i)\} + \{c \times \sum_{i=1}^{n} A_{non\_opaque} \times SHGCeq \times \omega_i)\}]$$

RESIDENTIAL ENVELOPE TRANSMITTANCE VALUE : ENS Part 1

RETV EUQATIONS TERMS	
$A_{envelope}$	envelope area (excluding roof) of dwelling units (m^2). It is the gross external wall area (includes the area of the walls and the openings such as windows and doors).
A_{opaque}	areas of different opaque building envelope components (m^2)
U_{opaque}	thermal transmittance values of different opaque building envelope components (W/m^2 .K)
$A_{non-opaque}$	areas of different non-opaque building envelope components (m^2)
$U_{non-opaque}$	thermal transmittance values of different non-opaque building envelope components (W/m^2 .K)
$SHGC_{eq}$	equivalent solar heat gain coefficient values of different non-opaque building envelope components
ω_l	orientation factor of respective opaque and non-opaque building envelope components; it is a measure of the amount of direct and diffused solar radiation that is received on the vertical surface in a specific orientation

RESIDENTIAL ENVELOPE TRANSMITTANCE VALUE : ENS Part 1

The coefficients of RETV formula for different climatic zones, are as below

Climate Zone	a	b	c
Composite	6.06	1.85	68.99
Hot-Dry	6.06	1.85	68.99
Warm-Humid	5.15	1.31	65.21
Temperature	3.38	0.37	63.69
Cold	Not Applicable for RETV		

EcoNiwas Samhita 2021

Eco – Niwas Samhita 2021 Scope

The Code Applies to

Residential buildings built on a plot area of ≥ 500 m^2

Residential part of ***Mixed land-use building*** projects, built on a plot area of ≥ 500 m^2.

ECO – NIWAS SAMHITA 2021 CODE COMPLIANCE

Prescriptive Method

Compliance Mandatory +

Point System Method

- Minimum Points
- Additional Points
- Maximum Points

Additional Score

Components	Minimum Points	Additional Points	Maximum Points
Building Envelope	47	40	87
Building Services			
Common area and exterior lighting	3	6	9
Elevators	13	9	22
Pumps	6	8	14
Electrical Systems	1	5	6
Indoor Electrical End-Use			
Indoor Lighting		12	12
Comfort Systems		50	50
ENS Score	70	130	200

Renewable Energy Systems Components	Minimum Points	Additional Points	Maximum Points
Solar Hot Water Systems		10	10
Solar Photovoltaic		10	10
Additional ENS Score		20	

ECO – NIWAS SAMHITA 2021 CODE COMPLIANCE

Project Category	Minimum ENS Score
Low rise buildings	47
Affordable Housing	70
High rise buildings	100

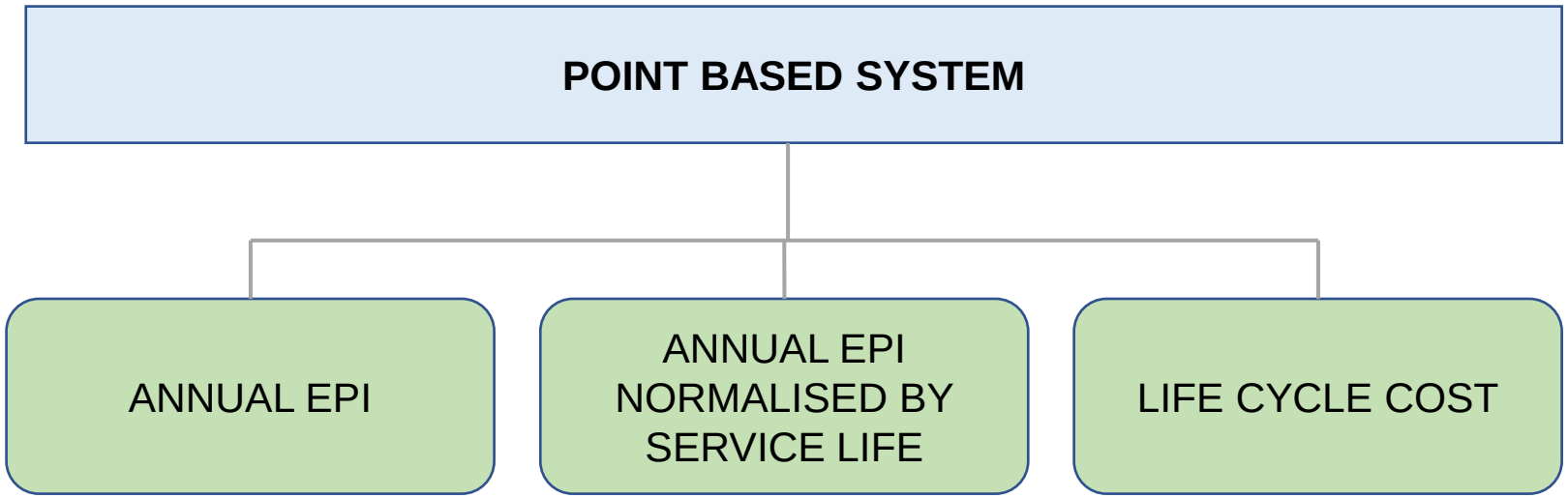
Low Rise Buildings: A structure of four stories or less, and/or a structure of up to 15 metres in height (without stilts) and up to 17.5 metres in height (including stilt).

Affordable Housing Projects:

- for Affordable houses or Dwelling Units (DUs)
- for Economically Weaker Section (EWS) category
- for Lower Income Group (LIG) category

High Rise Buildings: A structure with more than four stories and/or a height of more than 15 metres (without stilts) and 17.5 metres (including stilt).

Point Based System



The potential savings gained from the above metrics for various prototypes has led to the definition of MEPS for part-II building components and a proposal for an Integrated ENS.

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Advantages of Point Based System

- A point system is a less complicated way of assigning weight to building components that are relevant in terms of energy efficiency and compliance. Each dot does not always imply a percentage reduction in energy consumption.

- Singapore began with prescriptive compliance, but as the code grew, the point-based model was adopted as a means of compliance, combining trade-off and prescriptive criteria.

Ease of comprehending by the citizens	• **Easy to comprehend by citizens for both overall energy performance of a residential building and incorporated component level energy efficiency**
Trade-off	• Trade-off among components is possible but on a stepped EE improvements giving limited flexibility to owner to show compliance • Easy to deter possibility of gaming
Compliance	• Low expertise is required for doing and checking the compliance • Require simpler tool for showing compliance • Will have only one compliance approach
Future revision	• Easy to accommodate additions and removal of components from code. • Easier for states to make any revisions/amendments

Mandatory Requirements

1. **Building Envelope**: All of the ENS Part I requirements must be met.
2. **Power Factor Correction**: In all three phases, 0.97 at the point of connection or the state requirement, whichever is more strict.
3. **Energy Monitoring**: Common area lighting (Outdoor lighting, corridor lighting and basement lighting)
   - Elevators
   - Water pumps
   - Basement car parking ventilation system
   - Electricity generated from power back-up
   - Electricity generated through renewable energy systems
   - Lift pressurization system
4. **Electrical Vehicle Charging Station**: If it is installed, it must follow the new criteria for Charging Infrastructure established by the Ministry of Power.
5. **Electrical Systems**: Distribution losses in the ENS building must not exceed 3% of total power demand. At design load, the voltage drop for feeders is less than 2%.At design load, the voltage drop for the branch circuit is less than 3%.

Prescriptive Method

1. Building Envelope:
   - VLT and WFR – as per ENS Part 1
   - RETV (for all climate except cold) – max 12 W/m2
   - Thermal Transmittance for cold – max 1.3W/m2K
   - Roof – 1.2W/m2K
2. Common Area & Exterior Lighting: Either LPD or Efficacy and use of PhotoSensor

Common Areas	Maximum LPD (W/m^2)	Minimum luminous efficacy (lm/W)
Corridor lighting & Stilt Parking	3.0	All the permanently installed lighting fixtures shall use lamps with an efficacy of at least 105 lumens per Watt
Basement Lighting	1.0	All the permanently installed lighting fixtures shall use lamps with an efficacy of at least 105 lumens per Watt

Exterior Lighting Areas	Maximum LPD (in W/m^2)
Driveways and parking (open/ external)	1.6
Pedestrian walkways	2.0
Stairways	10.0
Landscaping	0.5
Outdoor sales area	9.0

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Prescriptive Method

3. **Elevators, if applicable::**
   - Lamps: 85l/W
   - Automatic switch off control
   - IE4 motors
   - VFDs
   - Regenerative drives
   - Group Automatic operation

4. **Pumps, if applicable**: Min Eff -70% or BEE 5 Star
5. **Electrical System, if applicable**:
   - Distribution loss less than 3%
   - Dry Type Transformer - as mentioned in table
   - Oil Type Transformer – BEE 5 Star

Point System Method – ENS 2021 Compliance

Point System Method

Minimum Points - are a set of points that must be obtained for each component in order to demonstrate ENS compliance

Additional Points - These are the points provided for implementing additional or improved energy efficiency measures in a component. These points can be combined with others to get the total score for ENS compliance described in section 3.1.2.

The total points available for each component are the **maximum points.**

Components	Minimum Points	Additional Points	Maximum Points
Building Envelope	47	40	87
Building Services			
Common area and exterior lighting	3	6	9
Elevators	13	9	22
Pumps	6	8	14
Electrical Systems	1	5	6
Indoor Electrical End-Use			
Indoor Lighting		12	12
Comfort Systems		50	50
ENS Score	70	130	200

Point System Method – ENS 2021 Compliance

1 - Building Envelope (87 Max Points out of which 47 are essential)

- Thermal Transmittance of Roof (7 Points)
- RETV (80 Points)

Thermal Transmittance of Roof	
Minimum: Thermal transmittance of roof shall comply with the maximum Uroof value of 1.2 W/m2·K.	Up to 4 Points
Additional: 1 Point for every reduction of 0.23 W/m2·K in thermal transmittance of roof from the Minimum requirement prescribed under §6.1(a).	Maximum 3 Points

RETV	
The RETV for the building envelope (except roof) for four climate zones, namely, Composite Climate, Hot-Dry Climate, Warm-Humid Climate, and Temperate Climate, shall comply with the maximum RETV of 15 W/m2.	44 Points
For RETV less than 15 and upto 12 W/m2, score will be calculated by following equation: 74 – 2 x (RETV) (@2 points per RETV reduction)	Up to 50 Points
Additional: For RETV less than 12 and upto 6 W/m2, score will be calculated by following equation: 110 – 5 x (RETV) (@ 5 points per RETV reduction)	Up to 80 points
Additional: For RETV less than 6 W/m2	80 Points

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Point System Method – ENS 2021 Compliance

2 – Common Area and Exterior Lighting (9 Points)

Common Areas	Maxm LPD (W/m^2)	Minimum luminous efficacy (lm/W)
Corridor lighting & Stilt Parking	3.0	All the permanently installed lighting fixtures shall use lamps with an efficacy of at least 85 lumens per Watt
Basement Lighting	1.0	All the permanently installed lighting fixtures shall use lamps with an efficacy of at least 85 lumens per Watt

Exterior Lighting Areas - at least 85 lm/W and maximum LPD requirements given in Table	Maximum LPD (in W/m^2)
Driveways and parking (open/ external)	1.6
Pedestrian walkways	2.0
Stairways	10.0
Landscaping	0.5
Outdoor sales area	9.0

Additional Points (6 points)	
Corridor lighting & Stilt Parking	1 Point for installing 95 lm/W Or 2 Point for installing 105 lm/W
Basement Lighting	1 Point for installing 95 lm/W Or 2 Point for installing 105 lm/W
Exterior Lighting Areas	2 Points for Installing photo sensor or astronomical time switch

Point System Method – ENS 2021 Compliance

3 – ELEVATORS (22 Points)

Minimum:

Elevators installed in the ENS building shall meet all the following requirements:

i. **Install high efficacy lamps for lift car lighting having minimum luminous efficacy of 85 lm/W**

ii. **Install automatic switch-off controls for lighting and fan inside the lift car when are not occupied**

iii. **Install minimum class IE 3 high efficiency motors**

iv. **Group automatic operation of two or more elevators coordinated by supervisory control**

13 Points

Additional:

i. Additional points can be obtained by meeting the following requirements:

ii. Installing the variable voltage and variable frequency drives. (4 points)

iii. Installing regenerative drives. (3 points)

iv. Installing class IE4 motors. (2 points)

9 Points

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Point System Method – ENS 2021 Compliance

4 – Pumps (14 Points)

Minimum: **Either hydro-pneumatic pumps having minimum mechanical efficiency of 60% or BEE 4 star rated Pumps shall be installed in the ENS building.**	**6 Points**
Additional points can be obtained by meeting the following requirements: i. Installation of BEE 5 star rated pumps (5 Points) ii. Installation of hydro-pneumatic system for water pumping having minimum mechanical efficiency of 70% (3 Points)	**8 Points**

Point System Method – ENS 2021 Compliance

5 – Electrical Systems (6 Points)

Minimum: **i. Power transformers of the proper ratings and design must be selected to satisfy the minimum acceptable efficiency at 50% and full load rating. The permissible loss shall not exceed the values listed in Table 8 for dry type transformers and BEE 4-star rating in Table 9 for oil type transformers.**	**1 Points**
Additional points can be obtained by providing all oil type transformers with BEE 5 star rating.	5 Points

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Point System Method – ENS 2021 Compliance

6 – Indoor Lightings (12 Points)

Minimum: **All the lighting fixtures shall have lamps with luminous efficacy of minimum 85 lm/W installed in all bedrooms, hall and kitchen.**	**4 Points**
Additional points for indoor lighting by installing all lighting fixtures in all bedrooms, hall and kitchen shall have lamps luminous efficacy as per following: i. 95 lm/w (3 Points) ii. 105 lm/W (8 Points)	Upto 8 Points

Point System Method – ENS 2021 Compliance

7 – Comfort Systems (50 Points) – Ceiling Fans

Minimum: **i. All ceiling fans installed in all the bedrooms and hall in all the dwelling units shall have a service value as given below:** • **For sweep size <1200 mm: equal or greater than 4 m3/minute·Watt** • **For sweep size >1200 mm: equal or greater than 5 m3/minute·Watt** **i. BEE Standards and Labeling requirements for ceiling fans shall take precedence over the current minimum requirement, as and when it is notified as mandatory.**	**6 Points**
Additional:	
Additional points for ceiling fans by installing in all the bedrooms and hall in all the dwellingunits as per following:	
i. 4 Star	1 Points
ii. 5 Star	3 Points

Point System Method – ENS 2021 Compliance

Weighted Average of different Comfort Systems installed in a building allowed for better flexibility (Points Achieved for AC)

Minimum: **i. Unitary Type: 5 Star** **ii. Split AC: 3 Star** **iii. VRF: 3.28 EER** **iv. Chiller: Minimum ECBC Level**	**20 Points**
Additional 9 points for : i. Split AC: 4 Star ii. VRF: Not Applicable as on date, however, whenever Star labelling of BEE is launched, Star 4 will be applicable iii. Chiller: Minimum ECBC+ Level as mentioned in ECBC 2017	**9 Points**
Additional 21 points for : i. Split AC: 5 Star ii. VRF: Not Applicable as on date, however, whenever Star labelling of BEE is launched, Star 5 will be applicable iii. Chiller: Minimum SuperECBC Level as mentioned in ECBC 2017	**21 Points**

Point System Method – ENS 2021 Compliance

8 – Solar Water Heating (10 Points)

Minimum: **The ENS compliant building shall provide a solar water heating system (SWH) of minimum BEE 3Star label and is capable of meeting 100% of the annual hot water demand of top 4 floors of the residential building.** **or** **100% of the annual hot water demand of top 4 floors of the residential building is met by the system using heat recovery**	**5 Points**
Additional: Additional points can be obtained by installing SWH system as per as per following: i. 100% of the annual hot water demand of top 6 floors of the residential building (2 points) ii. 100% of the annual hot water demand of top 8 floors of the residential building (5 points)	Upto 5 Points

Point System Method – ENS 2021 Compliance

9 – Solar Photo Voltaic (10 Points)

Minimum: **The ENS compliant building shall provide a dedicated Renewable Energy Generation Zone (REGZ) –** • **Equivalent to a minimum of 2 kWh/m2.year of electricity; or** • **Equivalent to at least 20% of roof area.** **The REGZ shall be free of any obstructions within its boundaries and from shadows cast by objects adjacent to the zone.**	**5 Points**
Additional: Additional points can be obtained by installing solar photo voltaic as per following: i. Equivalent to a minimum of 3 kWh/m2.year of electricity or Equivalent to at least 30% of roof area (2 points) ii. Equivalent to a minimum of 4 kWh/m2.year of electricity or Equivalent to at least 40% of roof area (5 points)	Upto 5 Points

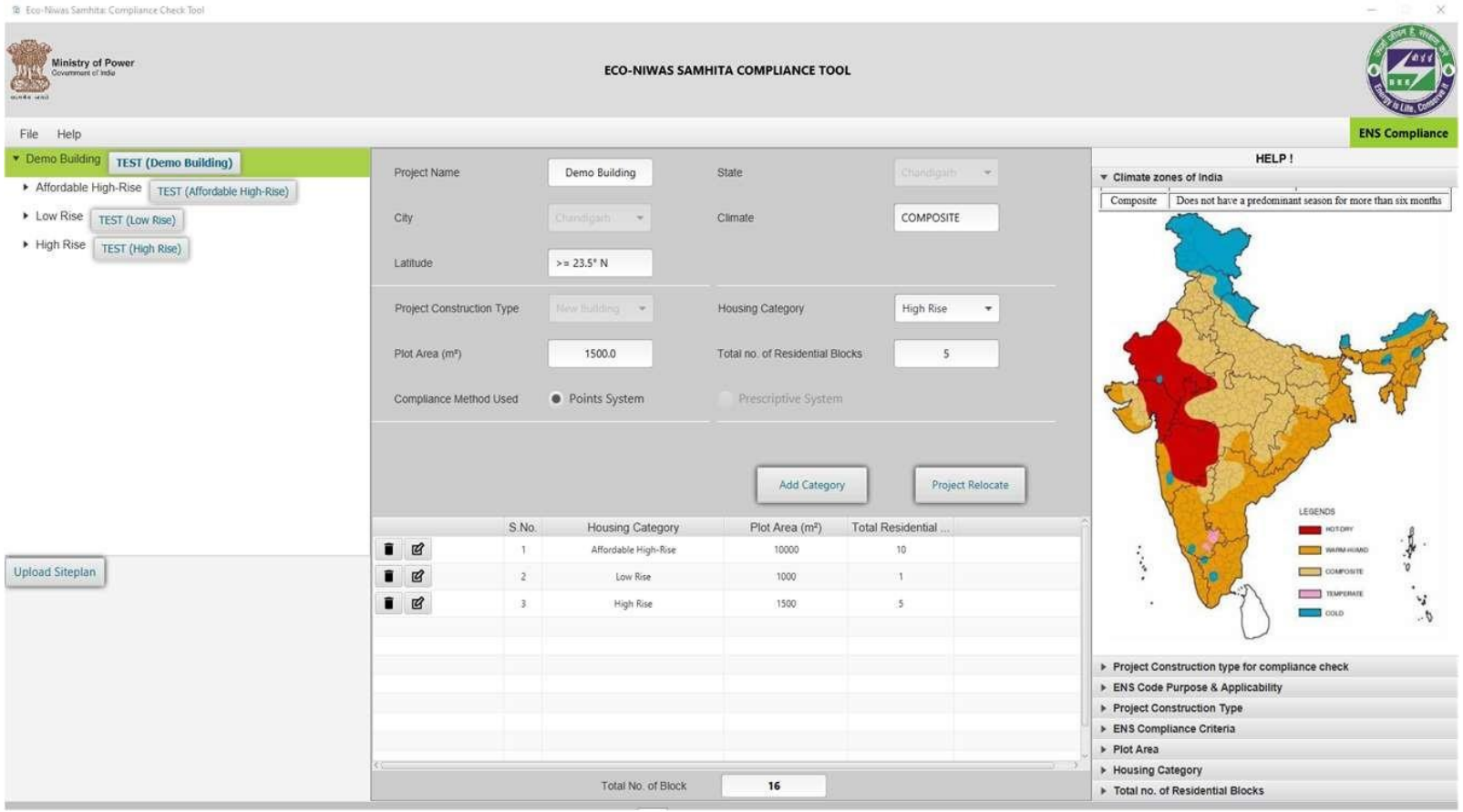
Introduction

- Quick design and compliance checks benchmarks of ECONIWAS SAMHITA.
- 5 key features in consideration:

1. User friendliness
2. Responsiveness
3. Adaptability
4. Dynamism
5. Resourcefulness.

- Compliance for Both Prescriptive and Points Based Systems.
- Categories included:

1. High rise
2. Low Rise
3. Affordable
4. Mixed Use



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ENS Compliance Tools Key Features

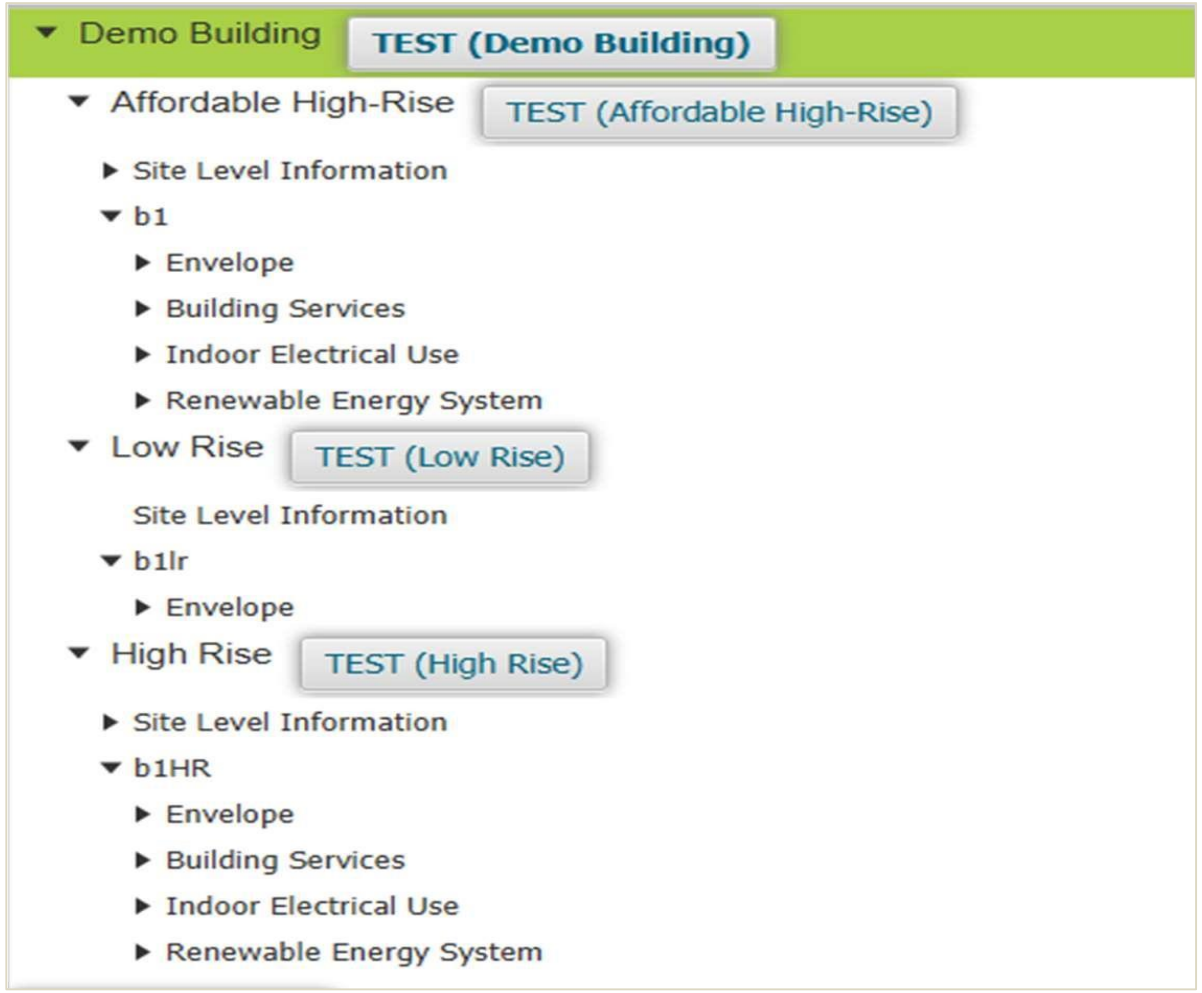
- Provisions for multiple housing category addition for compliance evaluation

	S.No.	Housing Category	Plot Area (m²)	Total Residential Block	
	1	Affordable High-Rise	10000	10	
	2	Low Rise	1000	1	
	3	High Rise	1500	5	

Total No. of Block **16**

ENS Compliance Tools Key Features

- Easy to navigate tree-view structure



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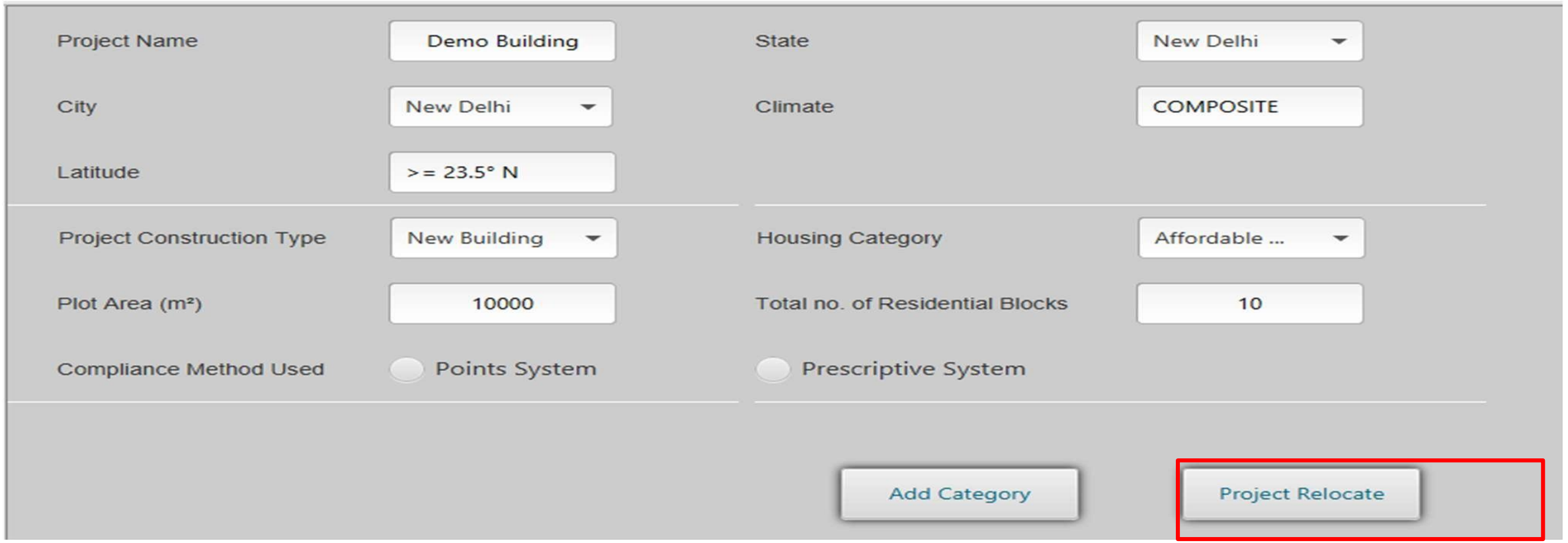
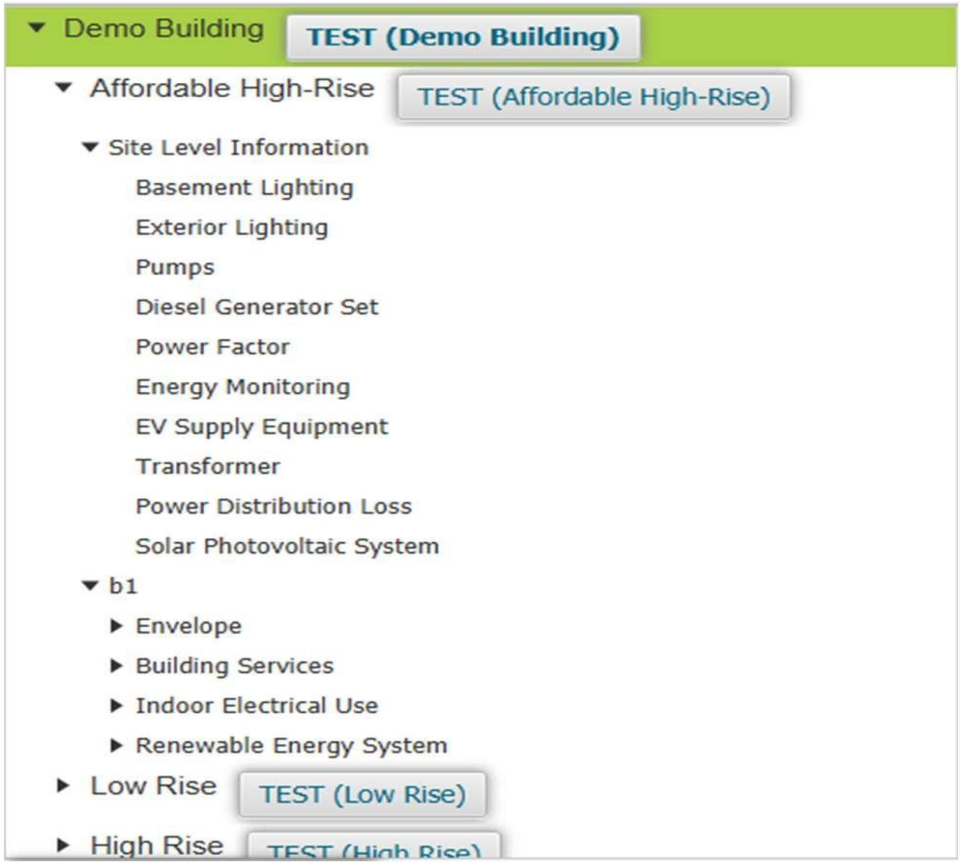
ENS Compliance Tools Key Features

- Project relocation feature for multiple domain use

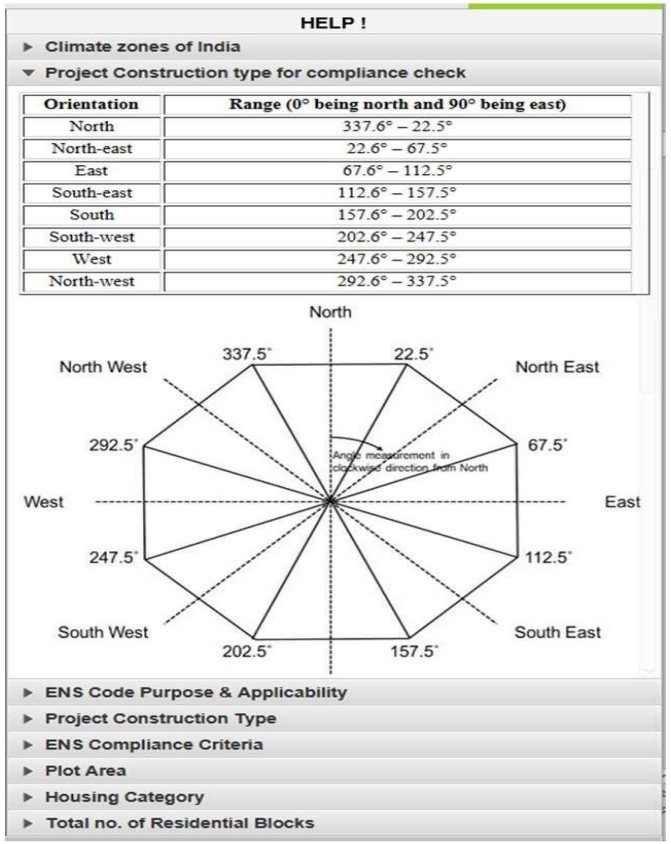


ENS Compliance Tools Key Features

- Segregated site level & block level inputs for ease in information flow

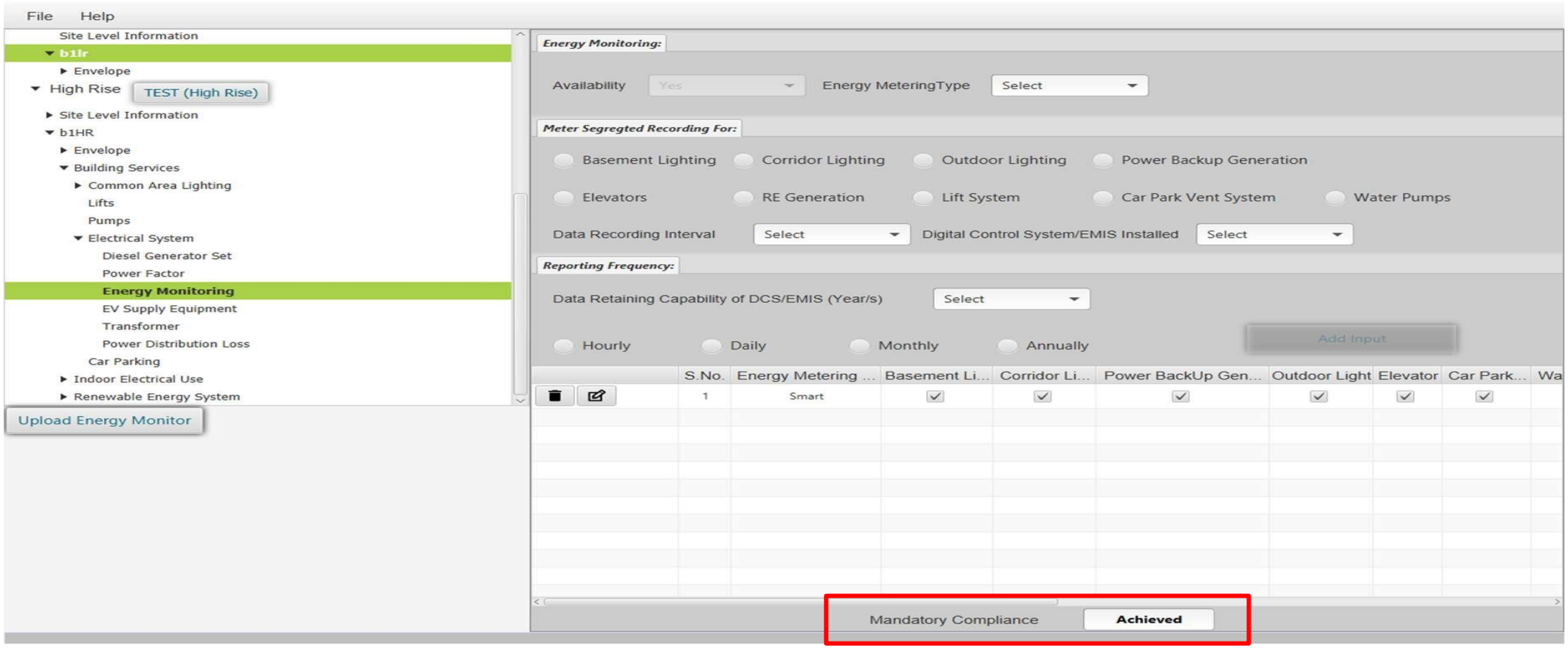


- Comprehensive help panel on each form for easy user referencing

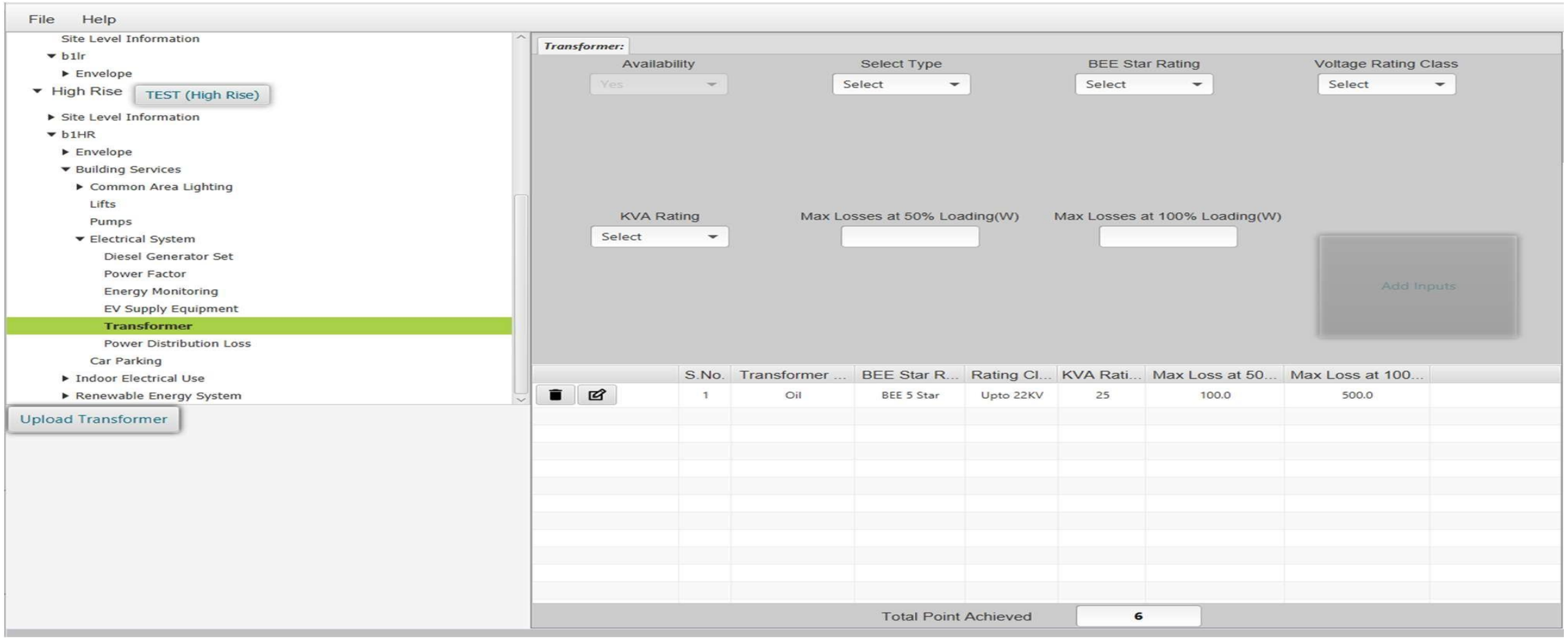


ENS Compliance Tools Key Features

- Component level display for mandatory provisions and points achieved



ENS Compliance Tools Key Features



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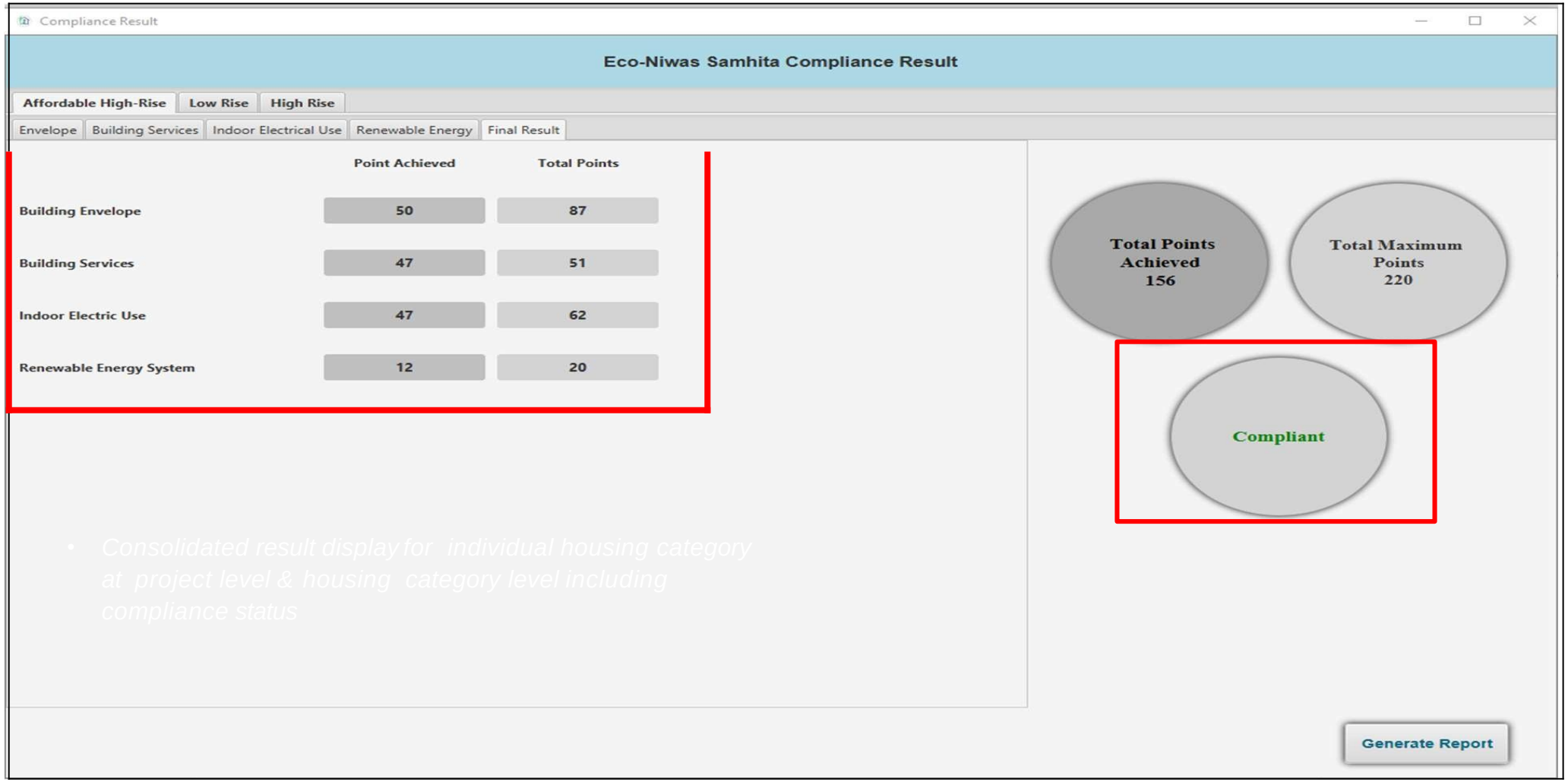
ENS Compliance Tools Key Features



- *Consolidated result display for individual housing category at project level & housing category level including compliance status*

ENS Compliance Tools Key Features

- Provisions for PDF output reporting for each input and corresponding output

Eco-Niwas Samhita: Compliance Check Report

ECO-NIWAS SAMHITA (ENS) COMPLIANCE EVALUATION REPORT

Project Information

Project Name	Demo Building
State	Chandigarh
City	Chandigarh
Climate	COMPOSITE
Latitude	>= 23.5° N
Building Construction Type	New Building
Compliance Method Used	Point System

Housing Category Information

Housing Category	Plot Area(m²)	Total No. of Residential Blocks	Total Basement Area(m²)	Total Exterior Light Area(m²)	Total Roof Area(m²)
Affordable High-Rise	10000	10	1000.0	1000.0	1000.0
Low Rise	1000	1	1000.0	1000.0	1000.0
High Rise	1500	5	100.0	100.0	100.0

Eco-Niwas Samhita: Compliance Check Report

Consolidated Compliance Status of the Project:

S.No.	Housing Categories	Total Points	Maximum Points	Minimum Points	Compliance Status
1	Affordable High-Rise	156	220	70	Compliant
2	Low Rise	53	87	47	Compliant
3	High Rise	82	220	100	Non Compliant

Eco-Niwas Samhita: Compliance Check Report

1. Affordable High-Rise : Compliance Result

1.1. Building Envelope:

S.No.	Component	Mandatory Requirements	Calculated value	Points Achieved	Maximum Points
1	RETV(W/m².K)	NA	14.59	44	80
2	U-Value Roof(W/m².K)	NA	0.53	6	7
3	WFRop	Achieved	32.0	NA	NA
4	VLT %	Achieved	60.0	NA	NA

1.2. Building Services:

S.No.	Component	Mandatory Requirements	Calculated value	Points Achieved	Maximum Points
1	Exterior Lighting	NA	--	3	3
2	Basement Lighting	NA	--	2	3
3	Corridor Lighting	NA	--	3	3
4	Lift	NA	--	22	22
5	Pump	NA	--	11	14
6	Diesel Generator Sets	Achieved	--	NA	NA
7	Power Factor Correction	Achieved	--	NA	NA
8	Energy Monitoring System	Achieved	--	NA	NA
9	Electric Vehicle Supply Equipment	Achieved	--	NA	NA
10	Transformer	NA	--	6	6
11	Power Distribution Loss	Achieved	--	NA	NA
12	Car Parking Basement Ventilation	Achieved	--	NA	NA

1.3. Indoor Electrical End Use:

S.No.	Component	Mandatory Requirements	Calculated value	Points Achieved	Maximum Points
1	Indoor Lighting	NA	--	12	12
2	Ceiling Fan	NA	--	7	9
3	Cooling Equipment	NA	--	28	41

1.4. Renewable Energy System:

S.No.	Component	Mandatory Requirements	Calculated value	Points Achieved	Maximum Points
1	Solar Hot Water Requirements	NA	--	7	10
2	Solar Photovoltaic System	NA	--	5	10

Dr. Arijit Ghosh 20-5-2022

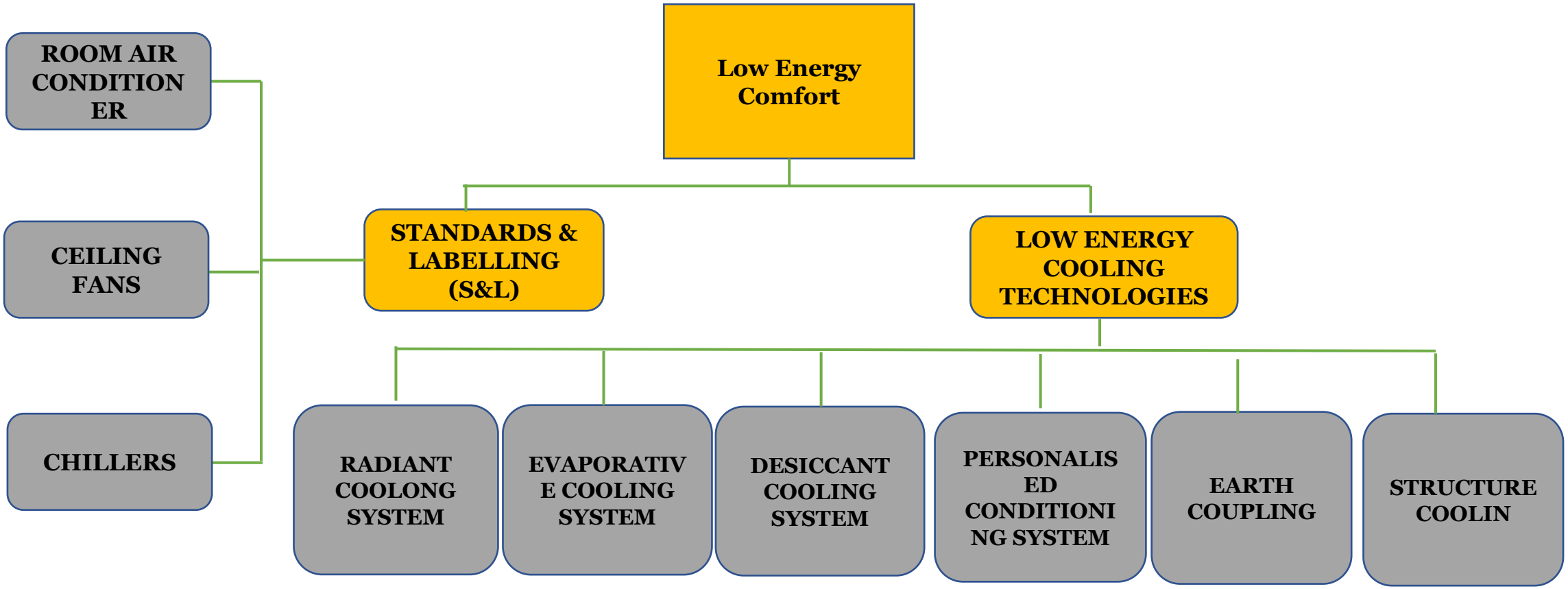
Thank you all once again for your kind attention

05-A

LOW ENERGY

COMFORT SYSTEM IN HOUSING

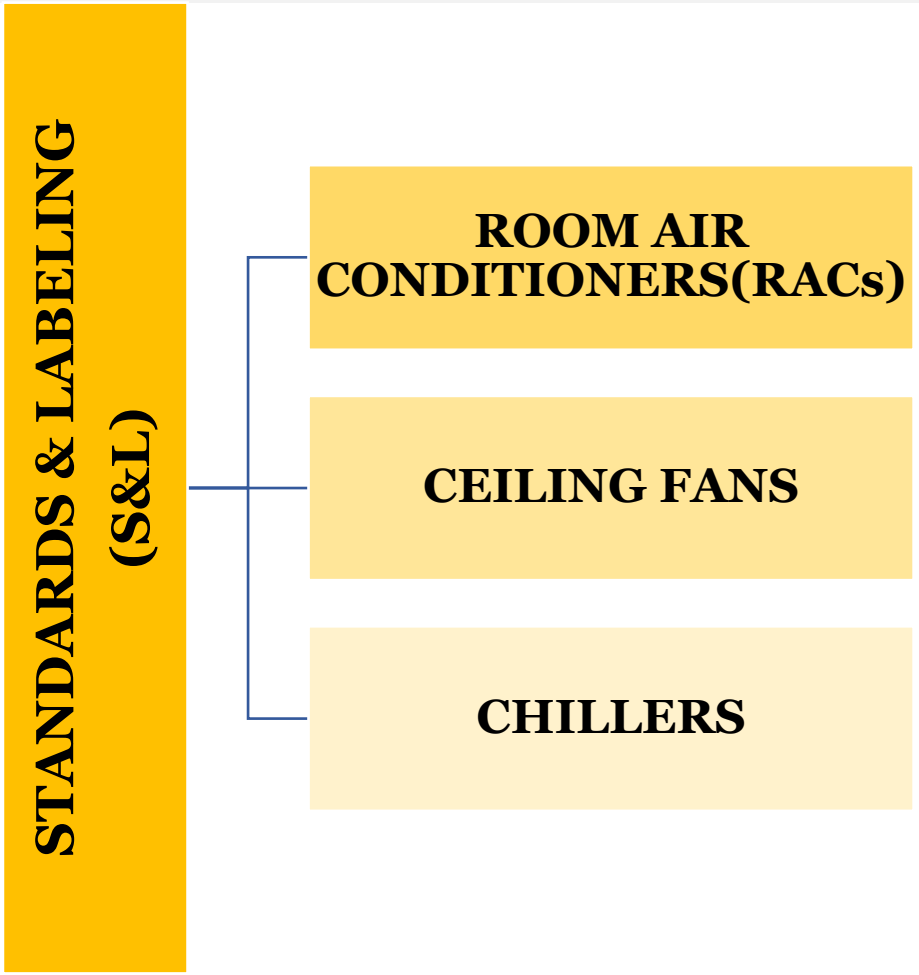
Low Energy Comfort System in Housing



Standards & Labeling (S&L)

S&L assists consumers in making educated decisions about appliance energy usage and promotes the market penetration of energy efficient appliances and equipment. BEE established the S&L program in 2006.

RACs are the only space cooling appliance under the mandatory labeling scheme. Ceiling fans and variable speed ACs are under the voluntary labeling scheme.



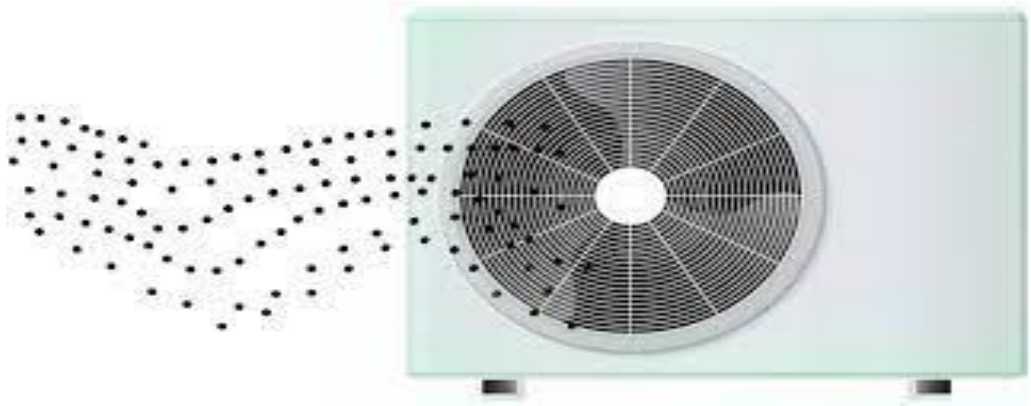
Standards & Labeling (S&L)

1 - ROOM AIR CONDITIONERS (RACs):

For variable capacity (inverter type) ACs, BEE established a new star grading technique called the Indian Seasonal Energy Efficiency Ratio (ISEER) in 2015.

This metric, which is based on the ISO-16358 standard with revisions to account for India's higher outdoor temperature ranges, will be used instead of the Energy Efficiency Ratio (EER).

ISEER takes into account the range of temperatures in Indian climate zones throughout the year to produce a more realistic estimate of cooling efficiency for the full year.



Standards & Labeling (S&L)

BEE star rating levels for inverter ACs effective from June 2015 through December 2019 (BEE, 2015)

STAR RATING	MINIMUM ISEER	MAXIMUM ISEER
1 – Star	3.10	3.29
2 – Star	3.30	3.49
3 – Star	3.50	3.99
4 – Star	4.00	4.49
5 – Star	4.50	-

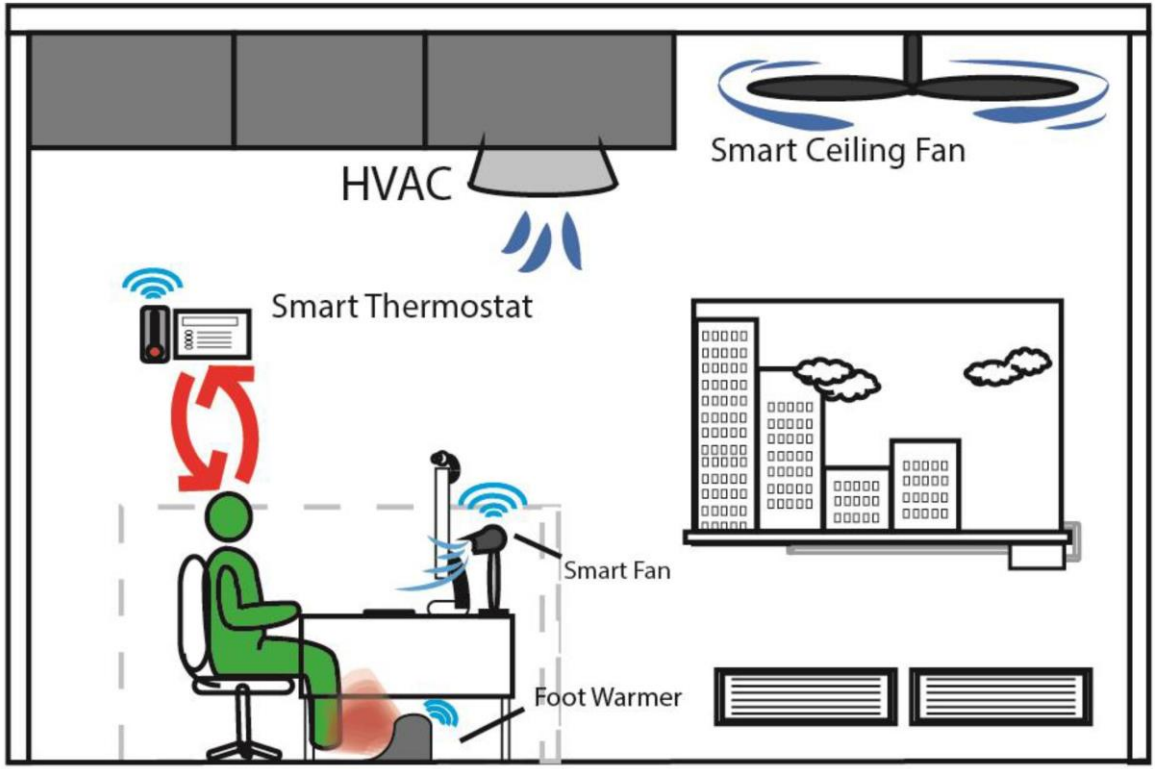
Standards & Labeling (S&L)

2 - CELING FANS:

Ceiling fans consumed 6% of the energy consumed by residential buildings in 2000, and are predicted to consume 9% by 2020 due to an increase in the number of ceiling fans installed.

Fan effectiveness, rather than efficiency, is a phrase used to describe the volume of air provided per minute per unit of power (m^3 /minute/W) delivered by a ceiling fan.

Both the BIS and the BEE give ratings to fans.



3 - CHILLERS:

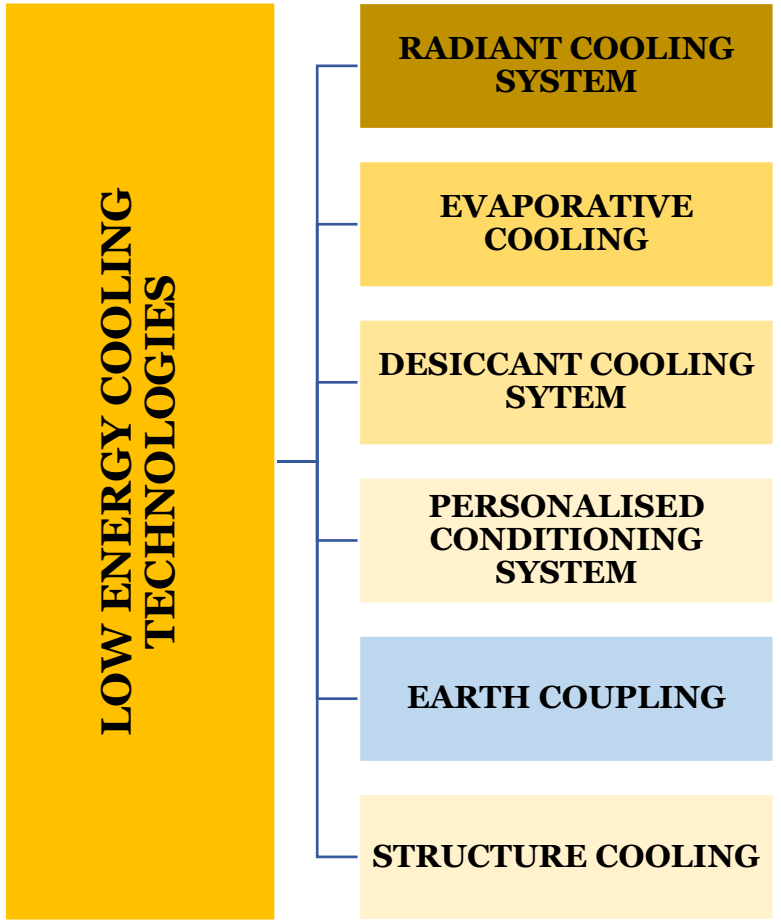
ECBC (version 2) sets minimum chiller performance efficiency based on Air-conditioning, Heating, and Refrigeration Institute (AHRI) standards that provide test circumstances more reflective of climate in the United States and Europe.

Recognizing the significance of the chiller standard, the ISHRAE has undertaken the responsibility of designing chiller test conditions. The standard, created collaboratively by ISHRAE and the RAMA, establishes a new set of rating and performance testing parameters (temperature, part load weightages, and fouling conditions) for both air and water cooled chillers.

ISHRAE has also created a standard for evaluating and testing variable refrigerant flow (VRF) systems.

Low Energy Cooling Technologies

These are energy-efficient cooling systems that are not commonly used. These can be utilized as stand-alone cooling systems or in conjunction with traditional air conditioning systems.



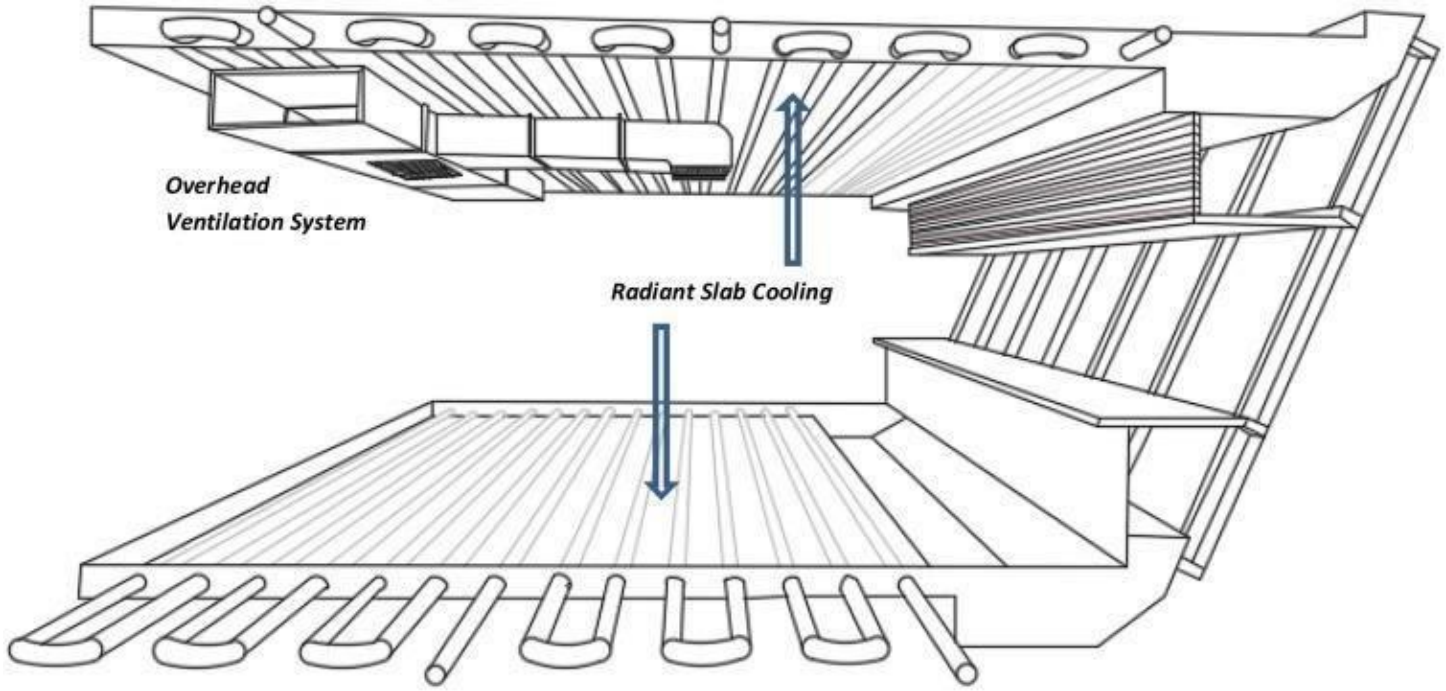
Low Energy Cooling Technologies

1 - RADIANT COOLING SYSTEM:

Radiant cooling makes use of actively cooled surfaces to enhance thermal comfort by transferring heat from the human body to the cooled surface via radioactive heat transfer.

Radiant-based HVAC systems absorb heat from the room, which is then removed by chilled water flowing through pipes installed in the floors, walls, or ceilings, or through externally fixed wall and ceiling panels.

The technique makes advantage of water's far higher thermal capacity than air.



2 - EVAPORATIVE COOLING:

The evaporative cooling technology is based on heat and mass transfer between air and cooling water

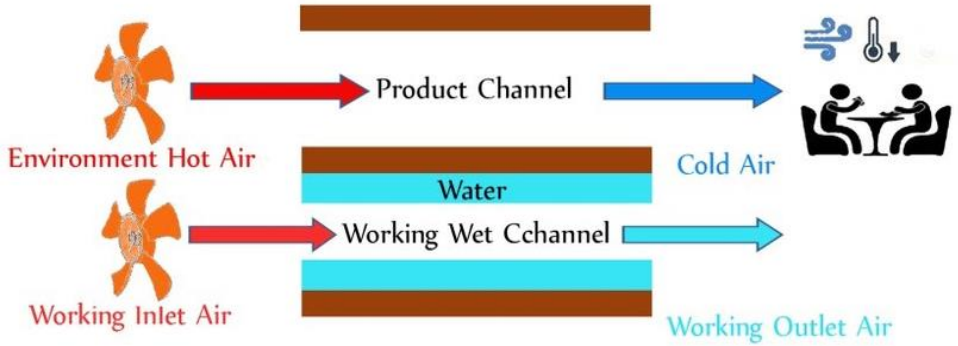
DIRECT EVAPORATIVE COOLING

It is based on mechanical and thermal contact between air and water

The Direct Evaporative Cooling System

INDIRECT EVAPORATIVE COOLING

It is based on heat and mass transfer between two streams of air, separated by a heat transfer surface with a dry side where only air is cooling and a wet side where both air and water are cooling



The Indirect Evaporative Cooling System

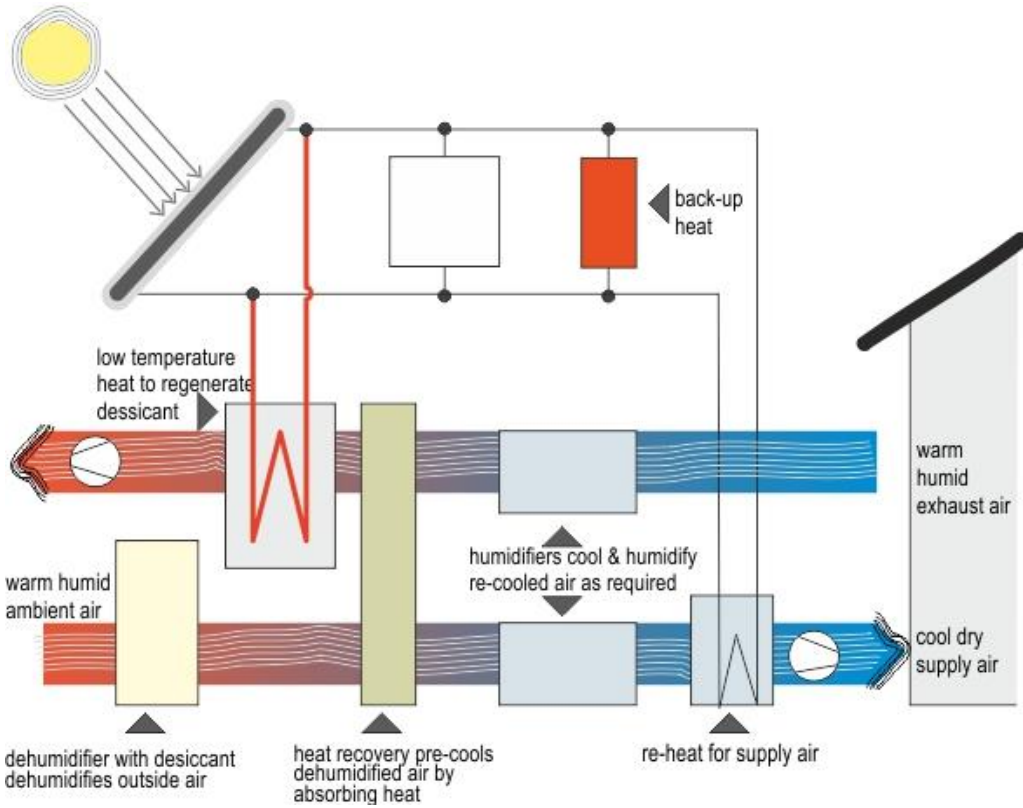
Low Energy Cooling Technologies

3 - DESICCANT COOLING SYSTEM:

A desiccant is a substance, either liquid or solid, which absorbs water molecules from the air and dehumidifies it.

DESICCANT COOLING SYSTEM

- **SOLID DESICCANT SYSTEM** — solid desiccant system where silica gel is used for a rotating bed of the wheel within the system
- **LIQUID DESICCANT SYTEM** — liquid desiccant system which consists of a contact surface, either a cooling coil or tower, wetted with liquid desiccant



The desiccant system also improves the quality of indoor air. Integration with traditional HVAC systems to remove latent heat can reduce cooling and heating energy usage by up to 30% and 5%, respectively.

Low Energy Cooling Technologies

PERSONALISED CONDITIONING SYSTEM

- A customized air-conditioning system at the office produces a microclimatic zone around a single occupant, ensuring that energy is only used where it is required.
- Because of its excellent localized energy utilization, this technology serves to improve thermal comfort for occupants while also reducing energy consumption.

EARTH COUPLING

- Due to the great thermal inertia of soil, the Earth maintains a relatively constant temperature just a few meters below the surface, which is less than the outside temperature in summer and higher in winter.
- By pumping or exchanging heat with the earth, geothermal technologies such as the Earth Air Tunnel Heat Exchanger (EATHE) and Ground Source Heat Pump (GSHP) utilize the earth's temperature stabilizing property to deliver central heating or cooling to a structure.

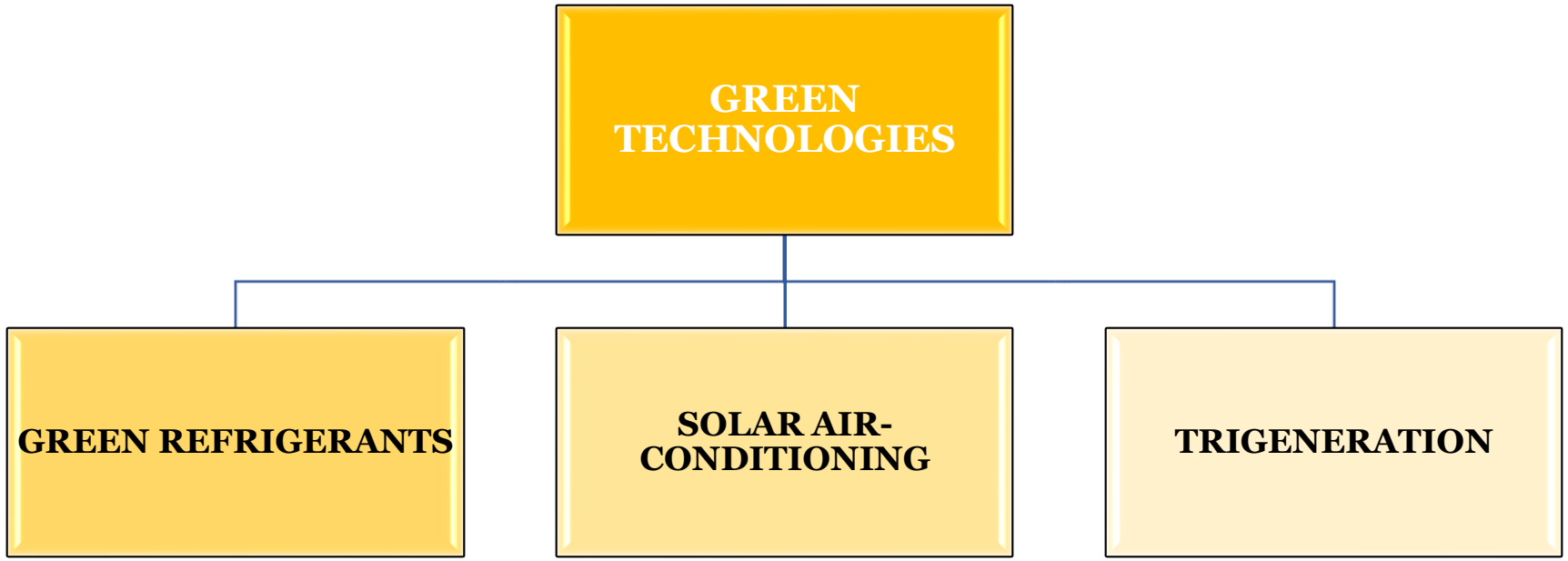
Low Energy Cooling Technologies

STRUCTURE COOLING

- By removing heat from the structure, structure cooling tries to lower the mean radiant temperature. This is accomplished by circulating water at room temperature through pipes implanted in slabs to drain heat from the building and prevent it from overheating. The larger thermal mass of water slows the transport of heat from the environment to the structure's innards.
- The heated water runs to the radiator, where it gives away the heat obtained and returns to the tank for recirculation, while the circulated water drains heat from the structure. Because it is a closed loop system, there is only one water requirement. There is no need to cold the water or use refrigerants; just the pump consumes energy.

Green Technologies

Green technology, such as RACs with green refrigerants, solar air-conditioning, and trigeneration, will have a significant influence on the environment if used wherever practical. India's energy security and contribution to minimizing climate change Changes in the climate.



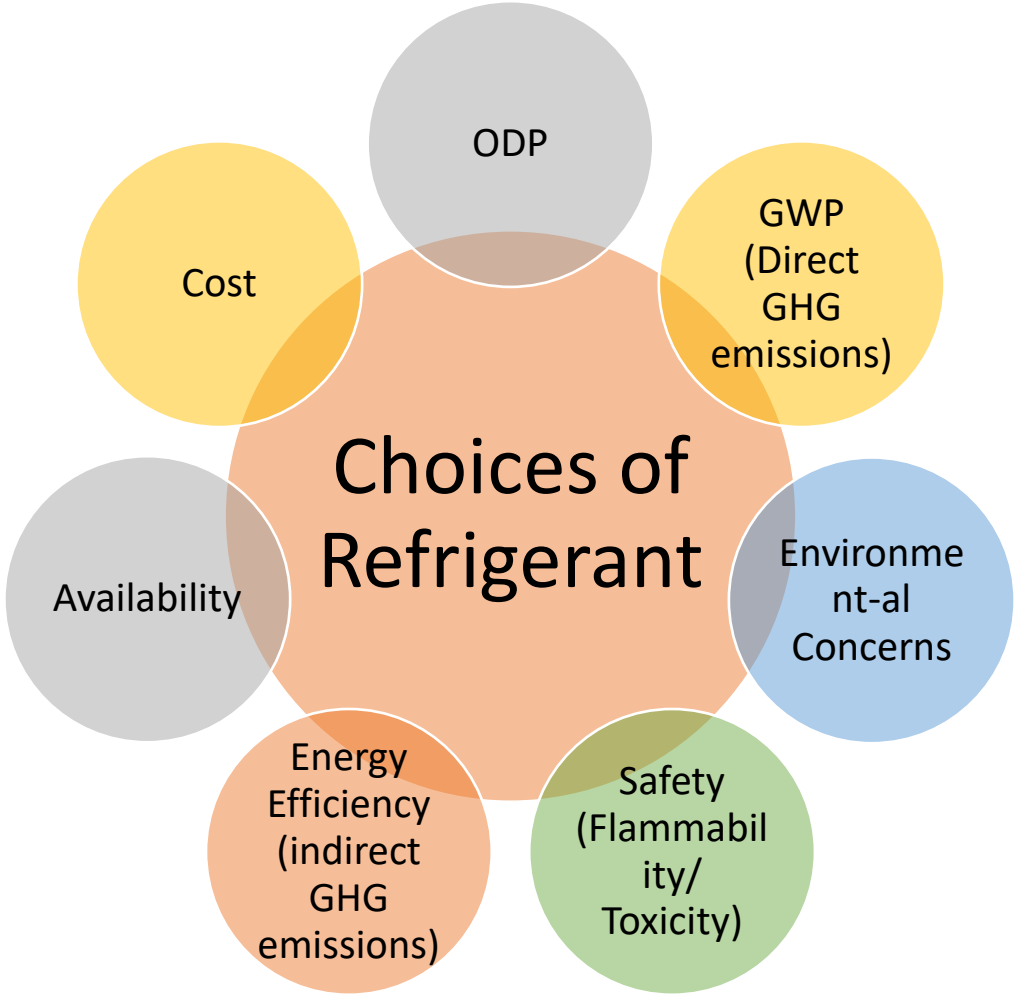
1 - GREEN REFRIGRANTS:

A green refrigerant would have the benefits of natural refrigerants and be energy efficient

Natural refrigerants have numerous advantages, including 0% ODP, a low GWP, participation in natural biogeochemical cycles, and the absence of permanent chemicals in the atmosphere, water, or biosphere. Carbon dioxide, ammonia, and hydrocarbons like propane, propene, and isobutene are among them. Natural refrigerants, like as isobutene in residential freezers and ammonia in big cooling systems, are commonly employed in various RAC applications.

One of the most significant issues with hydrocarbon-based natural refrigerants is the flammability, which can be mitigated by steps such as the use of appropriate materials, the selection of safe components, and operator training. CO2, a natural refrigerant, is inefficient in terms of energy use. When choosing a refrigerant, keep these considerations in mind. (2017, Green-cooling-initiative.org)

Green Technologies



A good refrigerant should be non-flammable, non-toxic, and odorless, with a very low GWP and no risk for ozone depletion.

Many next-generation refrigeration options are non-flammable and have an ultra-low GWP, making them suited for chiller applications with bigger refrigerant charge sizes, or non-flammable refrigerant mixes with a moderate GWP of less than 750.

The quickest way to accomplish environmental goals is to use non-flammable, low-GWP refrigerants in high-performance products.

Green Technologies

TYPES OF REFRIGERANTS AND THEIR GWP (ASSIMILATED FROM AEEE's SECONDARY RESEARCH

REFRIGERANT	GWP	ENERGY EFFICIENCY	COMPANIES	MARKET STATUS	COST
HCFC-22	High (1800)	High	All Phasing Out	GHG, scheduled for phase out under Montreal protocol	High
HFC-410a	High (1923)	Low	LG, Samsung, GE, Carrier	GHG, Ozone Safe	High
HFC-32	Medium (675)	High	Daikin, Fujitsu, Hitachi, Mitsubishi, Panasonic, Toshiba	Ozone Safe, Mildly flammable	Low
HC-290	Very Low (<5)	High	Godrej	Low GWP, best available for ozone safe in small room AC, highly flammable	Low
HFC BLENDS (DR7, L41, L20)	Medium (300-450)	Medium	DuPont, Honeywell	Low GWP, Low Flammable	Medium
HFOs	Very Low (<4)	Very High	In Research Phase	Environmental friendliness, cost-effectiveness	Low

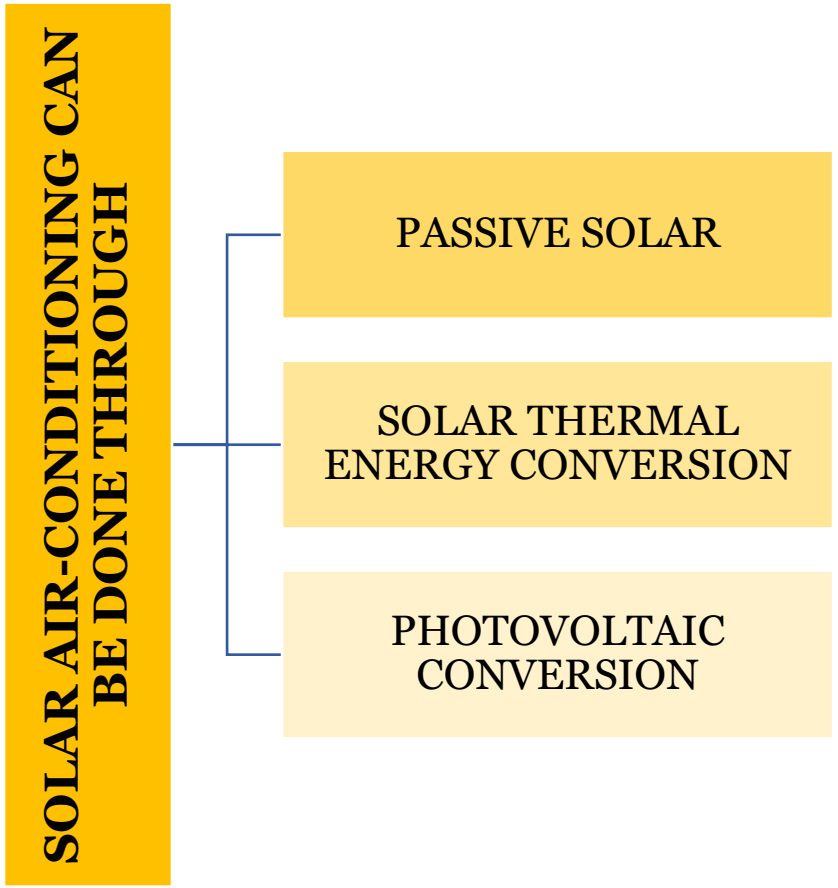
Green Technologies

2 - SOLAR AIR-CONDITIONING:

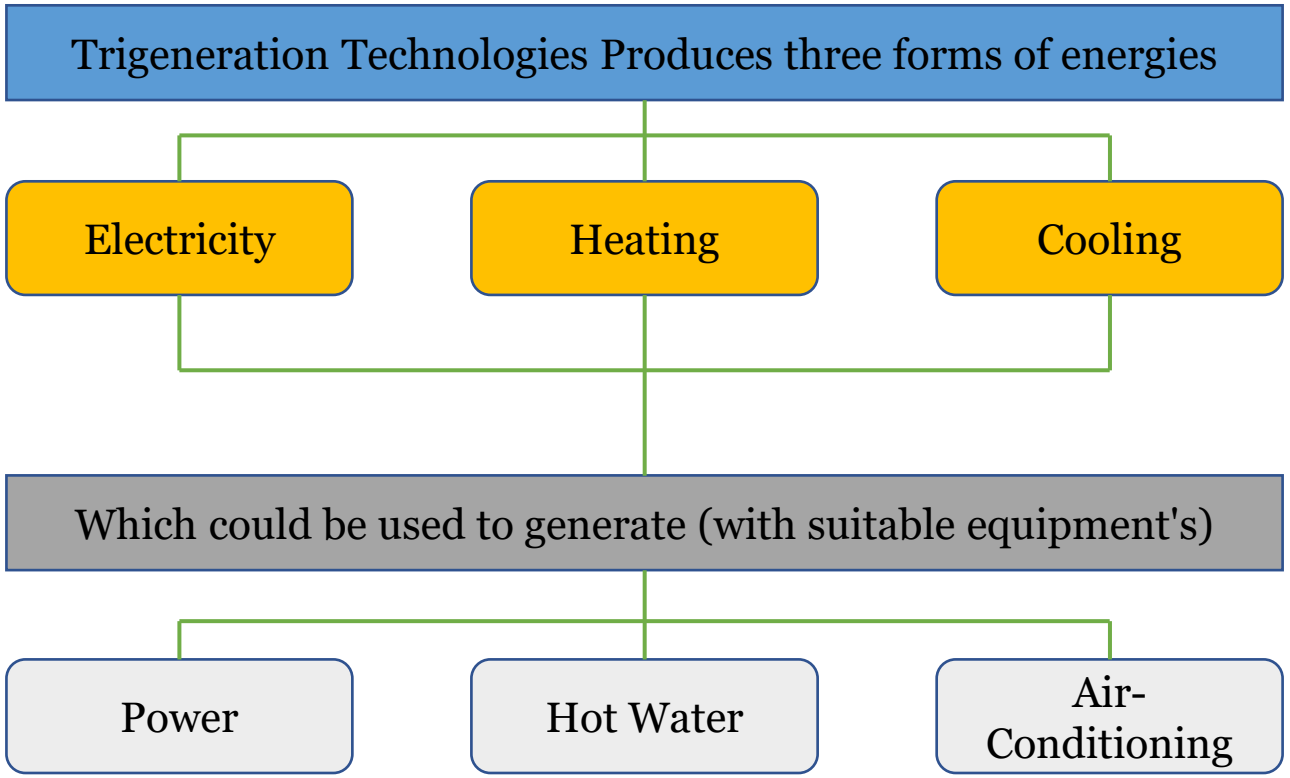
Solar air-conditioning refers to any air-conditioning system that uses solar power

The vapor absorption method is used to provide cooling in thermally operated chillers. Instead of employing compressors, desorption is used to enhance the refrigerant's vapor pressure and temperature. Chilled water is produced by thermally driven chillers, which is subsequently utilized to cool hot or warm areas of a building.

Solar absorption chillers have very cheap operating and maintenance expenses, and they use very little electricity. Solar air-conditioning has a current market potential of over 0.7 million TR and is growing at a pace of around 17% per year.



3 -TRIGENERATION:

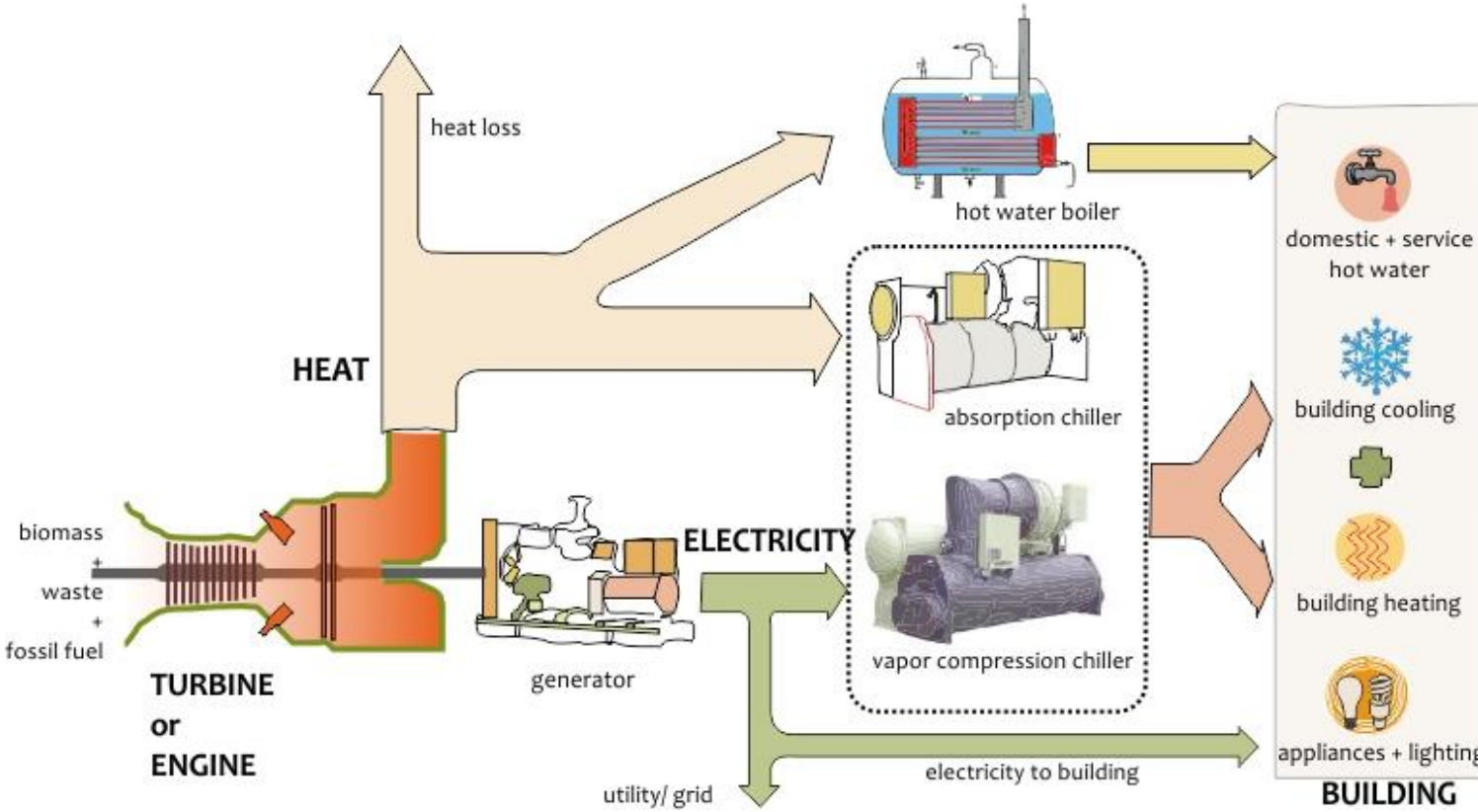


Green Technologies

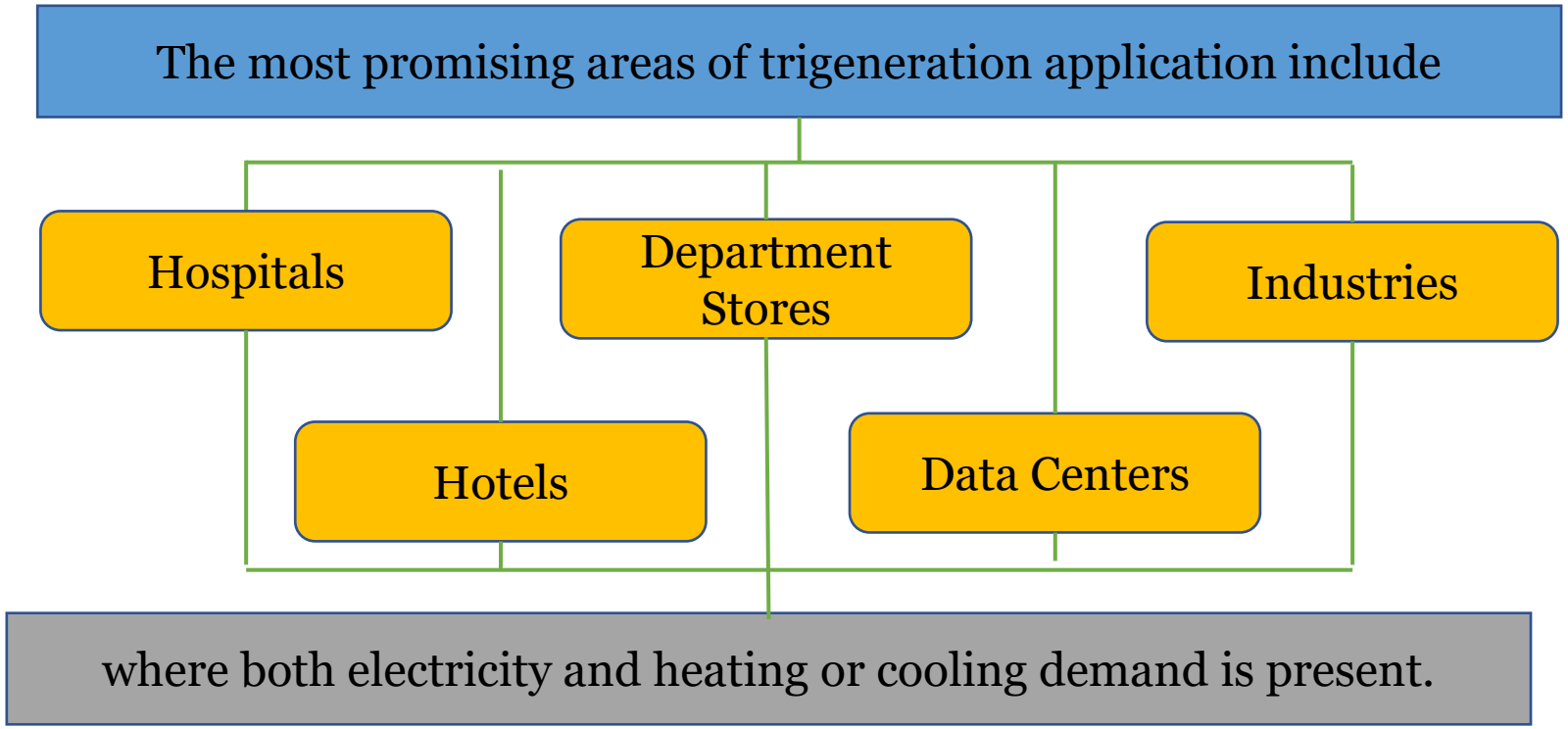
Absorption chillers can employ heat absorbed from waste burning, power generation with generators, or heat generated by solar panels to generate chilled water.

By utilizing a waste heat recovery system at the end user site, trigeneration systems can achieve great efficiency with no transmission losses.

If they can sell to the grid, they could potentially help India meet peak power demand and avoid harmful power outages.



Green Technologies



05-B

RESIDENTIAL STAR LABEL

Objectives of Star Labelling

Informing the user

Helping consumer make a informed decision while buying/leasing through the provision of direct, reliable and costless information

Assistance for Energy Efficiency

- Assist the home owner & building industry to identify the extent to which a new or existing house has the potential through design & construction to be of high efficiency via the design tool developed for the program

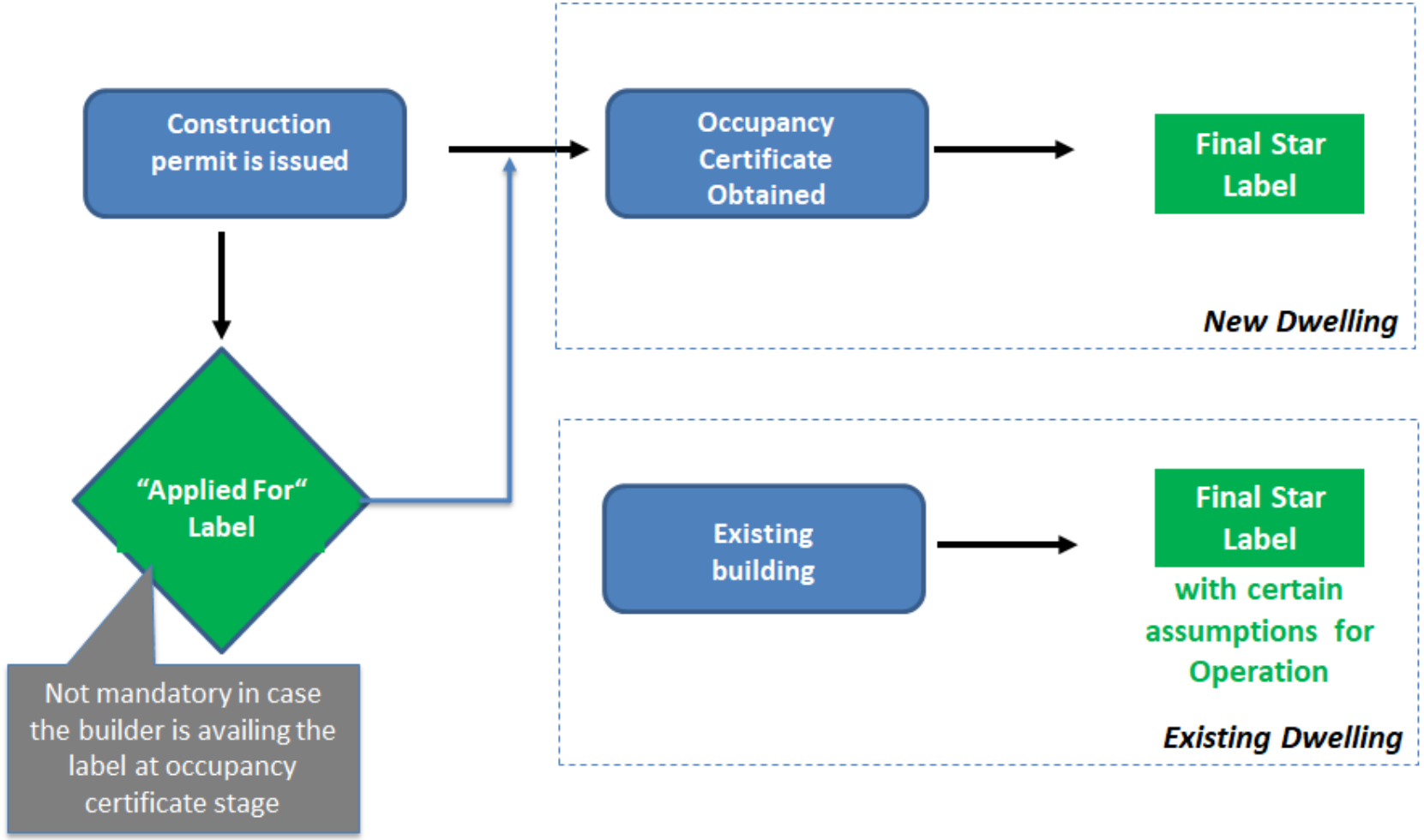
Market Transformation

Help transform the market by creating demand for energy efficient construction material and appliances and continue the process by scheduled revisions of labelling standards

Making Energy Efficient Homes

Make energy efficient homes to tackle the problem of growing power consumption in the sector which is projected to rise from 250 BU in 2018-19 to 700~ BU in 2030

Classification of labelling stages



Application processing stage

Label generation	New Dwelling stages			Existing Dwelling
	Developer	Developer	Owner	Owner
	"Applied For" Label	Final Star Label	Final Star Label	Final Star Label
Approval letter for the Label	Yes	Yes	Yes	Yes
Dwelling Passport (soft copy)	NA	Yes	Yes	Yes
Dwelling Name Plaque	NA	Yes	Yes	Yes

Star Rating Criteria & Calculation

Star Rating awarded in the basis on EPI (**Energy Performance Index**)

Energy Performance Index = Annual Energy Consumption (**kWh**)/Built up area (**m²**)

EPI Calculation = EPI for air conditioned spaces (~20% area) with 24 °C as set point (**E1**) with Air conditioner switched ON during occupied hours + EPI for other spaces (~80%) with natural ventilation (**E2**) set points defined by IMAC.
And EPI for other appliances: E3

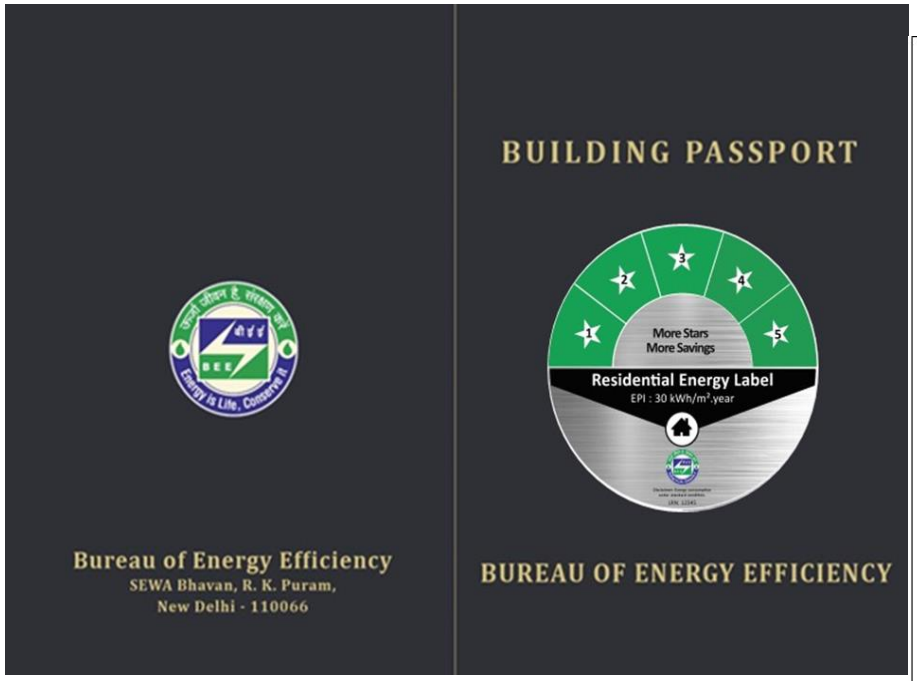
E1 & E2 includes following systems: Building envelope characteristics, Lighting system, and comfort system (AC)

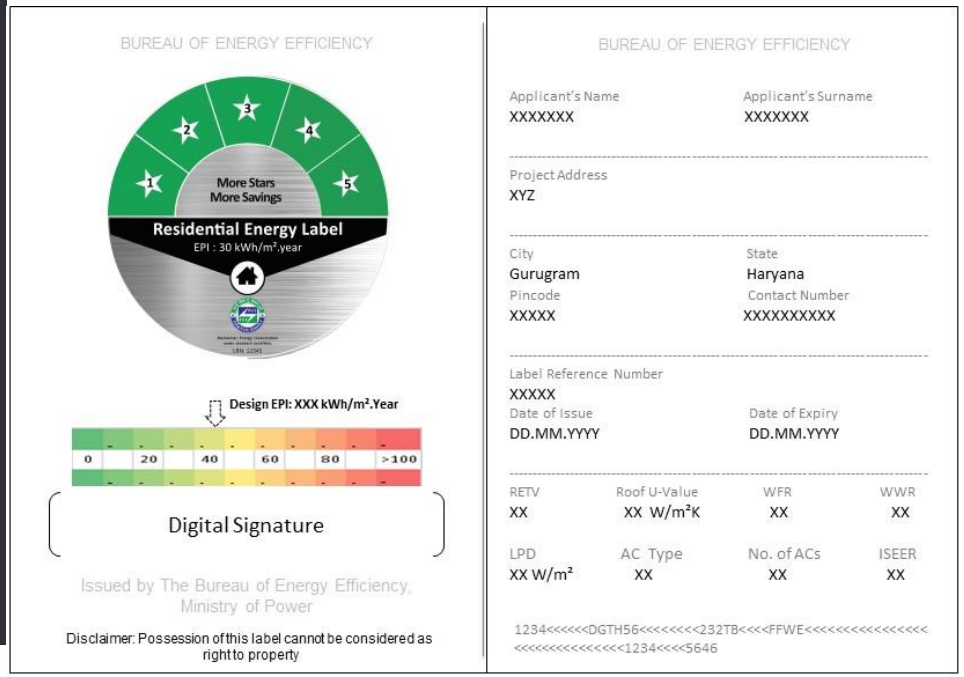
E3 includes appliances such as: Microwave oven, Grinder, , Refrigerators, TV, Water Pump, Washing Machine, etc.

Passport

The plaque will be provided to the applicant (developer / owner) of the respective residential dwelling upon approval of 'Final' label. The developer or owner would be required to submit request to BEE for the plaque.

Passport





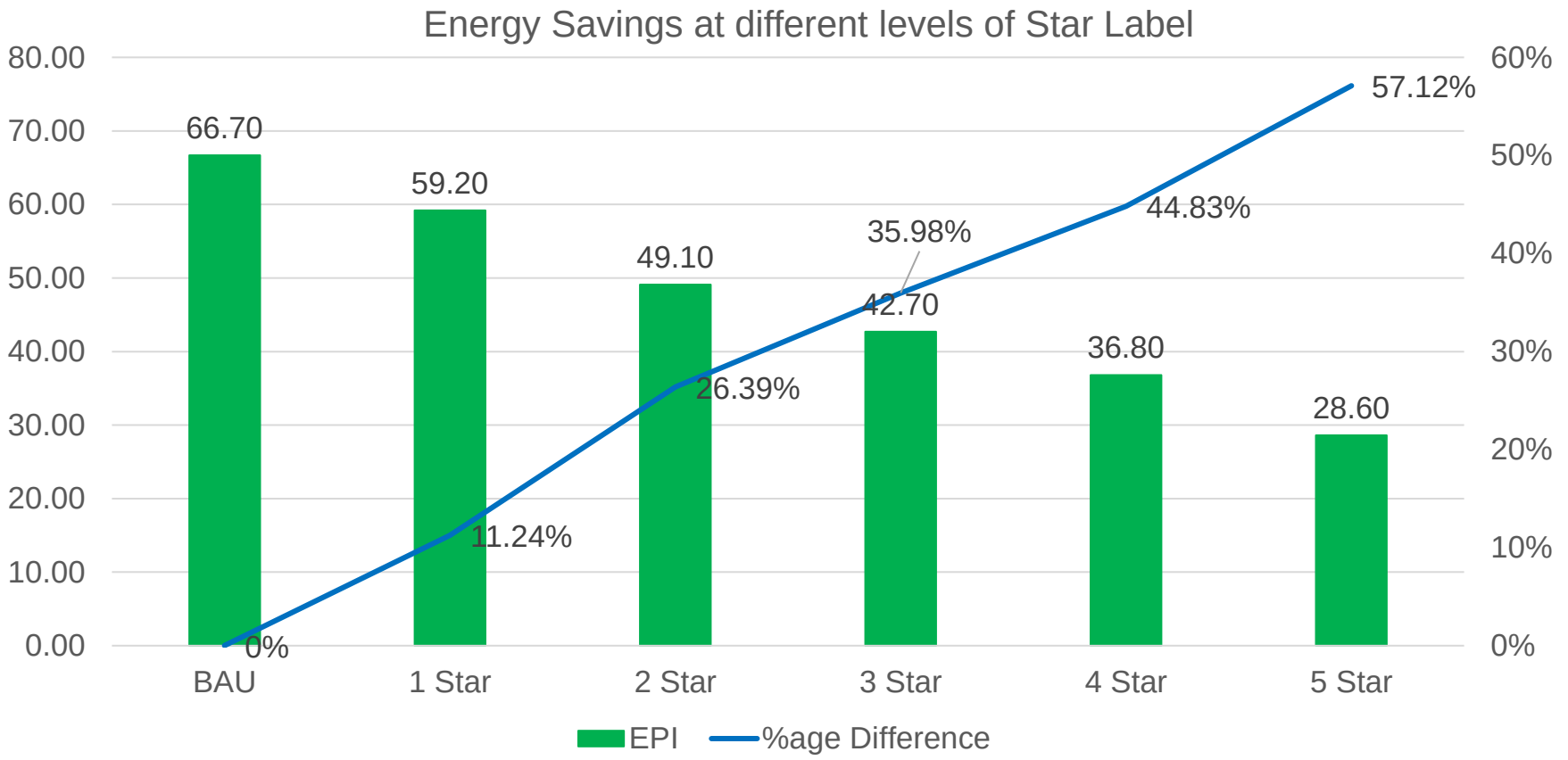
Upon approval from BEE, a building passport will be generated based on the details provided by label applicant.

The e-passport will be auto-emailed to the applicant

Indicative measures to achieve different star labels

Inputs	1 star	2 star	3 star	4 star	5 star
Wall U-Value (W/m². K)	**2.34 W/m².K (230mm Burnt Clay Brick)**	**1.78 W/m².K (230mm Flyash Brick + Plaster)**	**1.55 W/m².K (112.5mm Brick Wall + 50mm Air Gap + 112.5mm Brick Wall)**	**0.8 W/m².K (200mm AAC Block)**	**0.88 W/m².K (230mm Brick Wall + 25mm Insulation)**
Glass U-Value (W/m². K)	**5.8** W/m².K (Single Glazed Unit 6mm)	**5.8** W/m².K (Single Glazed Unit 6mm)	**1.76** W/m².K (6mm LowE Glass + 13mm Air + 6mm Clear Glass)	1.76 W/m².K (6mm LowE Glass + 13mm Air + 6mm Clear Glass)	**1.34** W/m².K (6mm LowE Glass + 13mm Air + 6mm Clear Glass)
SHGC	**0.82**	**0.82**	**0.57**	**0.57**	**0.57**
Roof U-Value (W/m². K)	**1.76** W/m².K (100mm RCC + 40mm Foam Concrete + 15mm Inner Plaster)	**1.76** W/m2.K (100mm RCC + 40mm Foam Concrete + 15mm Inner Plaster)	**1.76** W/m2.K (100mm RCC + 40mm Foam Concrete + 15mm Inner Plaster)	**1.02** W/m².K (150mm RCC + 25mm Insulation XPS + Brick Tile + 15mm inner plaster)	**0.7** W/m².K (150mm RCC + 40mm Expanded polystyrene + 15mm inner plaster)
AC ISEER	**3.1**	**3.5**	**3.5**	**4.0**	**4.5**
LPD (W/m²)	**3.0**	**2.0**	**2.0**	**2.0**	**1.4**
WWR	20%	15%	15%	15%	10%
EPI	**59.21**	**49.1**	**42.7**	**36.8**	**28.6**

Energy Savings at different star labels



This energy consumption reduction can be attributed to the reduced WWR at 15% compared to 25% for BAU case, a thermally efficient double-glazed unit, air cavity in the external wall assembly and a layer of foamed concrete in the roof

Residential Building Star Rating Plan

Hot & Dry

★	55 < EPI ≤ 67
★★	47< EPI ≤ 55
★★★	38< EPI ≤ 47
★★★★	29 < EPI ≤ 38
★★★★★	EPI ≤ 29

Warm & Humid

★	58<EPI≤64
★★	49<EPI≤58
★★★	39<EPI≤49
★★★★	30<EPI≤39
★★★★★	EPI≤30

Composite

★	52<EPI≤60
★★	45<EPI≤52
★★★	37<EPI≤45
★★★★	29<EPI≤37
★★★★★	EPI≤29

Temperate

★	28<EPI≤31
★★	24<EPI≤28
★★★	21<EPI≤24
★★★★	17<EPI≤21
★★★★★	EPI≤17

Scope & type of labelling Program: Bureau of Energy Efficiency

Energy Efficiency Label for Residential Buildings

- **'Applied For'** Label
- **'Final'** Label

New Residences

Existing Residences

EE Label for Res Buildings

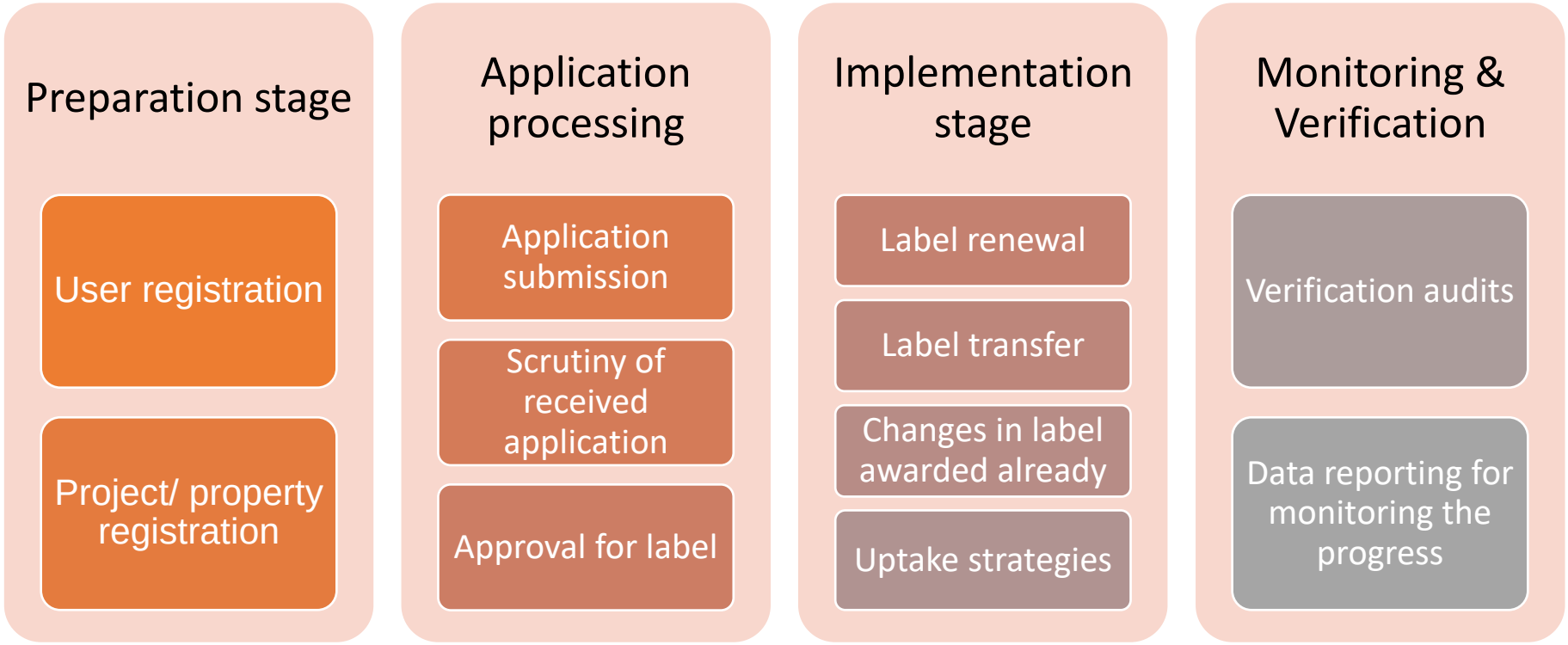
Label Criteria

There is **no minimum requirement** with respect to Area or Connected load (kW) for a dwelling unit to be covered under this labeling program.

- ❑ Star Rating awarded in the basis on EPI (**Energy Performance Index**)
- ❑ Energy Performance Index = Annual Energy Consumption (**kWh**)/Built up area (**m²**)
- ❑ BEE has prepared an **online platform** for the User of Label to apply for seeking an award of label under this program
- ❑ The online platform consists of a **Simulation-Based Tool** that will calculate the EPI of respective dwelling unit

Outline of the process for awarding BEE Star Label

- BEE Star Label for Residential Building:
- Applied For Label (specifically for developers or under construction residential buildings – Voluntary)
- Final Asset Label



05-C

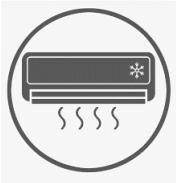
BEST PRACTICES

Best Practices in Indian Buildings

SIERRA's eFACiLiTY® Green Office Building, Coimbatore

- Location — Coimbatore, Tamil Nadu
- Coordinates — 11° N, 77° E
- Occupancy Type — Office
- Typology — New Construction
- Climate Type — Warm and Humid
- Project Area — 2,322 m2
- Grid Connectivity — Grid Connected
- EPI — 56 KWh/m2/
- Window Wall Ratio (WWR) is less than 40%
- glazing-harvest 86% daylight
- 100% rainwater harvesting and 100% wastewater treatment to tertiary standards- Zero discharge
- species- Landscape water demand reduce 40%

SIERRA's eFACiLiTY® Green Office Building, Coimbatore



Air-Conditioning

- Variable Refrigerant Flow system- Energy Efficiency Ratio (EER) of 13.85
- Smart Sensors - intelligently maintain temperature and fresh air supply

Indoor Air Quality

- Triple filtering & Demand Controlled Ventilation aided by CO2 sensors
- Real-time IoT sensors- levels of volatile organic compounds, humidity, and particulate matter 2.5 & 10

Water Efficiency

- 89% water savings are achieved using waterless urinals, high efficiency sensor faucets, reuse of treated water for flushing and reuse of stored rainwater for domestic use.
- Sequencing Batch Reactor (SBR) based STP System, rainwater filtration, Raw water treatment UV treatment etc.

Artificial Lighting and Controls

- 100% LED lights- 0.26 W per sq ft
- Sensor-activated passage lights, occupancy sensors, and lux sensors

Energy Monitoring

- Renewable Energy
- 60 KW rooftop solar PV with the automatic sprinkler cooling system- meets 80% of the energy demand and about 33% of the energy use further reducing the EPI to 18.8 KWh/m2/year

Best Practices in Indian Buildings

Industrial building

- Location: Lodsi, India
- Year :2019
- Area: 1000 Sqft
- Architects: Morphogenesis
- Purpose: manufacturing facility for a modern skincare company
- EPI (energy performance index) of 35kWh/m2/year
- https://www.archdaily.com/

Unnati Office

- Location Greater Noida, Uttar Pradesh
- Coordinates 29° N, 78° E
- Occupancy Type: Office, Private
- Typology New Construction
- Climate Type Composite
- Project Area 3,740 m2
- Date of Completion- 2018
- Grid Connectivity- Grid-connected
- EPI 60 kWh/m2/yr.
- https://www.archdaily.com/
- The building performs 59% better than a conventional office building in the region, and 40% of the building energy consumption is met through on site renewable energy generation

Unnati Office

Air-Conditioning

- The building has a hybrid HVAC system which is a combination of water-cooled air handling units and ceiling-embedded radiant cooling system.
- Cooling load distribution of the system is such that 55% of the load is met by the radiant cooling system and 45% by AHUs.

Building Envelope and Fenestration

- Truss reinforced insulated concrete panels (TRIC) used for the exterior walls are 25 mm concrete (AAC), 60 mm expanded polystyrene (EPS), and 25 mm concrete (AAC), and 10 mm plaster.
- The green roof insulation materials are 13 mm extruded polystyrene insulation and a 300 mm layer of green roof soil substrate

DayLighting

- 90% of the office spaces, including the core and service areas, receive uniformly distributed daylight.
- This can be attributed to the form, central courtyard, shallow floor plates, appropriate sizing and distribution of openings.
- All the windows have box shading that prevents glare.

Renewable Energy

The building draws 40% of its energy from the roof-top PV plant. The installed 100 kW solar PV generates 146 MWh/yr.

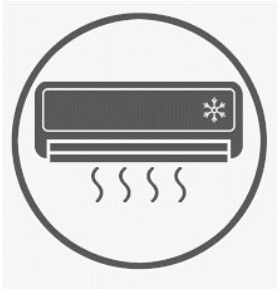
Best Practices in International Buildings

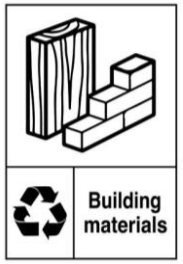
Shenzhen Institute of Building Research (IBR) Headquarters

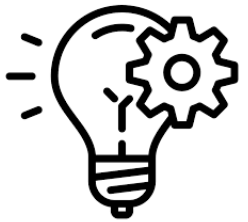
- Location Shenzhen, China
- Coordinates 39° N, 116° E
- Occupancy Type Office + research labs
- Typology New Construction
- Climate Type Humid subtropical
- Project Area 18,169 m2
- Grid Connectivity Grid Connected
- EPI 63 kWh/m2/yr
- https://www.hpbmagazine.org/
- Roof garden (green roof) shaded with a PV canopy

- Walls Type Insulated concrete panel with aluminum cladding
- Glazing Percentage Varies by orientation from 30% to 70%
- Windows-Effective U-factor for Assembly 0.35 Btu/h·ft°F
- Solar Heat Gain Coefficient (SHGC) 0.4
- Visual Transmittance 0.45
- Acoustic Isolation Performance 60 dbA

Shenzhen Institute of Building Research (IBR) Headquarters







Air-Conditioning
Natural ventilation in all the office spaces allows for direct contact with nature, and uses 30% less air conditioning
Water-loop heat pump, water-source heat pump, temperature and humidity are independently controlled, and high-efficiency and energy-saving air conditioning.

Roof Garden
A vertical landscape distributed throughout the building doubles the area available for greenery compared to the building's original footprint. The roof garden, "sky garden," and patio garden all help restore the ecological balance of the building site.

Material
Concrete with high-percent recycled material, wood products with 10% recycled materials. Construction materials sorted and collected for recycling. Use of local and native materials. Low-emission interior finishes

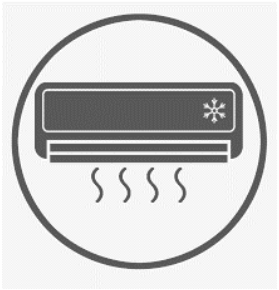
Artificial Lighting and Controls
Daylight for all the office spaces means no artificial lighting is needed during the day and provides views of the surrounding mountains from all of the workstations

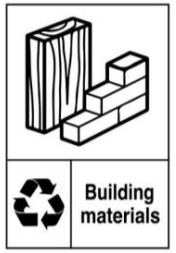
Best Practices in International Buildings

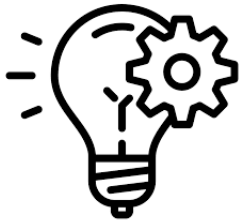
Bayalpata Hospital

- Location: Achham Nepal
- Coordinates: 29° N, 81° E
- Occupancy Type: Medical Complex
- Climate Type- Subtropical (due to elevation)
- Project Area: 4,225 m2
- Date of Completion 2019
- Grid Connectivity: Grid-connected
- EPI- 10 kWh/m2/yr
- The architecture maintains a vernacular scale through setbacks, gabled roofs, and low-cost heat-storing materials.

Bayalpata Hospital







Air-Conditioning

The structures comprises of massive rammed earth walls with insulated roofs. Material with thermal mass retains daytime heat gain in winter, while keeping the interiors cool by preventing overheating during summer.

The cross-breezes through courtyards, aided by clerestory ventilation and ceiling fans, promote natural ventilation and improve comfort conditions

Passive Strategies

The architecture maintains a vernacular scale through setbacks, gabled roofs, and low-cost heat-storing materials.

The complex includes low-rise one- and two-story structures organized around landscaped courtyards. The structures are heated and cooled passively (with the exception of the operating theatre and laboratories that are mechanically conditioned).

Material

Soil from the site was mixed with 6% cement content to stabilize the earth for better durability and seismic resistance. Reusable, plastic lock-in-place formwork facilitated faster construction, while local stone was used for foundations, pathways, and retaining walls.

Artificial Lighting and Controls

Inside the buildings, tall narrow windows and south-facing series of glazed clerestories brings in natural daylight reducing the need for artificial lighting.

Best Practices in International Buildings

Nowon Energy Zero House (EZ House)

- Location: Seoul, South Korea
- Coordinates 37° N, 127° E
- Occupancy Type- Multi-unit housing complex
- Climate Type Continental
- Project Area 17,652 m2
- Grid Connectivity Grid Connected
- https://www.schoeck.com/en/case-studies/nowon-energy-zero-house-ez-house

Nowon Energy Zero House (EZ House)

- **Nowon EZ House,** Korea's first zero-energy multi-unit housing complex, is the result of the project "Zero Energy Housing Activation Optimization Model Development and Demonstration Complex Development"
- Nowon EZ House was built using the highest level of passive technology and materials in Korea, some of which were the first to be used in the country.
- Structural thermal break solutions Schöck Isokorb® XT type K and XT type Z have been applied to prevent the thermal bridges in the balcony area.
- Thanks to the new technologies, EZ House is aimed to maintain a temperature of 20°C to 22°C in winter and 26°C to 28°C in summer – without any heating or cooling

Mobil House

- Location Dhaka
- Coordinates 23.8° N, 90.4° E
- Occupancy Type: Office
- Climate Type climate Tropical wet and dry
- Project Area 6,673 m2
- Date of Completion Oct 2019
- Grid Connectivity Grid-connected
- EPI (kWh/m2/yr)- 58 kWh/m2/yr

Site Layout & Planning

Due to size constraints of the site, the green cover on site is minimal. However, significant foliage has been incorporated within the large terraces distributed throughout the building. Potted plants and vertical gardens compensate for the lack of surface green cover.

Climate Responsive Design

The most striking feature of the building includes the landscaped and shaded terraces. These act as thermal buffers for the interior spaces.

Mobil House

Form and Massing

- The building mass has been oriented such that circulation elements like lift core and staircases are situated along the West façade.
- This shields the regularly occupied spaces like offices and reception from the solar gains from the west façade.
- The northeast façade, with less solar gain potential, incorporates large windows to allow daylight and outdoor views.

Facade and Envelope

- The envelope is made of 300 mm thick concrete walls, leading to high thermal mass which shields the buildings from heat gain during the daytime.
- The deep building terraces and courtyards enhance biophilia and create shaded outdoor breakout spaces.
- the windows – double-glazed panels with low emissivity and a U-value 1.1 W/m2k – also reduce heat gain.
- The glazing has a shading coefficient of less than 0.25, leading to further reduction in solar heat gain.

Daylight Design

- The building form is optimized to let in daylight, blocking solar heat gain.
- This is done through the deep terraces of the building which provide shading to the north-east façade.
- This façade, with its row of large windows, also lets in plenty of daylight.
- A significant number of occupants have access to daylight and views to the outside

Q&A