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HOUSING  
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CHALLENGE INDIA



Ministry of Housing and Urban Affairs  
Government of India



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# Introduction MoHUA, GIZ & Climate Smart Buildings

**Climate Smart Building Cell - Light House Project Agartala**



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Indo German Energy Programme: <https://www.giz.de/en/worldwide/15767.html>

GHTC - India: <https://ghtc-india.gov.in/>

## GIZ: Tasks Planned with MoHUA

The focal areas of  
**Indo-German  
cooperation**  
currently are:

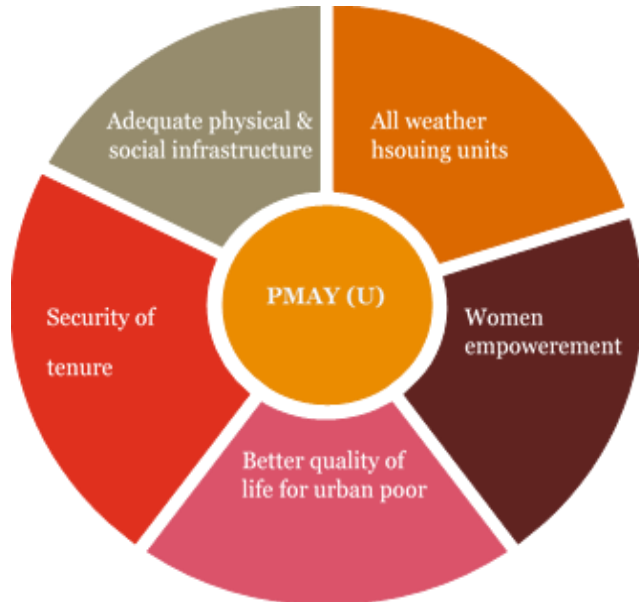
Energy

Environment,  
Preservation, and  
Sustainable Use of  
Natural Resources

Sustainable Urban  
& Industrial  
Development

Sustainable  
Economic  
Development

### PMAY - Project Objectives



### Key features of PMAY-U projects

**11.2 million**  
dwelling units are  
being constructed



**7.35 lakh  
crores**  
investment



**10 lakh**  
occupants in the  
EWS/LIG category  
benefitting

### Problems addressed through cafeteria approach by mission

Construction of  
affordable housing in  
Partnership with  
Public & Private  
Sectors

Promotion of  
affordable Housing  
through Credit  
Linked Subsidy

Slum rehabilitation  
with private  
developers using  
land as a resource

Subsidy for  
beneficiary-led  
individual house  
construction/enhanc  
ement. (ISSR)



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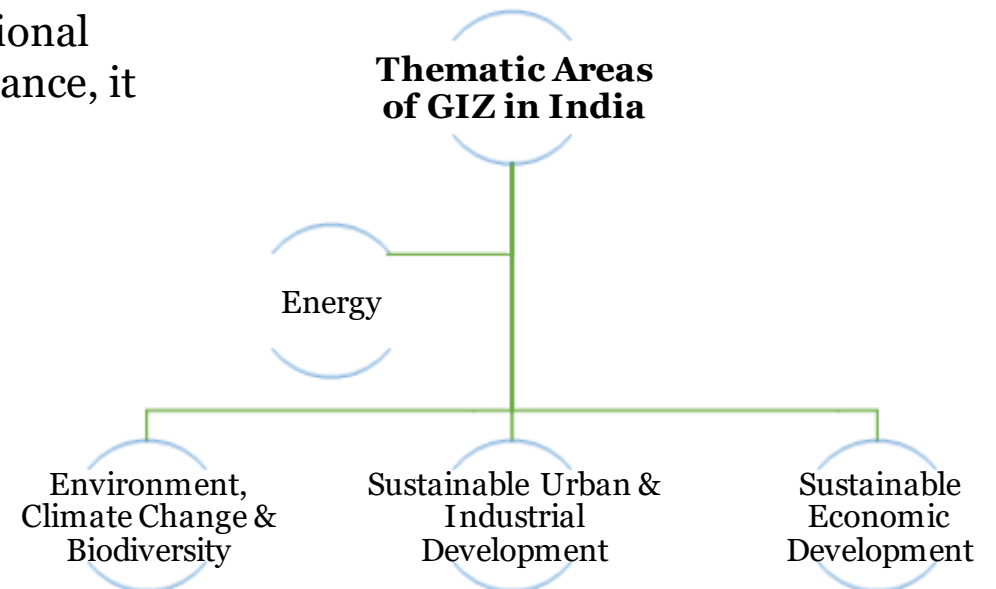
## About GIZ

- GIZ is an international cooperation enterprise for sustainable development which operates worldwide, on a public benefit basis.
- GIZ is fully owned by the German Federal Government, GIZ implement development programs in partner country on behalf of the German Government in achieving its development policy objectives.
- For over 60 years, the **Deutsche Gesellschaft für Internationale Zusammenarbeit** (GIZ) GmbH has been working jointly with partners in India for sustainable economic, ecological, and social development. Currently, GIZ has over 330 employees in India, of whom 85 per cent are national personnel.

The Govt. of India has launched several vital initiatives to address national issues & GIZ is contributing to some of those significant ones. For instance, it supports vital initiatives like Smart Cities, Skill India etc.

The thematic areas of work for GIZ in India are as follows:

- I. **Energy**
- II. **Environment, Climate Change & Biodiversity**
- III. **Sustainable urban & industrial development**
- IV. **Sustainable economic development**





## Climate Smart Buildings (CSB)

### Establishment of the Cluster Cell in Agartala, Tripura under Global housing Technology Challenge India (GHTC - India)

The **Climate Smart Buildings** project intends to address the majority of gaps identified in the affordable housing sector:

- By introducing of thermal comfort & climate resilience in the Local Government framework through Byelaws is an overarching objective.
- In order to achieve this objective, activities like documentation of LHP construction process from a sustainability perspective, knowledge transfer & capacity building through LHPs, performance monitoring & demonstration of thermal comfort in selected housing projects among others.

### State & UTs in East Cluster for establishing the Cell

Arunachal Pradesh	Assam	Manipur	Meghalaya
Mizoram	Nagaland	Sikkim	Tripura





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# Climate Smart Buildings (CSB) Cell Activities



## Climate Smart Buildings Cells: Work Packages

**WP1:** Facilitate implementation and monitoring of Light House Projects (LHPs)

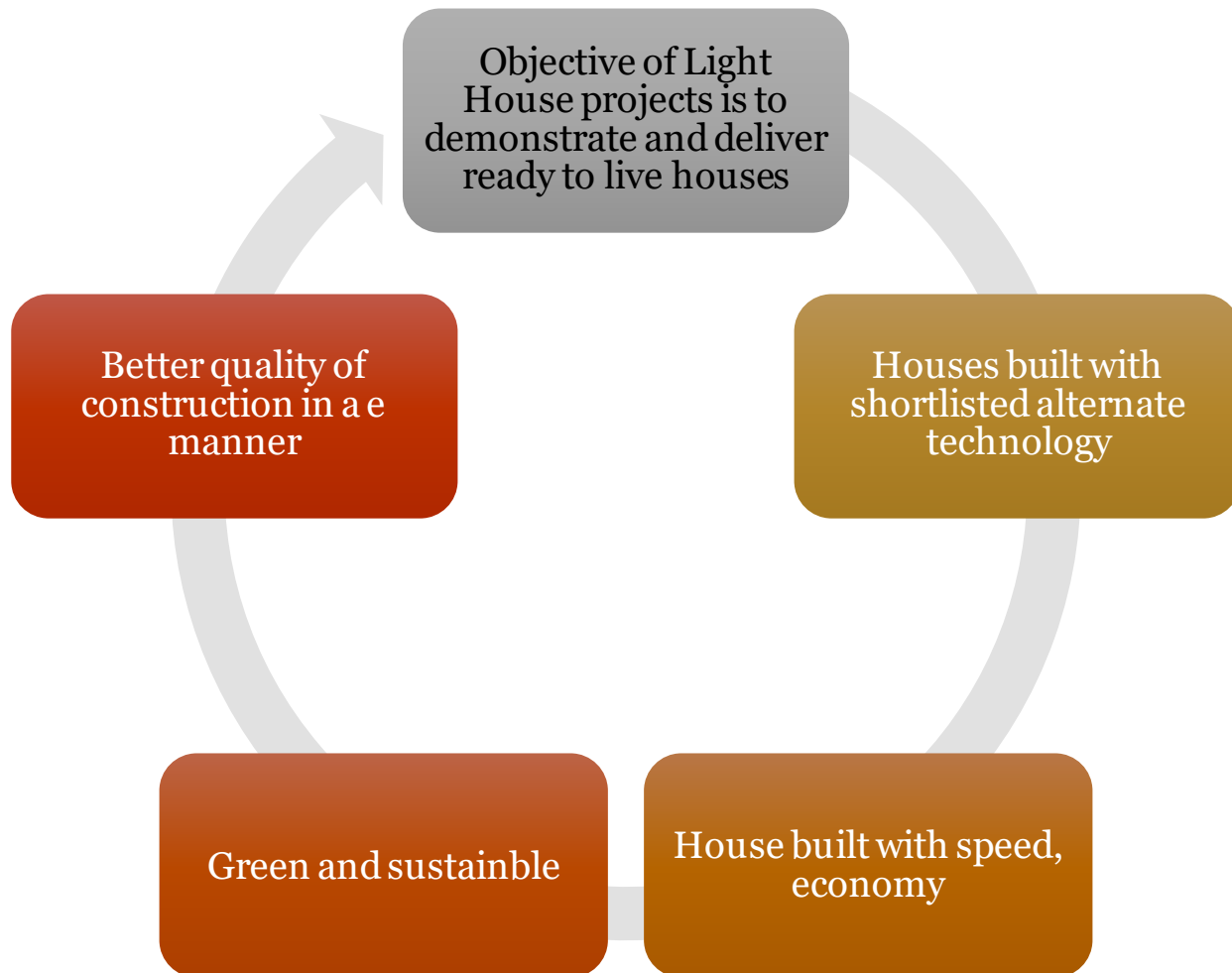
**WP 2:** Technical assistance to enhance thermal comfort in upcoming Demonstration Housing Projects (DHPs) and ARHCs (Affordable rental housing complexes) and other Public/Private housing projects

**WP 3:** Inclusion of climate resilience and thermal comfort requirements in building byelaws and Local Government framework

**WP 4:** Capacity development of Govt officials and private stakeholders on thermal comfort



# Light House Projects



LHP serves as LIVE Laboratories for different aspects of Transfer of technologies to field application, such as planning, design, production of components, construction practices, testing etc. for both faculty and students, Builders, Professionals of Private and Public sectors, and other stakeholders involved in such construction



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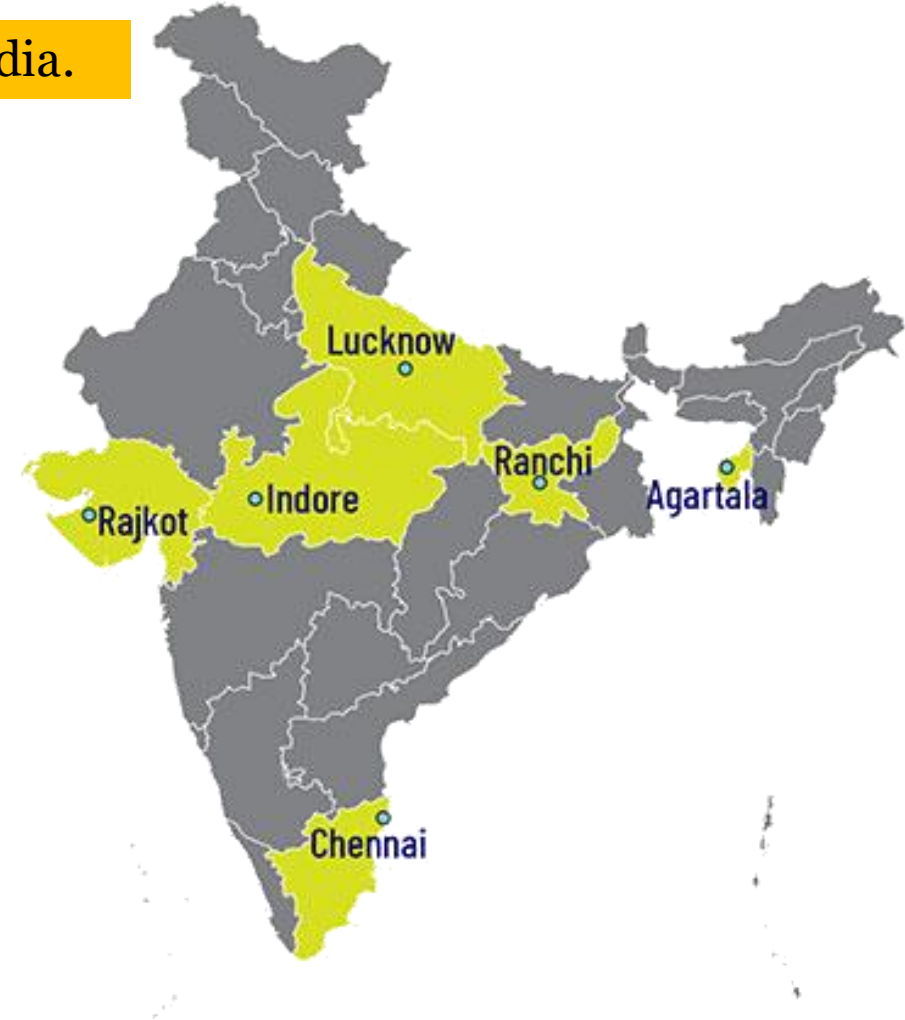
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# Light House Projects

## Under Global Housing Technology Challenge (GHTC) – India.

Currently the LHPs' are being implemented in six states (Uttar Pradesh, Gujarat, Madhya Pradesh, Jharkhand, and Tripura).

These projects will be made up of modern technology and innovative processes and reduce the construction time and make a more resilient, affordable, and comfortable house for the poor.







## Light House Projects

Following are the details of Construction Technologies being employed at the Light House Projects selected under the Global Housing Technology Challenge (GHTC) – India



### Monolithic Concrete Construction using Tunnel Formwork

- LHP Location: Rajkot, Gujarat
- No. of Houses: 1144



### Prefabricated Sandwich Panel System

- LHP Location: Indore, Madhya Pradesh
- No. of Houses: 1024



### Precast Concrete Construction System – Precast Components Assembled at Site

- LHP Location: Chennai, Tamilnadu
- No. of Houses: 1152



### Precast Concrete Construction System – 3D Volumetric

- LHP Location: Ranchi, Jharkhand
- No of Houses: 1008



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

- LHP Location: Agartala, Tripura
- No of Houses: 1000



### PVC Stay in Place Formwork System

- LHP Location: Lucknow, Uttar Pradesh
- No of Houses: 1040



# Monolithic Tunnel Formwork Technology – LHP Rajkot

In **‘TunnelForm’ technology**, concrete walls and slabs are cast in one go at site giving monolithic structure using high-precision, re-usable, room-sized, Steel forms or molds called ‘TunnelForm’.

‘TunnelForm’ system uses customized engineered steel formwork consisting of two half shells which are placed together and then concreting is done to form a room size module. Several such modules make an apartment.



## Construction Process

Stripping of the  
formwork from the  
previous day.



Positioning of the  
formwork for the  
current day's  
phase, with the  
installation of  
mechanical,  
electrical and  
plumbing services.



Installation of  
reinforcement in  
the walls and slabs.



Concreting



# Monolithic Tunnel Formwork Technology – LHP Rajkot

## Special Features

Facilitating rapid construction of multiple/ mass modular units (similar units).

Making structure durable with low maintenance requirement.

The precise finishing can be ensured with no plastering requirement.

The concrete can be designed to use industrial by-products such as Fly Ash, Ground granulated blast furnace slag (GGBS), Micro silica etc. resulting in improved workability & durability, while also conserving natural resource

Being Box type monolithic structure, it is safe against horizontal forces (earthquake, cyclone etc.)

The large number of modular units bring economy in construction.





## Prefabricated Sandwich Panel System – LHP Indore

- Factory made **Prefabricated Sandwich Panel System** is made out of cement or calcium silicate boards and cement mortar with EPS granules balls, and act as wall panels.
- Under this LHP, houses are being constructed using Prefabricated Sandwich Panel System with Pre-Engineered Steel Structural System.
- In this system the **EPS Cement Panels** are manufactured at the factory in controlled condition, which are then dispatched to the site. The panels having tongue and groove are joint together for construction of the building.



### Special Features

Being dry walling system, brings speed in construction, water conservation (no use of water for curing of walling components at site).

The sandwich panels have light weight material as core material, which brings resource efficiency, better thermal insulation, acoustics & energy efficiency.

Being light in weight results in lower dead load of building & foundation size.



## Precast Concrete Construction System – Precast Components Assembled at site – LHP Chennai

An already established technology for building construction, Precast concrete construction is a system where the individual precast components such as walls, slabs, stairs, column, beam etc, of building are manufactured in plant or casting yard in controlled conditions. The finished components are then transported to site, erected & installed. The technology provides solution for low rise to high rise buildings, especially for residential and commercial buildings.



The construction process comprises of manufacturing of precast concrete Columns, Beams and Slabs in steel moulds.

The reinforcement cages are placed at the required position in the moulds.



Concrete is poured and compaction of concrete is done by shutter/ needle vibrator.



Casted components are then moved to stacking yard where curing is done for required time and then these components are ready for transportation and erection at site.



These precast components are installed at site by crane and assembled through in-situ jointing and/or grouting etc.



## Precast Concrete Construction System – Precast Components Assembled at site – LHP Chennai

### Special Features

Nearly all components of building work are manufactured in plant/casting yard & the jointing of components is done In-situ leading to reduction in construction time.

The controlled factory environment brings resource optimization, improved quality, precision & finish.

The concrete can be designed industrial by-products such as Fly Ash, Ground granulated blast furnace slag (GGBFS), Micro silica etc. resulting in improved workability & durability, while also conserving natural resources.

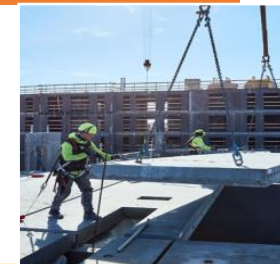
Eliminates use of plaster.

Helps in keeping neat & clean construction site and dust free environment.

Optimum use of water through recycling.

Use of shuttering & scaffolding materials is minimal.

All weather construction & better site organization.





# Precast Concrete Construction System – 3D Volumetric – LHP Ranchi

**3D Volumetric concrete** construction is the modern method of building by which solid precast concrete structural modules like room, toilet, kitchen, bathroom, stairs etc. & any combination of these are cast monolithically in Plant or Casting yard in a controlled condition

## Construction Process

Sequential construction in the project here begins with keeping the designed foundation of the building ready, while manufacturing of precast concrete structural modules are taking place at the factory.

Factory finished building units/modules are then installed at the site with the help of tower cranes.



Gable end walls are positioned to terminate the sides of building. Pre stressed slabs are then installed as flooring elements.



Rebar mesh is finally placed for structural screed thereby connecting all the elements together.



Consecutive floors are built in similar manner to complete the structure.





# Precast Concrete Construction System – 3D Volumetric – LHP Ranchi

## Special Features



About 90% of the building work including finishing is complete in plant/casting yard leading to significant reduction in construction & occupancy time.

The controlled factory environment brings resource optimization, improved quality, precision & finish.

With smooth surface it eliminates use of plaster.

The monolithic casting of walls & floor of a building module reduces the chances of leakage.

The system has minimal material wastage (saving in material cost), helps in keeping neat & clean construction site and dust free environment.

Use of Optimum quantity of water through recycling.

Use of shuttering & scaffolding materials is minimal.

All weather construction & better site organization





## Light Gauge Steel Structural System & Pre – engineered Steel Structural System – LHP Agartala

**Light Gauge Steel Frame (LGSF) System** uses factory made galvanized light gauge steel components.

The components/sections are produced by cold forming method and assembled as panels at site forming structural steel framework upto G+3 building.



### Construction Process

The sequence of construction comprises of foundation laying, fixing of Pre-Engineered Steel Structural System, fixing of tracks, fixing of wall panels with bracings as required, fixing of floor panels, decking sheet, fixing of electrical & plumbing services and finally fixing of concrete walling panels with light weight concrete as infill.

The other options of dry walling components such as sandwich panels with insulation material in between can also be used.

Similarly, the floors can either be composite slab/deck slabs/precast hollow core slabs as per the need & requirements.



## Light Gauge Steel Structural System & Pre – engineered Steel Structural System – LHP Agartala

### Special Features



High strength to weight ratio. Due to light weight, significant reduction in design earthquake forces is achieved. Making it safer compared to other structures.

Fully integrated computerized system with Centrally Numerical Control (CNC) machine primarily employed for manufacturing of LGSF sections provide very high Precision & accuracy.

Construction being very fast, a typical four storied building can be constructed within one month.

Structure being light, does not require heavy foundation

Structural element can be transported to any place including hilly areas to remote places easily making it suitable for far flung regions including difficult terrains.

Structure can be shifted from one location to other without wastage of materials.

Steel used can be recycled multiple times

The system is very useful for post disaster rehabilitation work.



## PVC Stay in Place Formwork System – LHP Lucknow

- The plant manufactured rigid poly-vinyl chloride (PVC) based polymer components serve as a permanent stay-in-place finished form-work for concrete walls. In order to achieve speedier construction, strength and resource efficiency, the composite structure with Pre-Engineered Steel Structural System as structural members is being used in the present project.



### Construction Process

Construction is done in a sequential manner where at first, the Prefabricated PVC Wall panels and Pre-Engineered Steel Structural Sections as per the design are transported to the Site.

Then, these Sections are erected on the prepared foundation using cranes and required connections.



Floor is installed using decking sheet. Once the structural frame and floor is installed and aligned, wall panels are fixed on decking floor.



The pre-fabricated walling panels having provisions of holes for services conduits, are fixed along with the reinforcement & cavities inside the wall panels are filled with concrete.



Upon installment of wall panels, flooring and ceiling, the finishing work is executed.



# PVC Stay in Place Formwork System – LHP Lucknow

## Special Features

Having formwork already as part of system, the construction of building is faster as compared to conventional buildings. The formwork needs some support only for alignment purpose.

In case of concrete as filling material, the curing requirement of concrete is significantly reduced, thus saving in precious water resources.

The formwork system does not have plastering requirement & gives a very aesthetic look.







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# DEMONSTARTION HOUSING PROJECT (DHP)



# Demonstration Housing Project -DHP

## Objective

To facilitate wide spread dissemination and adoption of both proven, emerging and sustainable building materials and technologies in preference to the conventional

Create enabling environment for the large scale adoption of such materials and technologies in different geo-climatic part of the country, thus making housing more affordable and accessible

Assessment of enhanced acceptability of houses built with new innovative technology.

Technical evaluation and documentation of the innovative technology adopted



# Demonstration Housing Project -DHP

## Salient Features

Minimum carpet area of each unit: 30 Sq. Mt. or as per the prevailing guidelines of the respective state with two habitable rooms, separate kitchen, bathroom, toilet and balcony

Each project to be featured with onsite infrastructure development like internal roads, pathways, boundary wall, underground water tank, external electrification, etc.

Innovative technology suitable to the region to be selected in consultation with respective State Government.

Houses are designed as per the dimensional requirements in National Building Code (NBC) 2016.

Building design with disaster resistant features as per the requirements of BIS and international standards in regard to earthquake, cyclone and flood resistant features.

The state Government to provide land and identify beneficiary of the DHPs

The DHP will act as training cum resource project for training on emerging technologies for the people involved in building sector





# Demonstration Housing Project at Eastern Cluster States

## DHP at Tripura



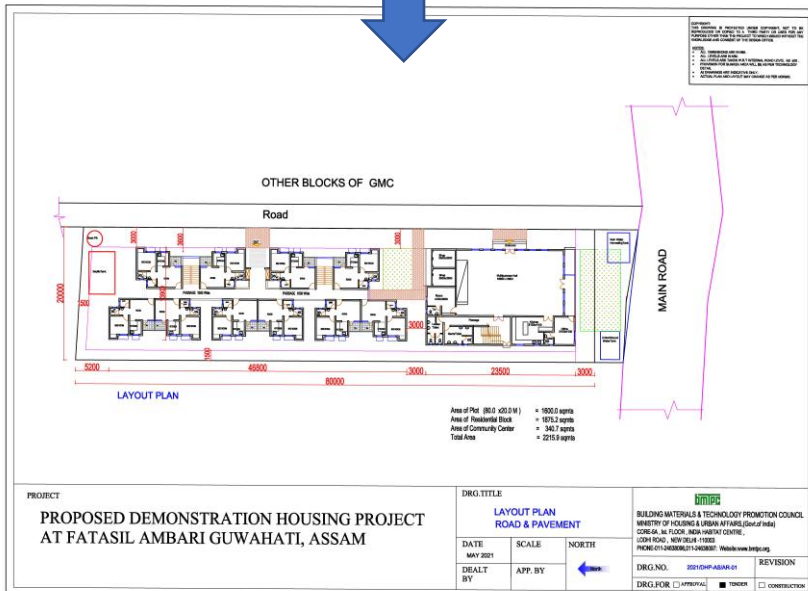
DHP Location	Technology Used	Usage	Number of Houses
Agartala, West Tripura	Stay in place formwork system-structural stay in place steel form work	Shelter for Destitute Women	40 (G+1)





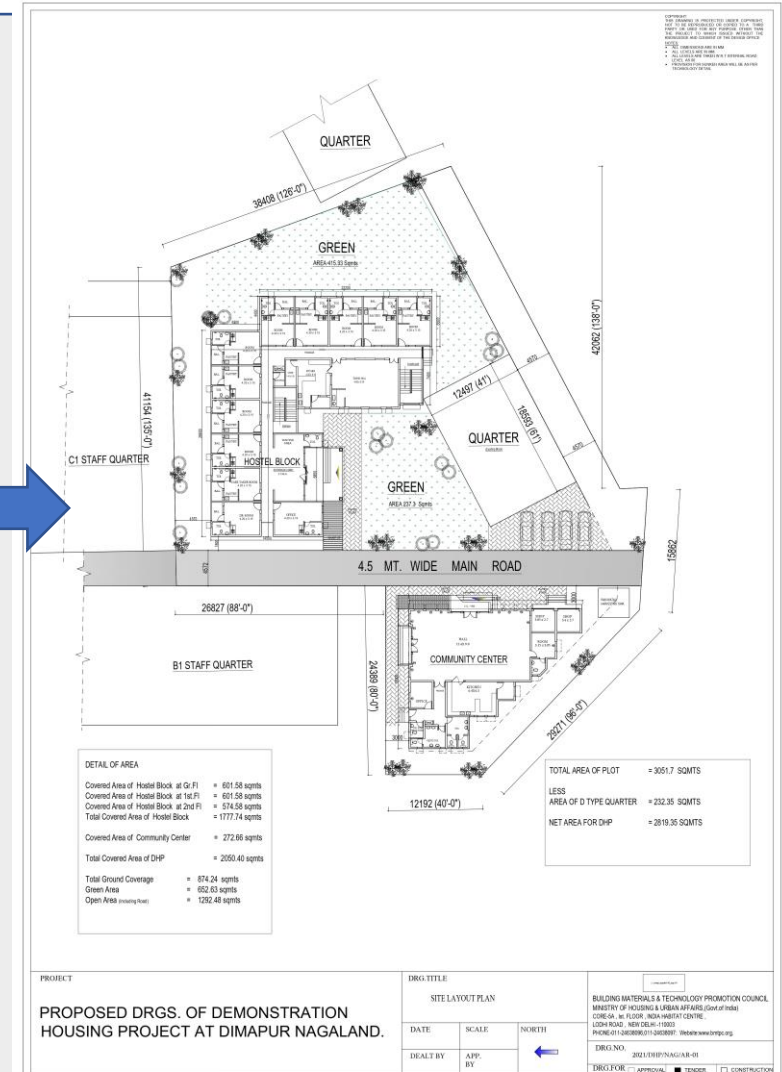
# Upcoming Demonstration Housing Project (DHP) under Eastern Cluster States

**Assam:**  
Accommodation for Contractual  
Safai  
Karmachari and Community  
Centre-G+3 at  
Fatasil Ambari, Guwahati



**Nagaland:**

Working Women  
Hostel at PWD  
Housing Complex ,  
Sematila , Dimapur  
under PMAY (U) -  
G+2







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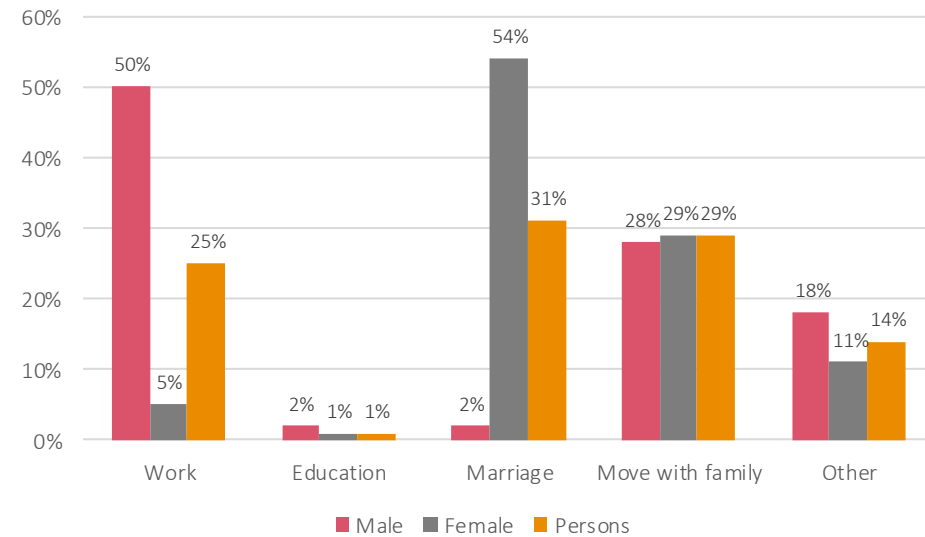
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# AFFORDABLE RENTAL HOUSING COMPLEXES (ARHCs)



# Rationale behind ARHCs

- As per the 2011 Census, India had 45.6 Cr migrants (38% of the population) compared to 31.5 Cr migrants in 2001 (31% of the population).
- Driving force of great migration to urban areas is for economic betterment with employment opportunities
- Their objective being maximise saving for native resident family by minimizing rental expenses to an extent of compromising the living condition like slums, unauthorized colonies or on roads.



Reasons for inter-state migration (Source: Census 2011)



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# Affordable Rental Housing Complexes (ARHCs )

## Objective

Address the vision of 'Aatma Nirbhar Bharat' by creating affordable rental housing for urban migrants/poor

Create conducive ecosystem for Public/Private Entities to leverage investment in rental housing

Provide dignified living to urban migrant/poor with necessary civic amenities near their workplace on affordable rent



# Affordable Rental Housing Complexes (ARHCs )

## Salient Features

To be implemented in all Statutory Towns, Notified Planning Areas and areas under Special Area/ Development Authorities / Industrial Development Authorities

ARHCs can be a mix of Single/Double bedrooms DUs (30/60 sqm carpet area) with living area, kitchen, toilet and bathroom and Dormitory Bed (10 sqm carpet area) with common kitchen, toilet and and bathroom

A maximum of 33% houses with double room permissible in a project

Institutional Rental Mechanism: In-block renting for smooth implementation and sustained income



# Affordable Rental Housing Complexes (ARHCs )

## List of ARHCs in States under East Cluster

Conversion of completed/ incomplete houses under erstwhile schemes of Basic Services to Urban Poor (BSUP) and Integrated Housing and Slum Redevelopment Program (IHSDP) of Jawaharlal Nehru National Urban Renewal Mission (JnNURM) and Rajiv Awas Yojana (RAY)

*Circular No. N-11022/51/2020-HFA-V-UD/FTS-9088338 dated 31/12/2020 issued by MoHUA (HFA-V Division)*

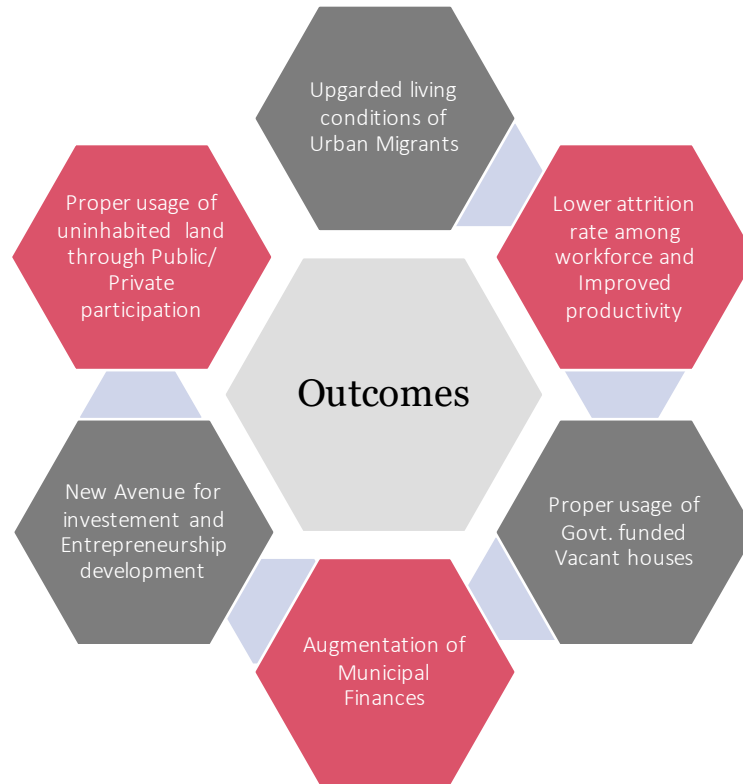
S.N	States	City/Town	Under Construction (Nos)	Un-occupied (Nos)	Grand Total (Nos)
1.	Arunachal Pradesh	Bomdila	384	-	384
		Dirang	320	-	320
		Itanagar	576	752	1328
		Palin	256	-	256
	Arunachal Pradesh Total		1536	752	2288
2.	Assam	Guwahati	1844	-	1844
	Assam Total		1844	-	1844
3.	Meghalaya	Nongpoh	112	16	128
		Shillong	-	112	112
		Tura	-	123	13
	Meghalaya Total		112	251	363
4.	Mizoram	Aizawl	-	197	197
	Mizoram Total		-	197	197
5.	Nagaland	Chumukedima	352	32	384
		Dimapur	-	280	280
		Kohima	360	1152	1512
		Medziphama	90	-	90
		Tseminyu	100	-	100
	Nagaland Total		902	1464	2366
6.	Tripura	Amarpur	406	-	406
		Khowai	188	-	188
		Kumarghat	483	-	483
		Sabroom	72	-	72
	Tripura Total		1149	-	1149





# Affordable Rental Housing Complexes (ARHCs )

## Expected Outcome





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# UNDERSTANDING THERMAL COMFORT



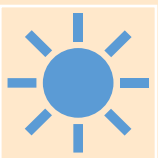
## What is Thermal Comfort?



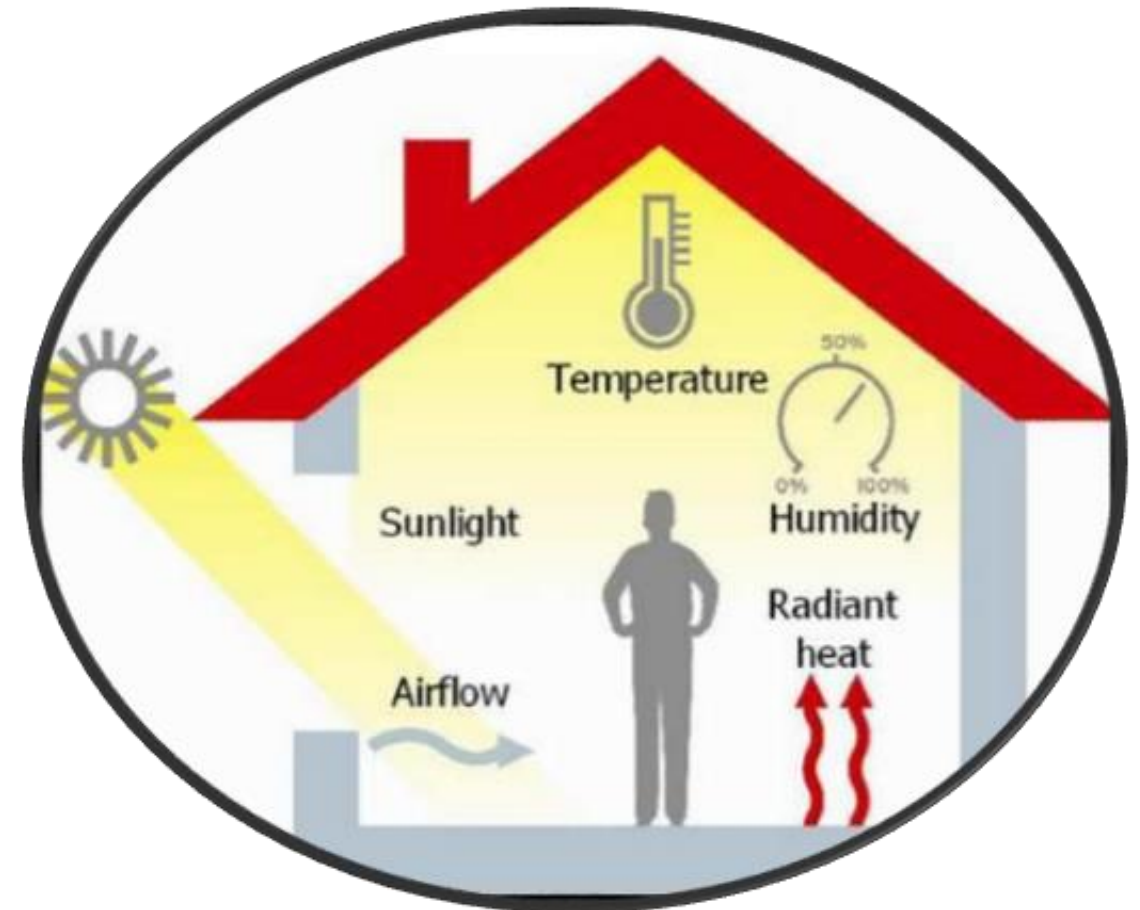
Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment.



Thermal neutrality is maintained when the heat generated by human metabolism is allowed to dissipate, thus maintaining thermal equilibrium with the surroundings.



Environmental factors (such as humidity and sources of heat in the workplace) combine with personal factors (i.e., clothing) and work-related factors (how physically demanding one's work is) influences the 'thermal comfort'.





# Importance of Thermal Comfort

2

People adjust their behavior to cope with their thermal environment, such as by adding or removing clothing, changing their posture unconsciously, selecting a heating source, moving closer to or farther away from cooling/heating sources, and so on.

3

When this option (removing a jacket or moving away from a heat source) is gone, issues develop since people are no longer able to adjust. People are unable to adapt to their environment in some cases because the environment in which they work is a product of the processes of the task they are doing.

1

You can increase morale and productivity while also enhancing health and safety by regulating thermal comfort. Because their capacity to make decisions and/or do manual tasks deteriorates in excessively hot and cold conditions, people are more prone to behave unsafely



## THERMAL ENVIRONMENTS CAN BE DIVIDED LOOSELY INTO THREE BROAD CATEGORIES:

### THERMAL COMFORT

Broad satisfaction with the Thermal Environment i.e. most people are neither too hot nor too cold.

### THERMAL DISCOMFORT

People start to feel uncomfortable i.e. they are too hot or too cold, but are not made unwell by the conditions.

### THERMAL DISCOMFORT

Heat stress or cold stress, is where the thermal environment will cause clearly defined harmful medical conditions, such as dehydration or frost bite

### THERMAL DISCOMFORT



# Thermal Discomfort can be induced



by a generalized warm or cool discomfort of the body



by an unpleasant chilling or heating of a specific region of the body.

# Factors affecting Thermal Comfort

## PHYSICAL FACTORS

## PHYSIOLOGICAL FACTORS

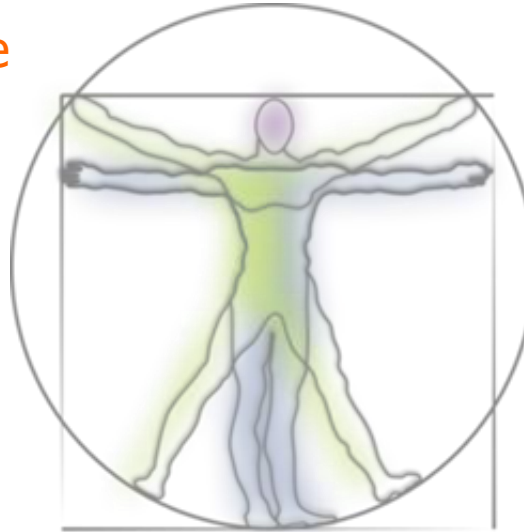
Environmental  
Parameters

Mean Radiant Temperature

Air Temperature

Air Speed

Humidity



Metabolic Rate

Clothing



Personal  
Parameters

# PHYSICAL FACTORS

•01

•Air Temperature



•02

•Mean Radiant  
Temperature



•03

•Radiant Temperature  
Asymmetry



# PHYSICAL FACTORS

## AIR TEMPERATURE – the temperature of the air surrounding a body

The ideal temperature for sedentary work is usually between **20°C and 26°C**

## RADIANT TEMPERATURE – the heat that radiates from a warm object

Heat can be generated by equipment, which raises the temperature in a specific region.

### PHYSICAL FACTORS

## AIR VELOCITY – the speed of air moving across the worker

It's best if the air flow rate is between **0.1 and 0.2 m/s.**

## HUMIDITY – the amount of evaporated water in the air

Air-conditioning can easily attain ideal relative humidity values of **40 percent to 70 percent.**

# 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. Layers of insulating clothing keep a person warm or cause overheating by preventing heat loss. The better the insulating ability of a garment, the thicker it is in general. 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

CLOTHING	Clo
T-shirts, shorts, Light socks, Sandals	0.30
Shirt, Trousers socks, Shoes	0.70
Jacket, Blouse, Long skirt, stockings	1.00
Trousers, Vest, Jacket Coat, Socks Shoes	1.50

## CLOTHING LEVELS & INSULATION

# PHYSIOLOGICAL FACTORS

ACTIVITY	Met
Seated, Relaxed	1.0
Sedentary Activity (office, dwelling, school, laboratory)	1.2
Standing, Light Activity (shopping, laboratory, light industry)	1.6
Standing, Medium activity (shop assistant, domestic work, machine work)	2.0

## METABOLIC RATE



## Thermal Comfort Indices

### 1. Effective Temperature (ET)

- The temperature of still, saturated air at which the same amount of heat is released is known as the effective temperature. as well as a general influence on comfort the atmosphere is being investigated.
- Temperature, humidity, and other factors the same thermal output is produced by the same wind velocity. A person's sensations are assumed to have a temperature that is effective.

### Initially two scales were developed

#### Basic Scale

one of which referred to men stripped to the waist and called the basic scale.

#### Normal Scale of Effective Temperature

The other applies to men fully clad in indoor clothing and called the normal scale of effective temperature.

**The same effective temperature is defined as a combination of temperature, humidity, and wind velocity that produces the same thermal experience in an individual.**

### 2. Tropical Summer Index (TSI)

- The TSI is defined as the temperature of calm air at 50% relative humidity which imparts the same thermal sensation as the given environment. The 50% level of relative humidity is chosen for this index as it is a reasonable intermediate value for the prevailing humidity conditions.

## THERMAL INDICES

# Thermal Comfort Indices

## CORRECTED EFFECTIVE TEMPERATURE (CET)

The use of globe temperature reading instead of the air temperature reading to make allowance for the radiant heat.

The scale was compiled only for men either seated or engaged in light activity.

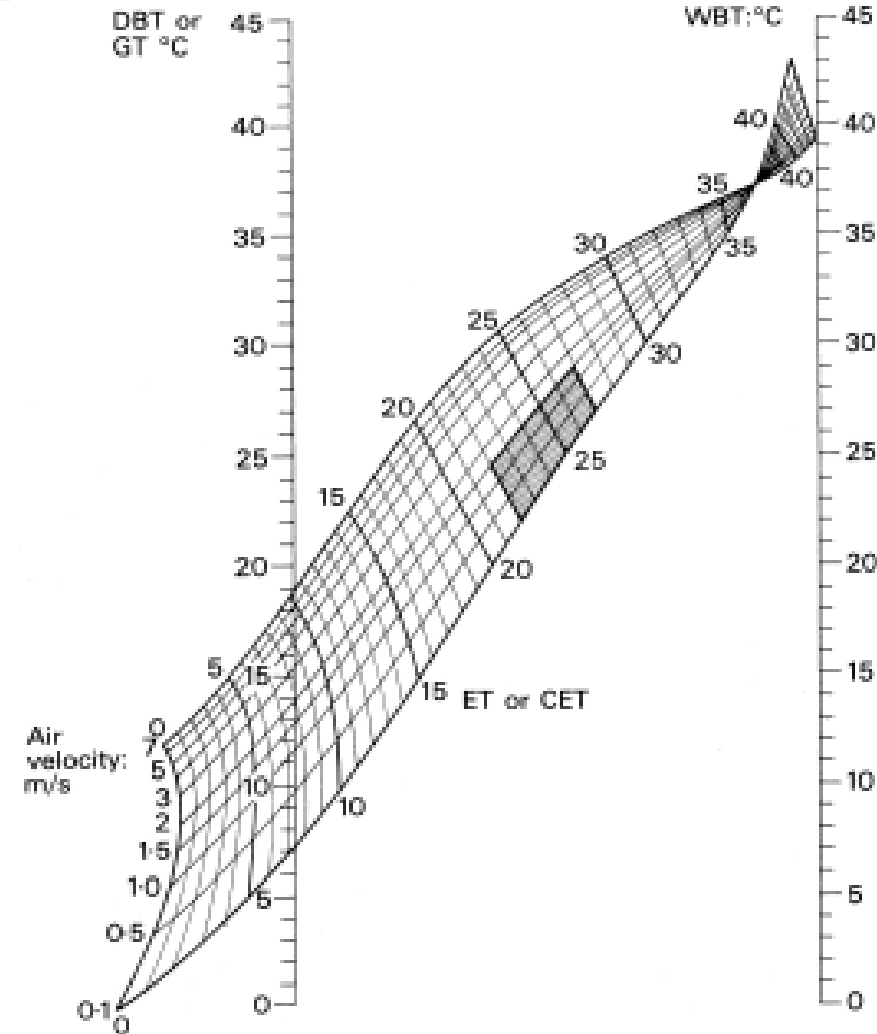


Figure represents the Corrected Effective Temperature (CET) Nomogram

# Thermal Comfort Indices

## 2 - Tropical Summer Index

The TSI is defined as the temperature of calm air at 50% relative humidity which imparts the same thermal sensation as the given environment. The 50% level of relative humidity is chosen for this index as it is a reasonable intermediate value for the prevailing humidity conditions.

Mathematically, TSI (°C) is expressed as

$$TSI = 0.308t_w + 0.745t_g - 2.06\sqrt{V} + 0.841$$

Where,

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



# Thermal Comfort Indices

The ranges of environmental conditions and TSI covered in this study are:

Globe Temperature	20-42 °C
Wet Bulb Temperature	18-30 °C
Air Speed	0-2.5 m/s
TSI	15-40 °C

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

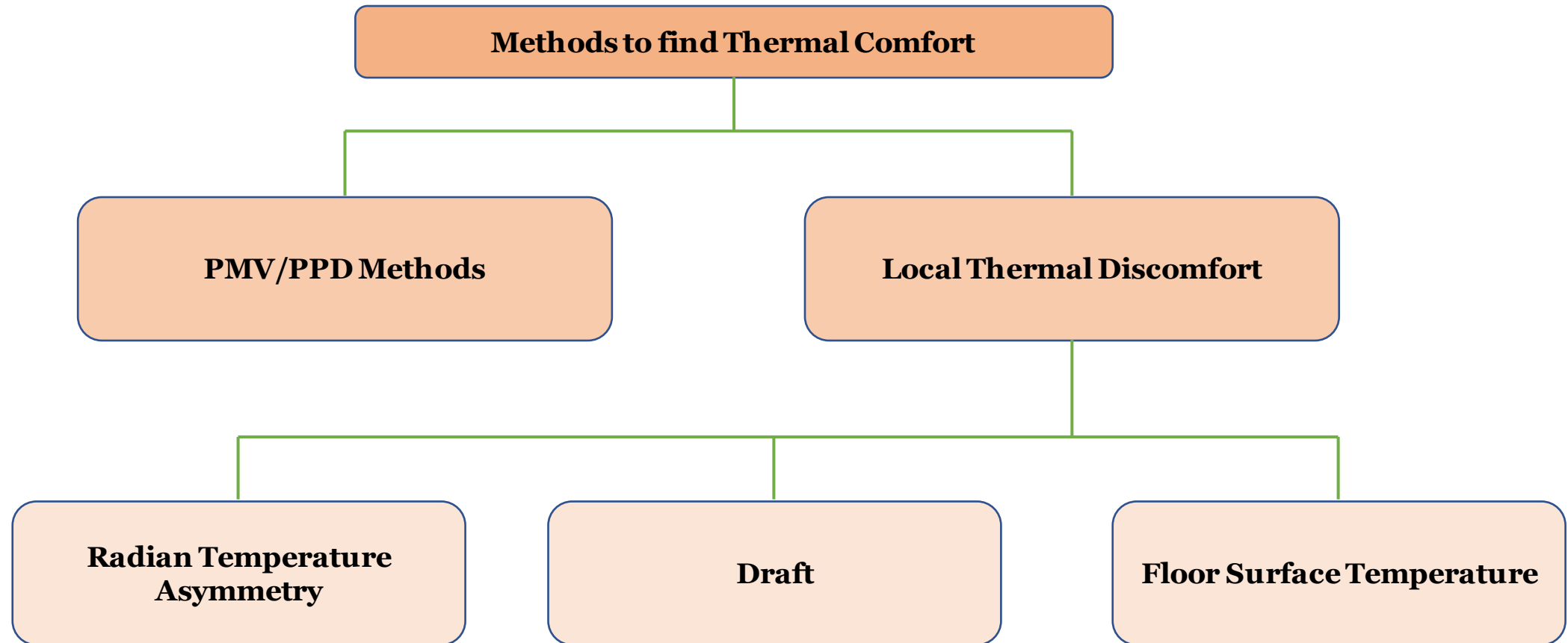
# Thermal Comfort Indices

## 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

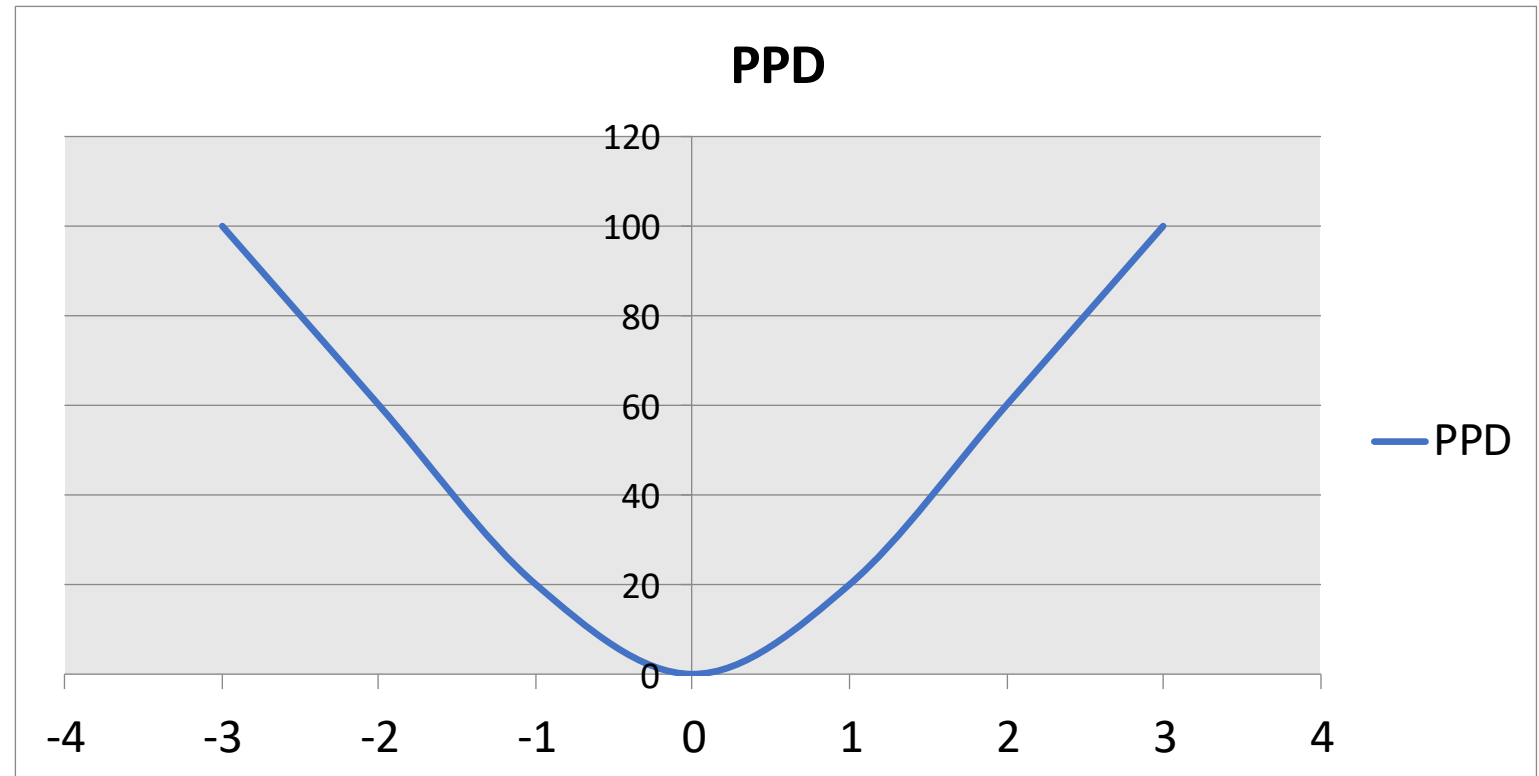
The warmth of the environment was found tolerable between 30 and 34°C (TSI), and too hot above this limit. On the lower side, the coolness of the environment was found tolerable between 19 and 25°C (TSI) and below 19°C (TSI), it was found too cold.

# Methods to find Thermal Comfort



# Methods to find Thermal Comfort

To describe comfort, the PMV/PPD model was constructed utilizing heat-balance equations and empirical investigations on skin temperature. Subjects are asked to rate their thermal comfort on a seven-point scale ranging from cold (-3) to hot (+3) in standard thermal comfort surveys.





## Methods to find Thermal Comfort

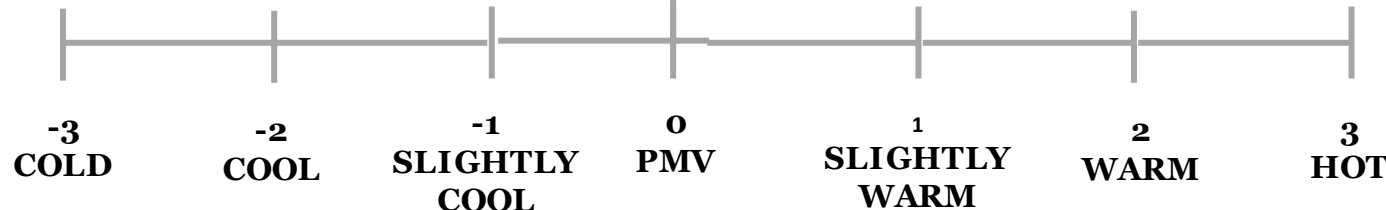
The comfort zone is determined by the combinations of the six parameters for which the Predicted Mean Vote (PMV) is within the recommended range ( $-0.5 \text{ PMV} + 0.5$ ), with the PMV equal to zero denoting thermal neutrality. While anticipating a population's thermal feeling is a crucial step in determining what conditions are pleasant, it is more vital to assess whether individuals will be satisfied.

### Illustrations

Individuals may take short cuts to get out of cold environments

Employees might not wear personal protective equipment properly in hot environments increasing the risks

One's ability to concentrate on a given task may start to drop off, which increases the risk of errors occurring





# Methods to find Thermal Comfort

It is critical to avoid local thermal discomfort, whether it is produced by a vertical air temperature difference between the feet and the head, an asymmetric radiant field, local convective cooling (draught), or contact with a hot or cold floor. When a person's thermal sensitivity is cooler than neutral, they are more sensitive to local discomfort, and when their body is warmer than neutral, they are less sensitive.

## LOCAL THERMAL DISCOMFORT

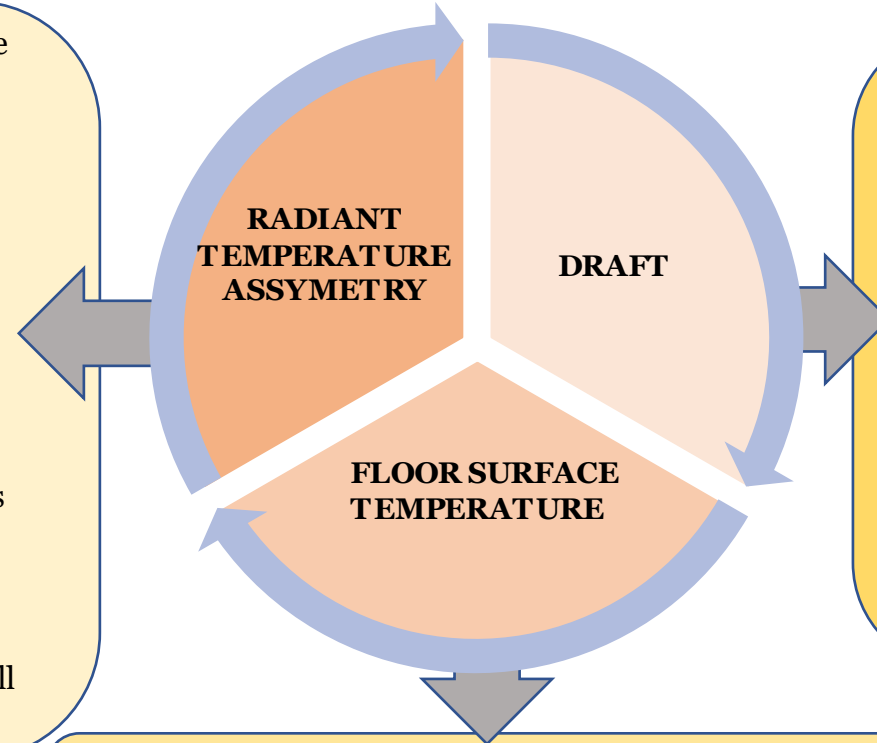
**RADIANT  
TEMPERATURE  
ASYMMETRY**

**DRAFT**

**FLOOR SURFACE  
TEMPERATURE**

# Local Thermal Discomfort

- **Large variances** in the heat radiation of the surfaces that surround a person might create local discomfort or impair acceptance of the temperature circumstances.
- The temperature disparities across diverse surfaces are limited by **ASHRAE Standard 55**. Because some asymmetries are more sensitive than others, such as a warm ceiling against hot and cold vertical surfaces, the limitations vary depending on which surfaces are involved.
- The ceiling cannot be more than **+5 °C (9.0 °F)** warmer than the other surfaces, but a wall can be up to **+23 °C (41 °F)** warmer.



- While **air movement** can be enjoyable and give pleasure in some situations, it can also be unwelcomed and cause discomfort in others.
- The undesired air movement is known as "**draught**," and it is most noticeable when the complete body's thermal sense is cool.
- A **draught** is most likely to be felt on exposed body regions such as the head, neck, shoulders, ankles, feet, and legs, although the sensation is also affected by air speed, air temperature, activity, and clothing.

Depending on the **footwear**, too hot or too cold floors might be uncomfortable. In rooms where users will be wearing lightweight shoes, ASHRAE 55 advises keeping floor temperatures between **19–29 °C (66–84 °F)**.

# Methods to find Thermal Comfort

There will always be a percentage dissatisfied occupants.  
Often it will be the same person, therefore the values should not be added

CATEGORY	PPD (PREDICTED PERCENTAGE DISSATISFIED)	PMV (PREDICTED MEAN VOTE)	DR (DRAUGHT RISK)
	%	-	%
A	< 6	$-0.2 < PMV < +0.2$	< 10
B	< 10	$-0.5 < PMV < +0.5$	< 20
C	<15	$-0.7 < PMV < +0.7$	< 30

# Thermal Comfort in Affordable Housing

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**70% of the buildings** needed in India by 2030 have yet to be constructed. Maintaining the status quo is pointless, and there is a huge opportunity to properly incorporate passive design strategies across our built environment.

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**Passive solutions** for thermal comfort in buildings can greatly reduce cooling, ventilation, and lighting requirements

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**Less reliance on mechanical cooling/heating** approaches reduces the generation of surface ozone, resulting in better air quality

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Building techniques that are more sensitive will tend to reduce disparities in thermal comfort between different income classes as more people become aware of the benefits of **sustainable building design**.

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# Thermal Comfort in Affordable Housing

## Impact of Thermally Comfortable Affordable Housing

Thermal comfort in housing is one of the key pillars to achieve India's National Cooling Action Plan target of reducing cooling energy need by 20-40 per cent by 2037-38.

## Overview of affordable housing sector

Thermal comfort housing can have numerous positive impacts

Lower operational costs for the economically weaker sections

Broader market & outreach for the sustainable material & technology market

Social benefits rising from better comfort conditions like boost in academic performance of kids, improvement in quality of life of the women

Boost to meet the targets of Paris Agreement & achievement of sustainable development goal specially number 3, 11 & 13

Better health and well being of the occupants

**80 million**

households in India are estimated to be living in slums

**20 million**

current housing shortage in Urban areas

**40 million**

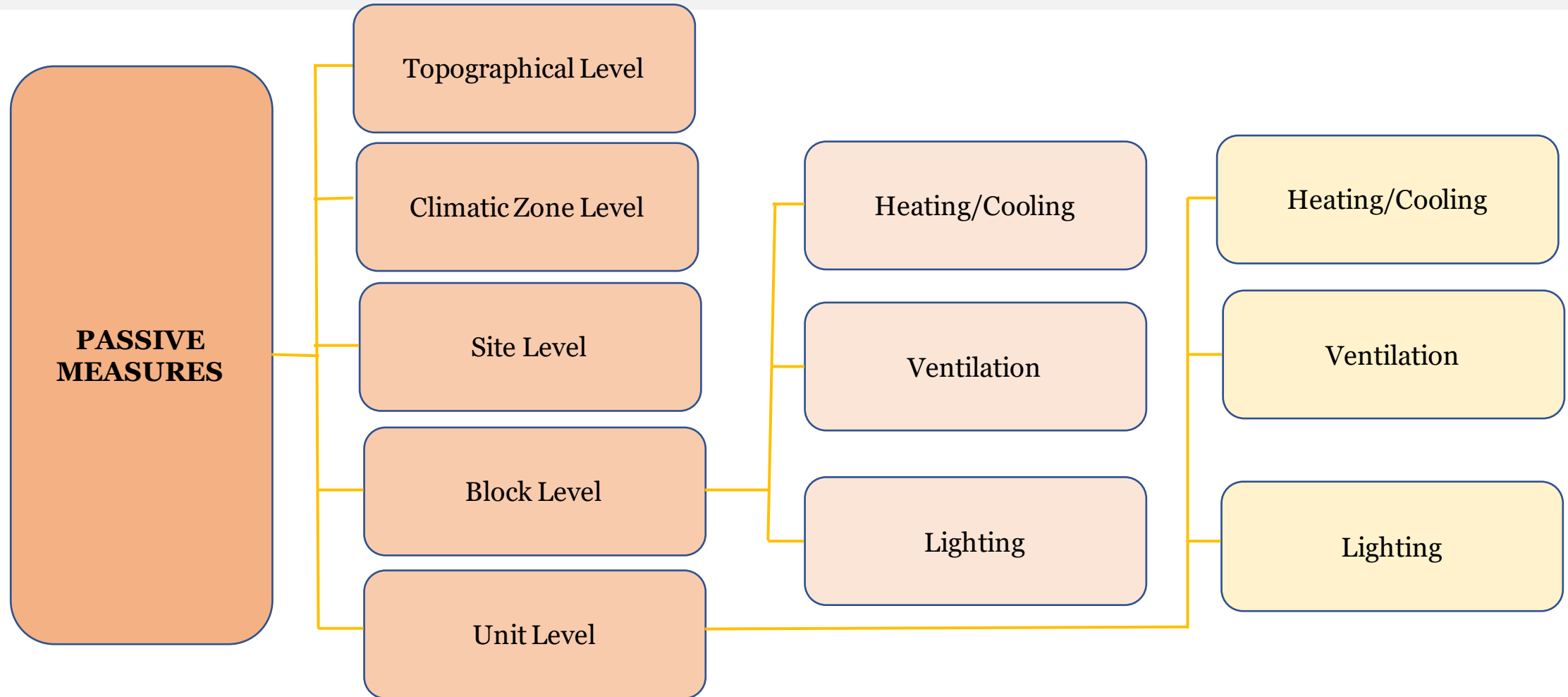
current housing shortage in Rural areas

**70%**

housing shortage in Rural areas is mainly in affordable segment



# Passive Measures & Building Physics





# Passive Measures to improve Thermal Comfort in Affordable Housing

## Topographical Level

- Protecting mountains, forests, watersheds, rivers, wetlands, farmlands, coasts and cities against climate change.

## Climatic Zone Level

- Designing according to climatic conditions such as temperature, rainfall, wind direction, solar radiation, humidity etc.

## Site Level

- To take advantage of the congenial and mitigate the adverse characteristics of the site and its micro-climatic features.

## Block Level

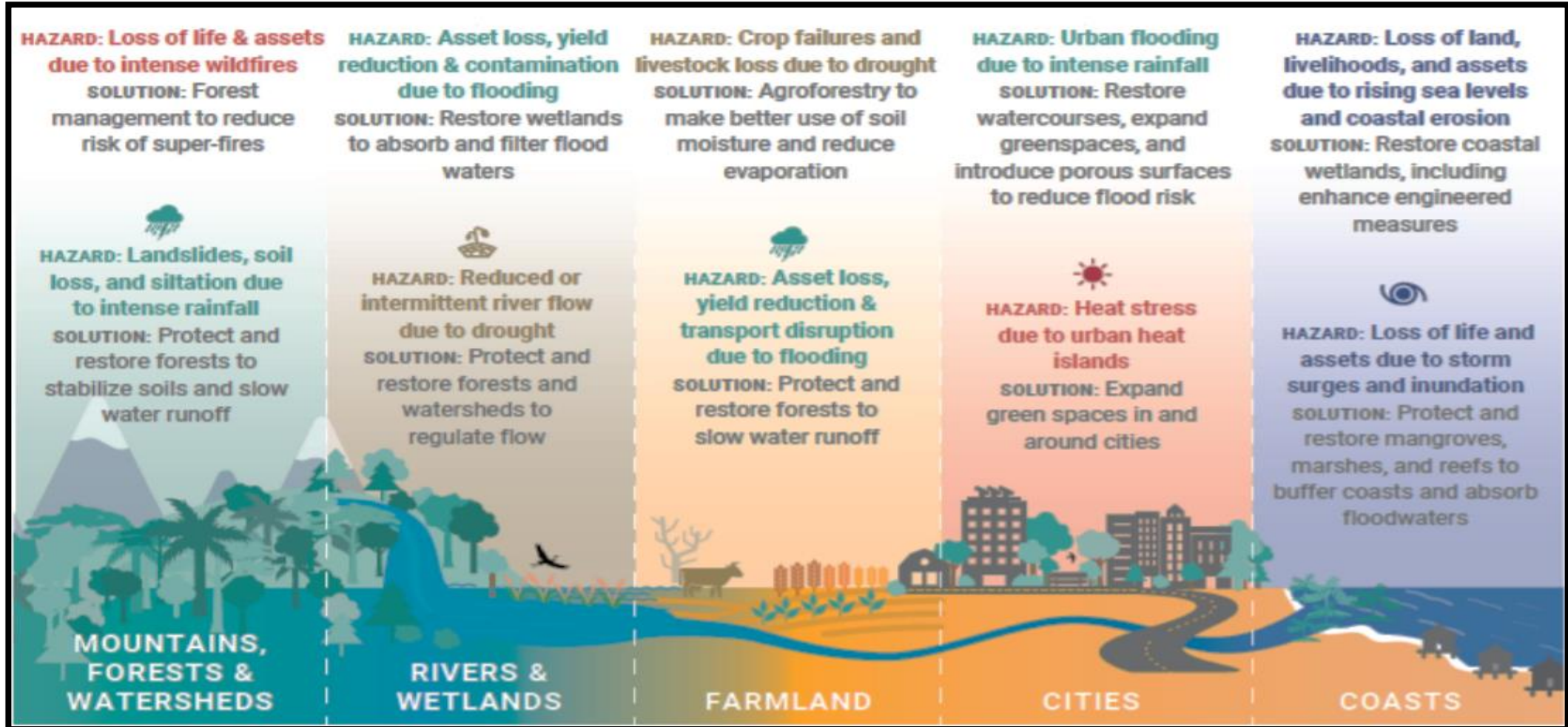
- Interaction of block with surrounding ones and vegetation so that it is not deprived of heating/cooling, ventilation and lighting.

## Unit Level

- Design strategies at unit level that influences heat, light and ventilation based on climatic conditions.



## Tropical Level







## Climatic Zone Level

Best exemplified by vernacular/traditional architectural typologies that respond to the specific climate of the region.

Examples:

- Earth architecture with thick walls and small windows for maximum insulation in Ladakh.
- Courtyard havellis in Rajasthan which leverage pressure differences and mutual shading for natural cooling and ventilation.
- Sloping roofs and to protect from heavy rains in Kerala



*Source: University of Waterloo, Tropical Climate Analysis*



## Site Level

Reducing 'Heat Island' effect by techniques such as:

- Building around courtyards/open courts
- Leveraging mutual shading of blocks
- Creating wind passages through site massing
- Reducing hard paving to allow water absorption
- Using complimentary vegetation that control sunlight penetration through seasonal changes





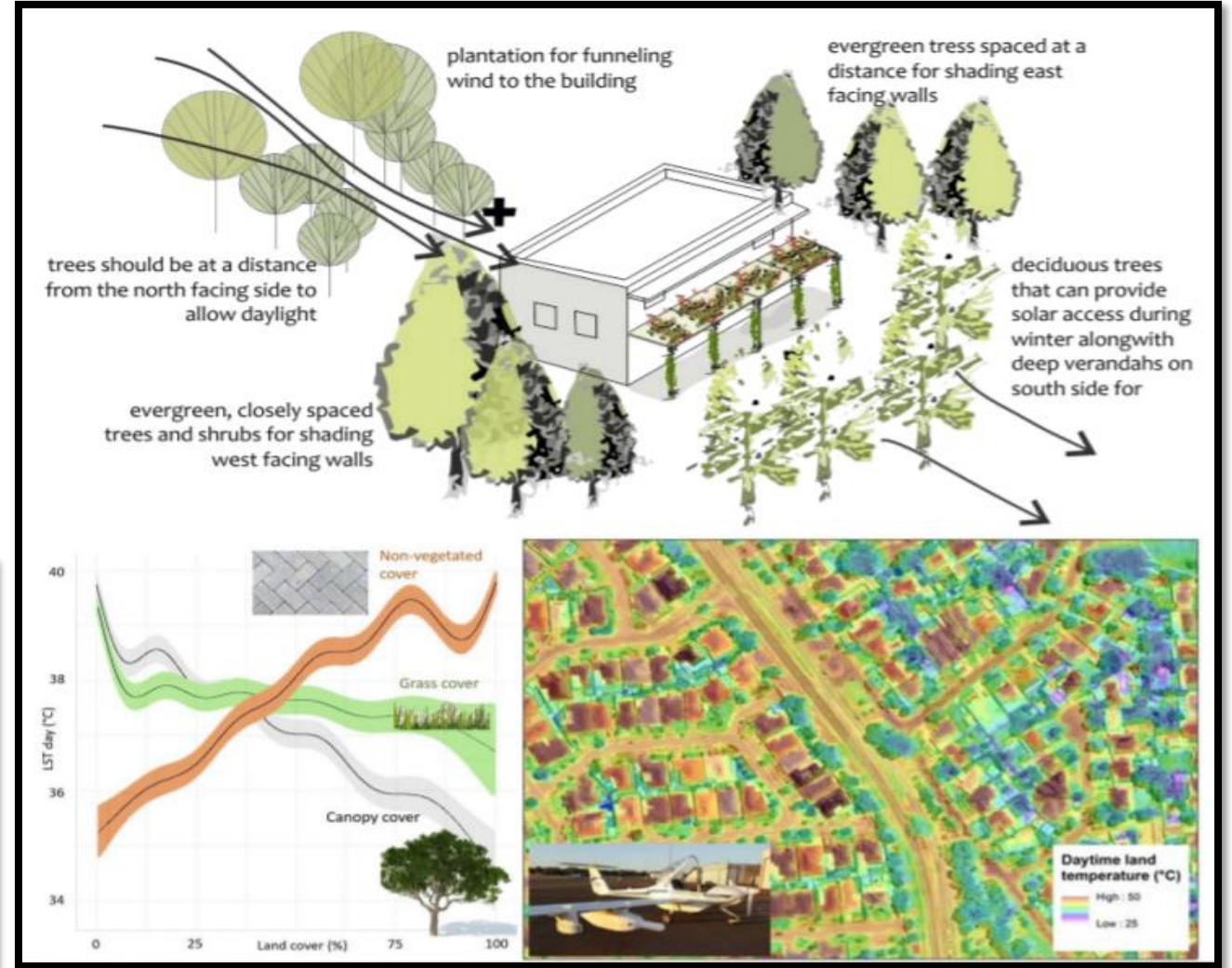
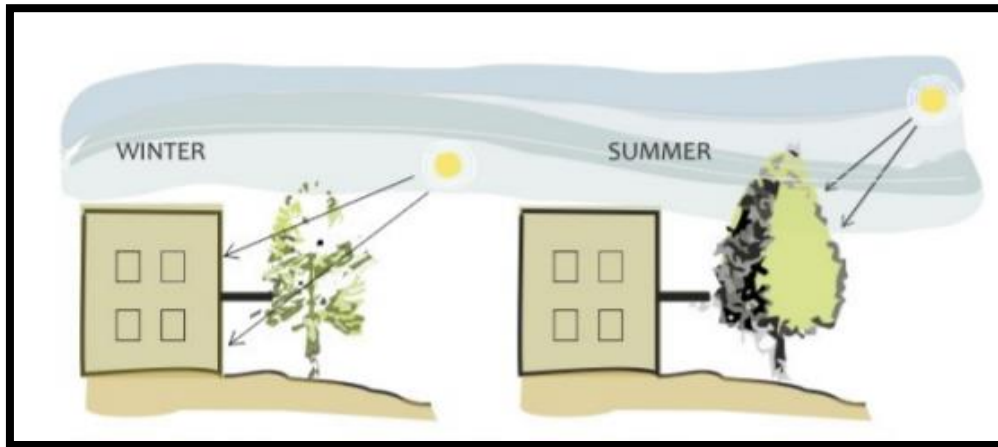


## Site Level: Leveraging Plantations

Appropriate plantation of trees to promote shading and ventilation can temper extreme weather to a significant degree.

In Adelaide, a study estimated that districts with higher vegetation cover remained cooler by up to 6°C during heatwave conditions.

The image below shows deciduous trees allow sun penetration in winter and block sun access during summer.

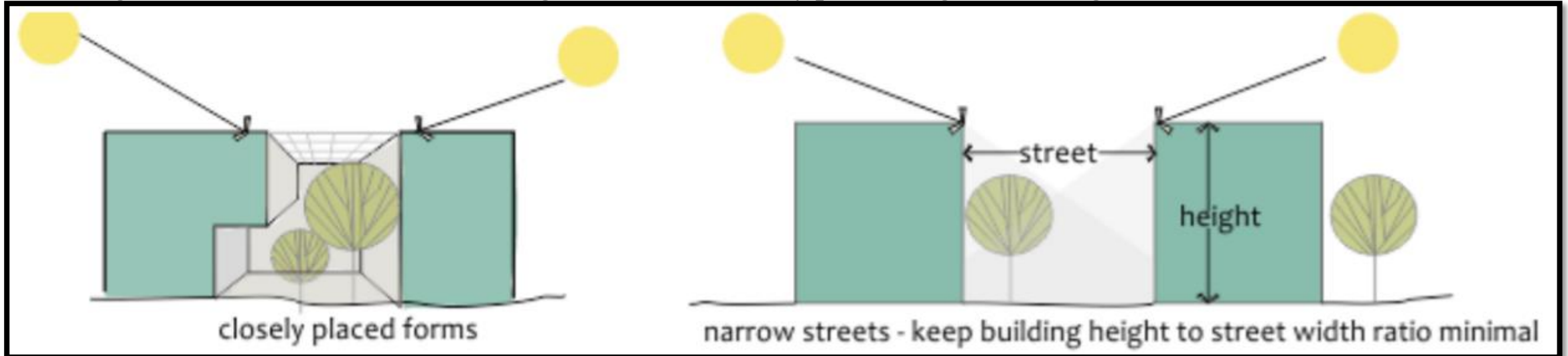




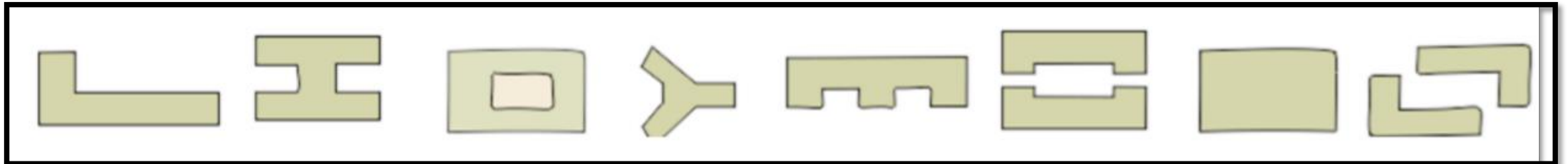
## Block Level

### Heating / Cooling Strategies

Arrange blocks such that mutual shading is achieved, thereby preventing solar heat gains in warm months.



Arrange longer facades along north / south to encourage glare free lighting in summer and maximize solar penetration in winter.



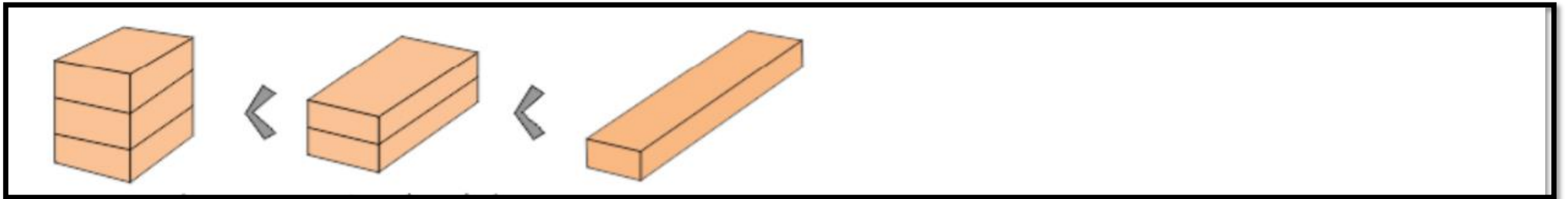


## Block Level

### Heating / Cooling Strategies

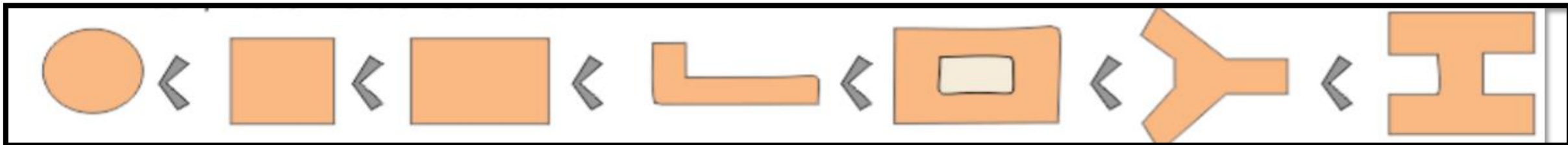
Minimize surface area to building volume and perimeter to area ratios in extreme climate zones to minimize exposure to solar radiation.

**Minimize P/A ratio in extreme climates**



Increase compactness by reducing surface area for the same volume.

**Minimize P/A ratio in extreme climates**

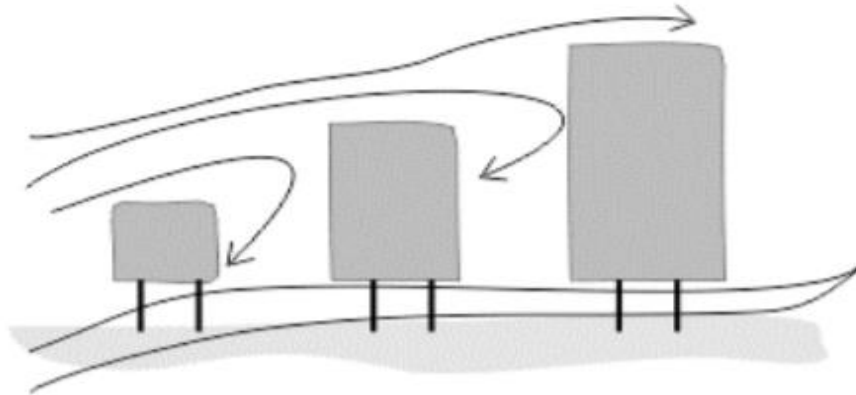




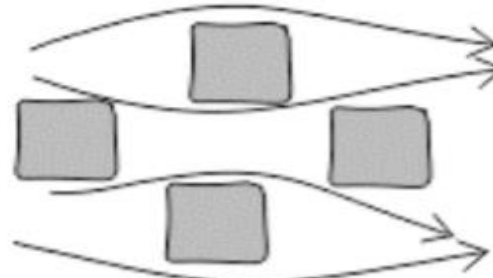
## Block Level

### Heating / Cooling Strategies

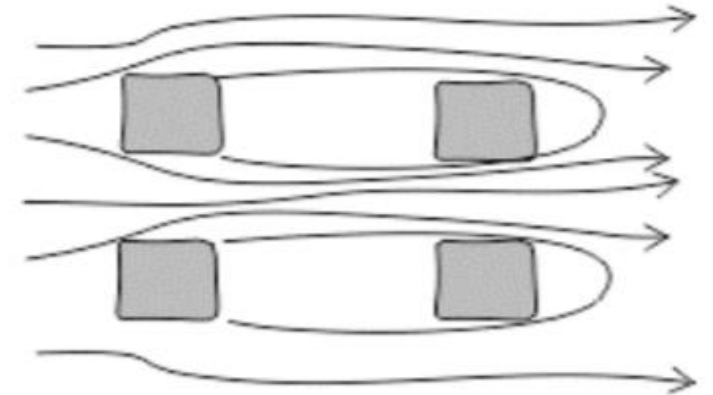
Buildings should be oriented to avoid creation of 'wind shadows'



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



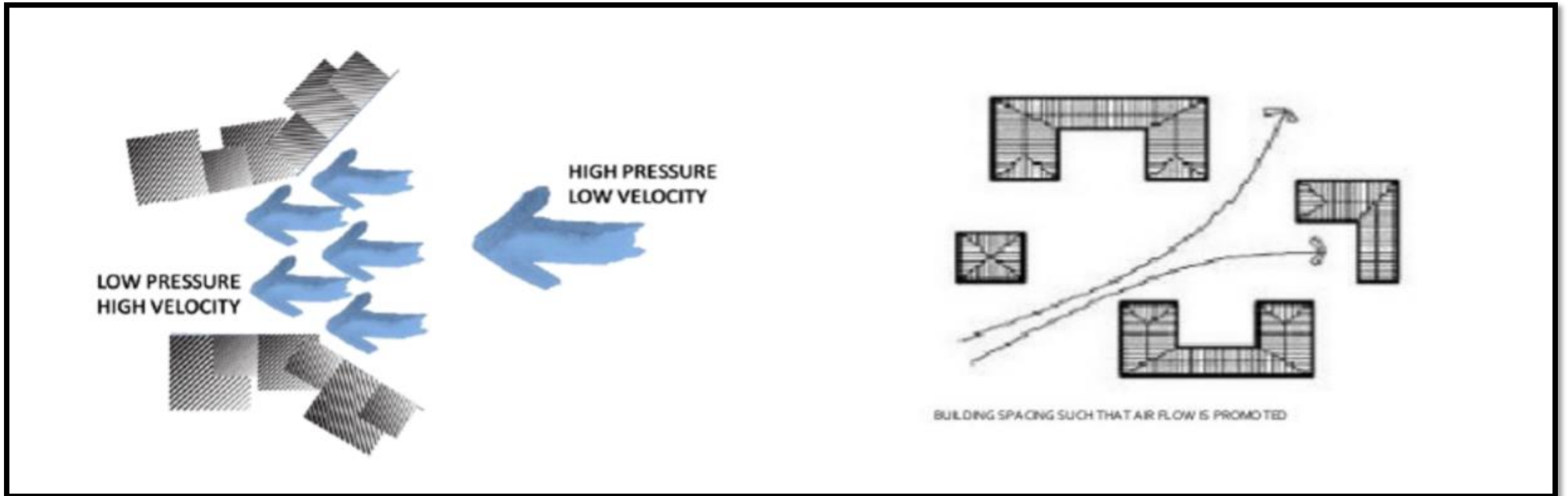




## Block Level

### Ventilation Strategies

Wind flows can be harnesses by creating variably sized courts and catchment areas. This can enhance ventilation and serve an overall cooling effect for the blocks.

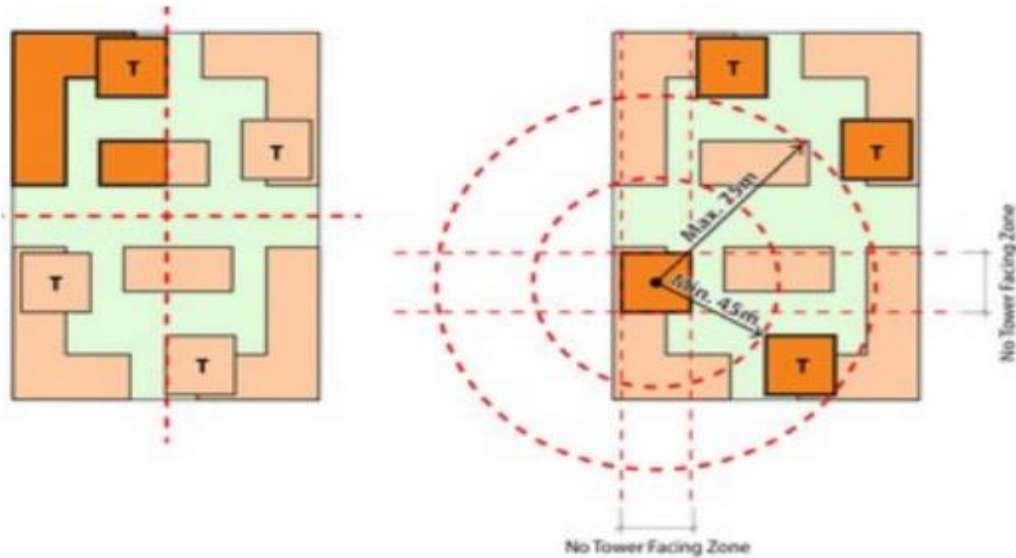


Source: MaS, SHIP



## Block Level

### Lighting Strategies



#### RULE 1-1

Since full block is optimal, each zone as a potential small block is also optimal.

#### RULE 1-2

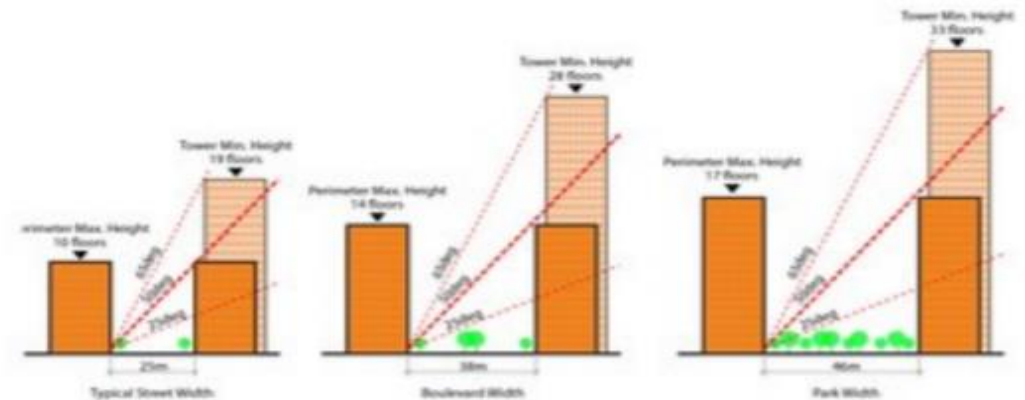
Generally, 1 tower per each zone.

#### RULE 2-1

Any tower should be separated a minimum of 45m center to center of a tower to minimize the impact on each other.

#### RULE 2-2

Towers should be located at no more 75m apart to maintain typology efficiency. Additionally, towers should not directly face each other.



#### RULE 3-1

The tower and perimeter block height is defined by the street or courtyard width and a range of BRE recommended obstruction angles.

25 deg (BRE recommended) : conventional window design will usually give reasonable result.  
65 deg (BRE recommended) : it is very difficult to provide adequate daylight, unless very large windows are used.

50 deg (KPF recommended): it provides higher density with reasonable solution to improve daylight condition through designing adequate room layout and enlarged windows



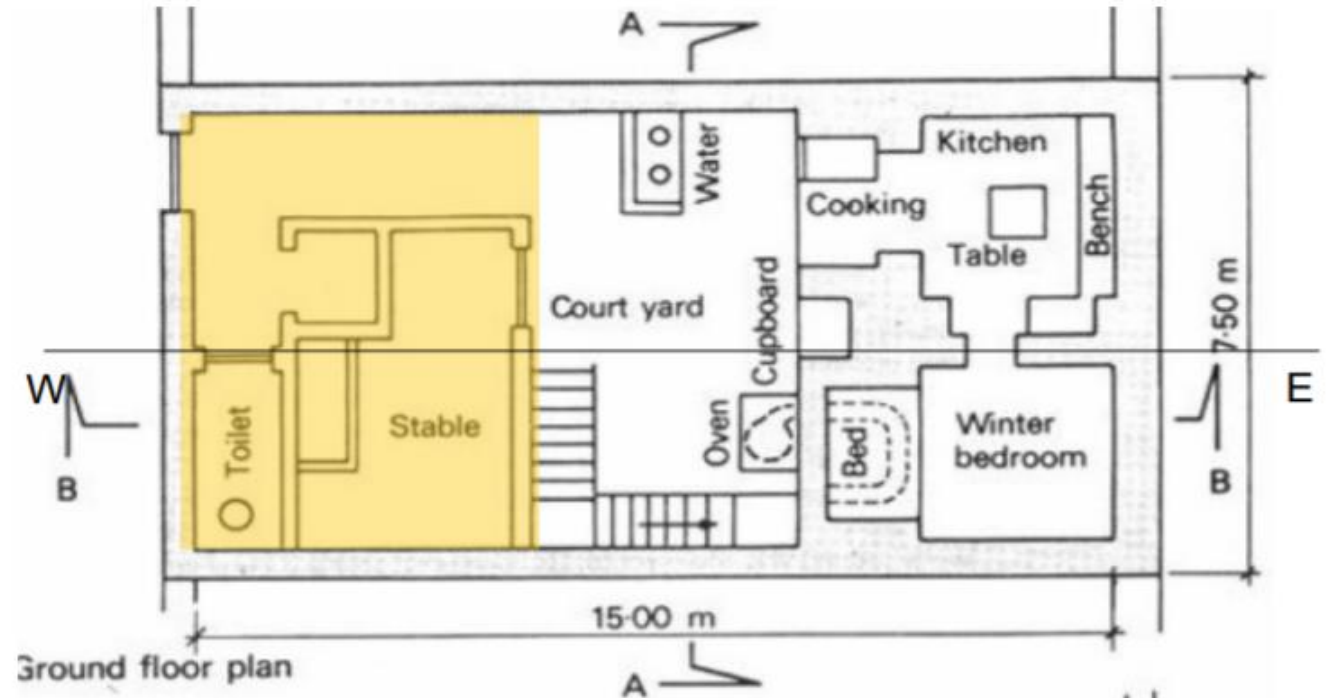


## Unit Level

### Heating / Cooling

#### Form and Orientation

- The alteration in solar path affects solar radiation penetration patterns during different seasons and consequently, heat gain and loss in a building.
- Moderately compact courtyard type internal planning. Lesser exposure to sun on East-West external walls to minimize heat gain.
- Non-habitable rooms (stores, toilets, etc) can be effectively used as thermal barriers if planned and placed on the east and especially, the west end of the building.



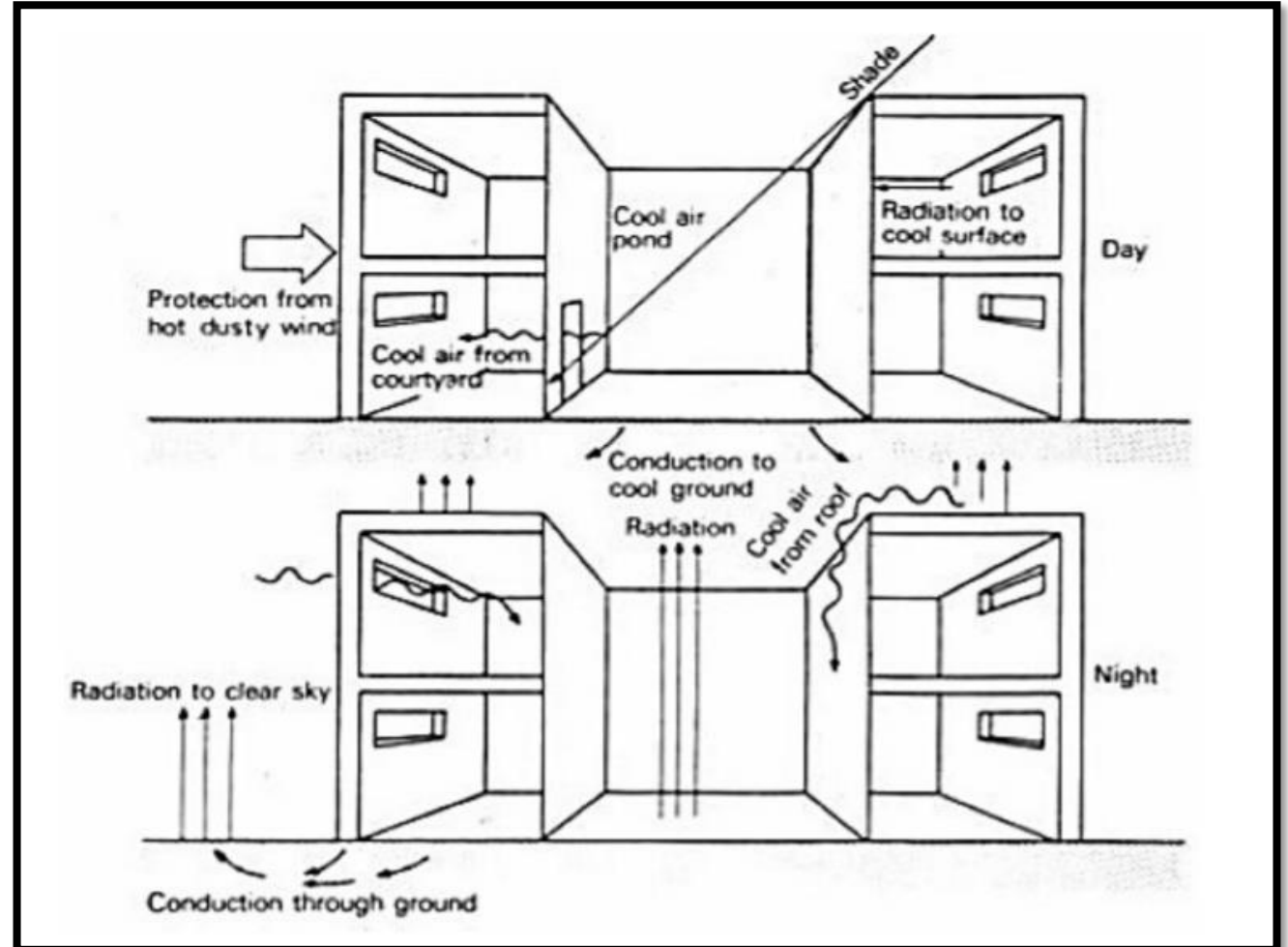


## Unit Level

### Heating / Cooling

#### Form and Orientation

- Courtyard Effect – high walls cut off the sun, and large areas of the inner surfaces and courtyard floor are shaded during the day.
- Cooler air, cooler surfaces, the earth beneath the courtyard will draw heat from the surrounding areas, reemitting it to the open sky during the night.



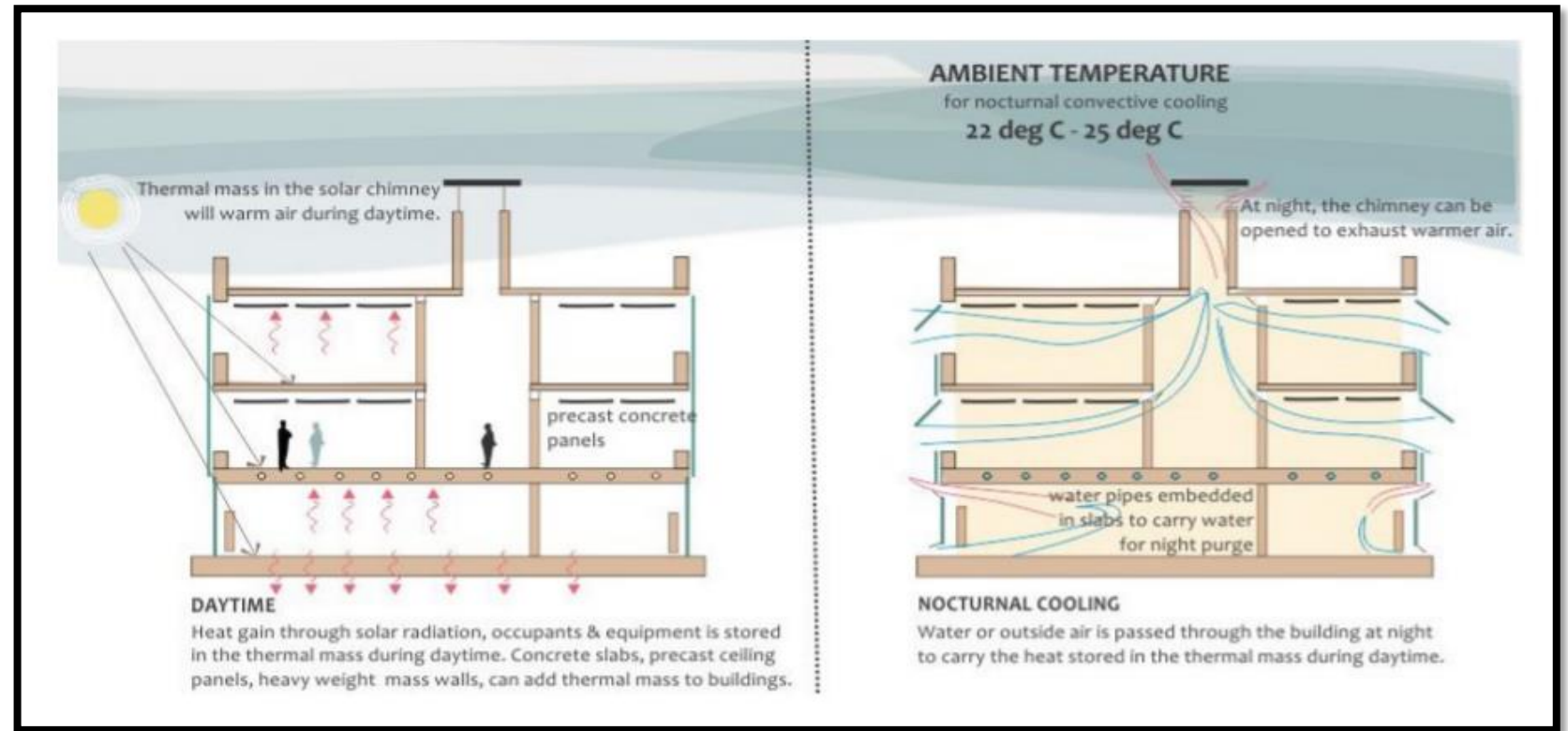


## Unit Level

### Heating / Cooling

#### Form and Orientation

- Thermal mass can be used with nocturnal convective cooling or night cooling for cooling buildings passively.
- Diurnal swing must be high for thermal mass to be an effective passive cooling and heating strategy.



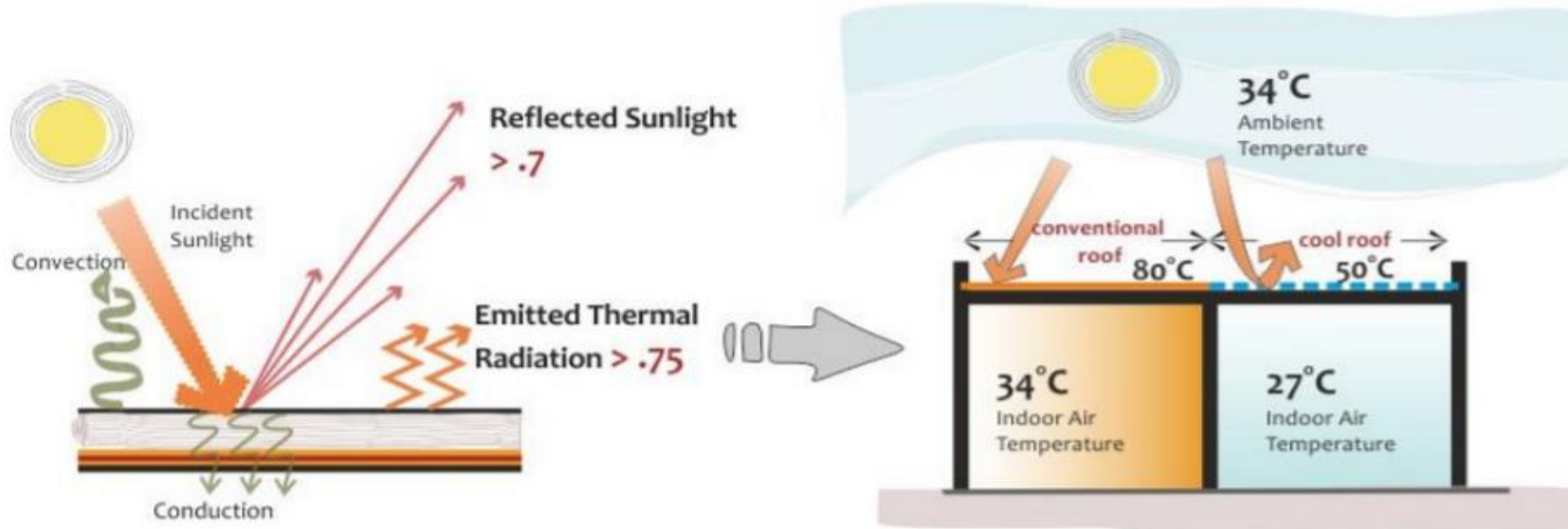


## Heating / Cooling

### Unit Level

#### Cool Roofs

- Thermal emittance (re-radiation of absorbed heat), and solar reflectance of cool roofs is much higher than conventional roofs, which enables them to prevent solar radiation from being passed on to the interior of a building. Cool roofs reduce annual air conditioning energy use of a single story building up to 15%



Performance of cool roofs can be assessed in terms of thermal emittance, solar reflectance or Solar Reflectance Index (SRI), which is a measure of both emittance and reflectance.

Cool roofs are able to maintain a temperature differential of 6-8 deg celcius between ambient and indoor air temperature due to high thermal emittance and solar reflectance.



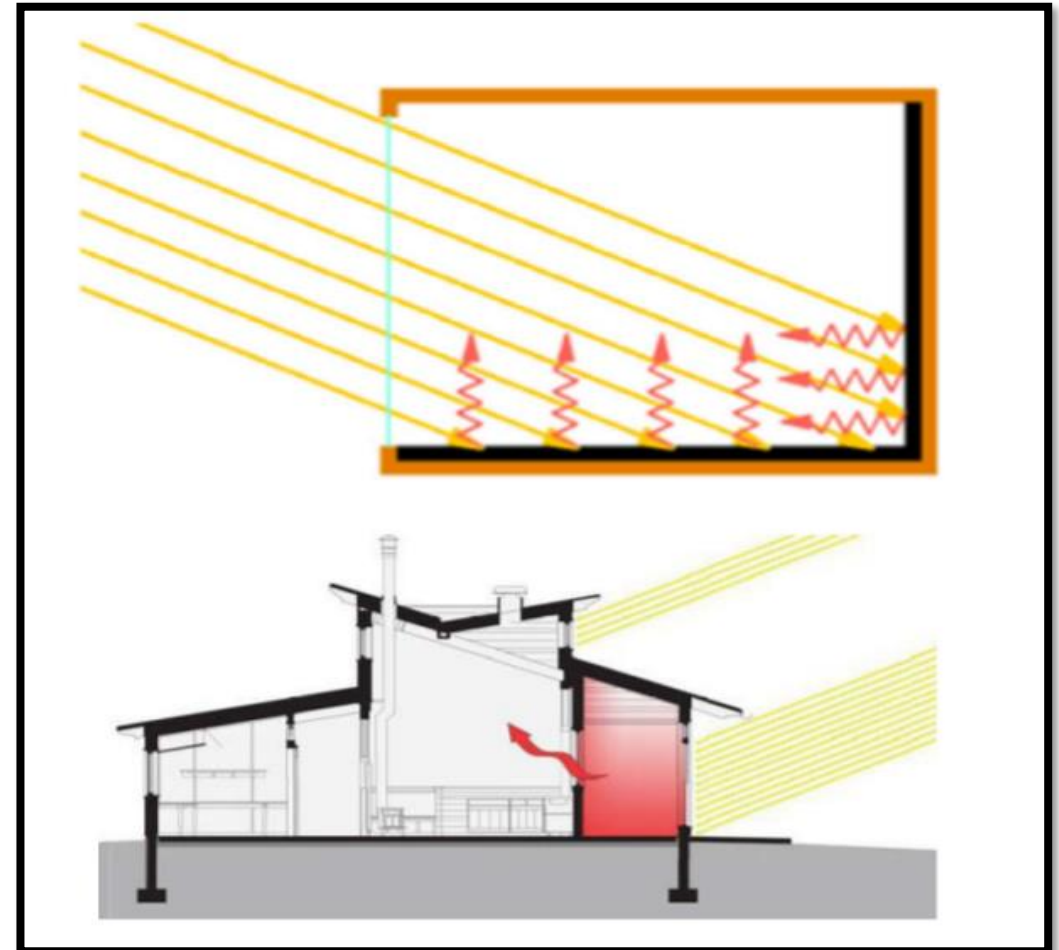


## Unit Level

### Heating / Cooling

#### Direct Heat Gain

- Sunlight is admitted into the living spaces, directly through openings or glazed windows, to heat the walls and floors and thereby the air inside.
- The glazed windows are generally located facing south to receive maximum sunlight during winter (in northern hemisphere). They are generally double glazed, with insulating curtains, to reduce heat loss during night time.
- Glazed corridors and verandahs can also be used to trap sunlight transfer heat to living / working spaces beyond. At night these buffers can help retain heat in living area.





## Unit Level

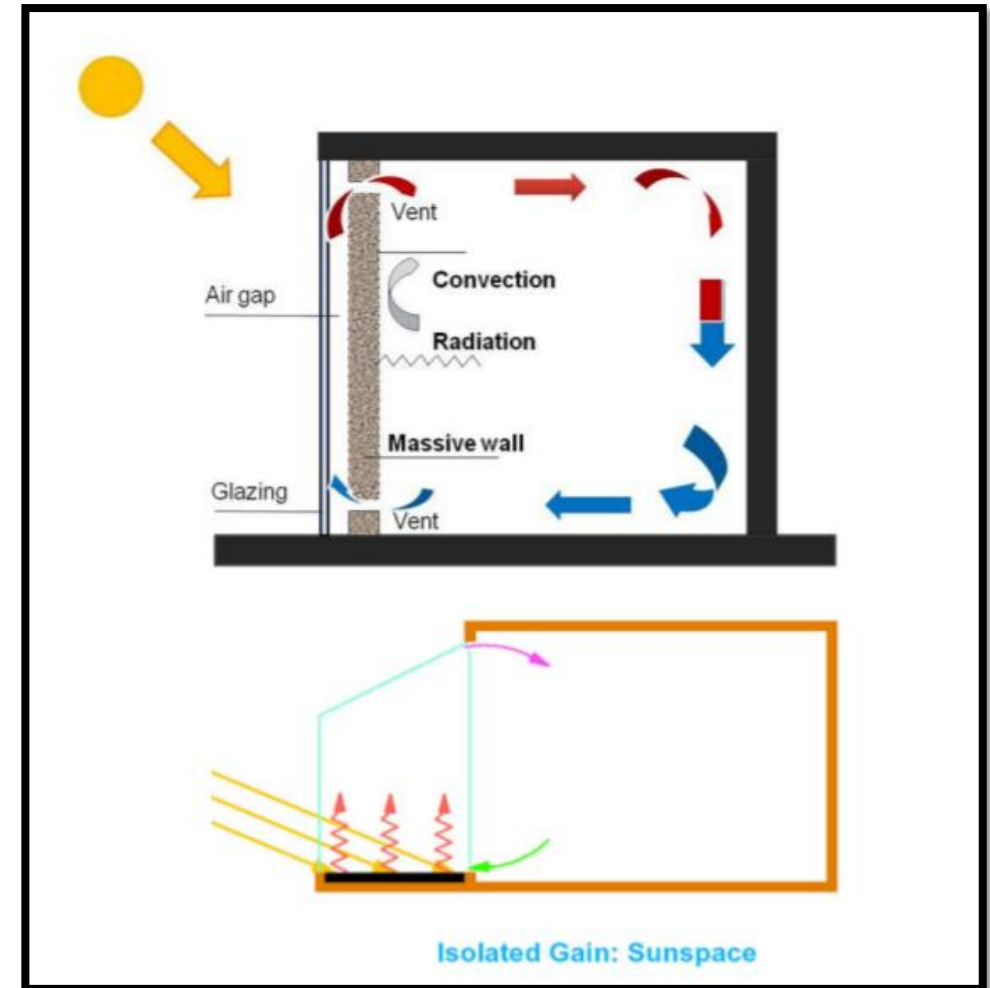
### Heating / Cooling

#### Indirect Heat Gain

- Trombe walls, thick solid walls with vents along with lower and upper ends, can be used in conjunction with glazing along south facades to have a heating effect on internal air circulation.

#### Isolated Heat Gains

- The south facing sunspace can be created with glazing, wherein sunlight heats trapped air, and convection enables its internal circulation.





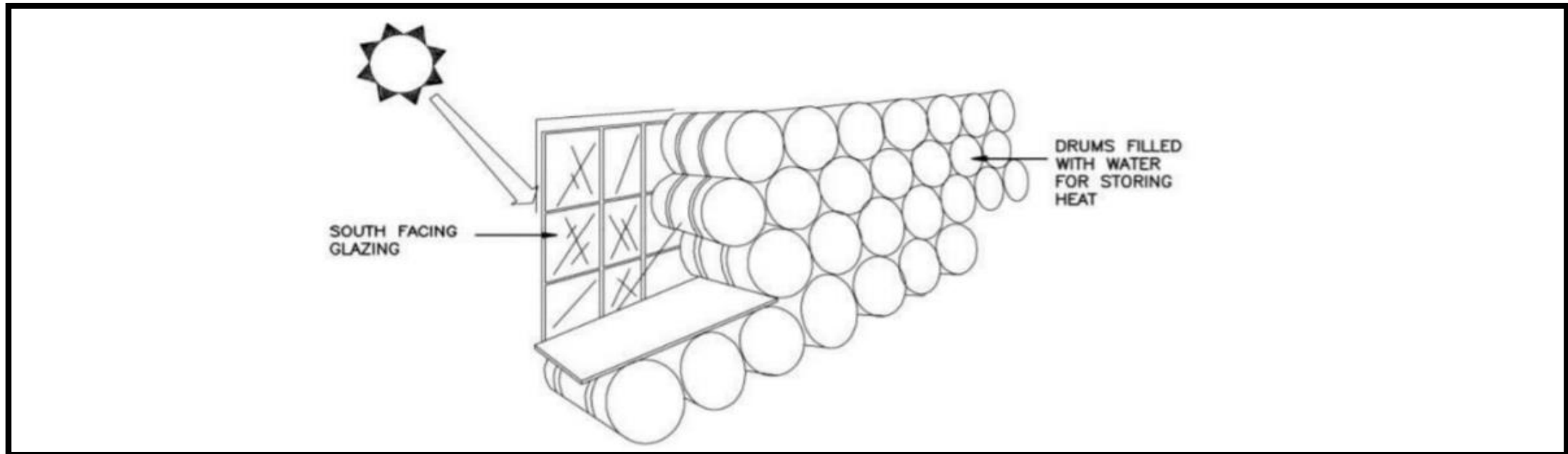


## Unit Level

### Heating / Cooling

#### Water Walls

- Water walls are based on the same principle as that of the Trombe wall, except that they employ water as the thermal storage material. Water walls are thermal storage wall made up of drums of water stacked up behind glazing. It is painted black externally to increase the absorption of radiation. This setup can store more heat than concrete walls due to higher specific heat.



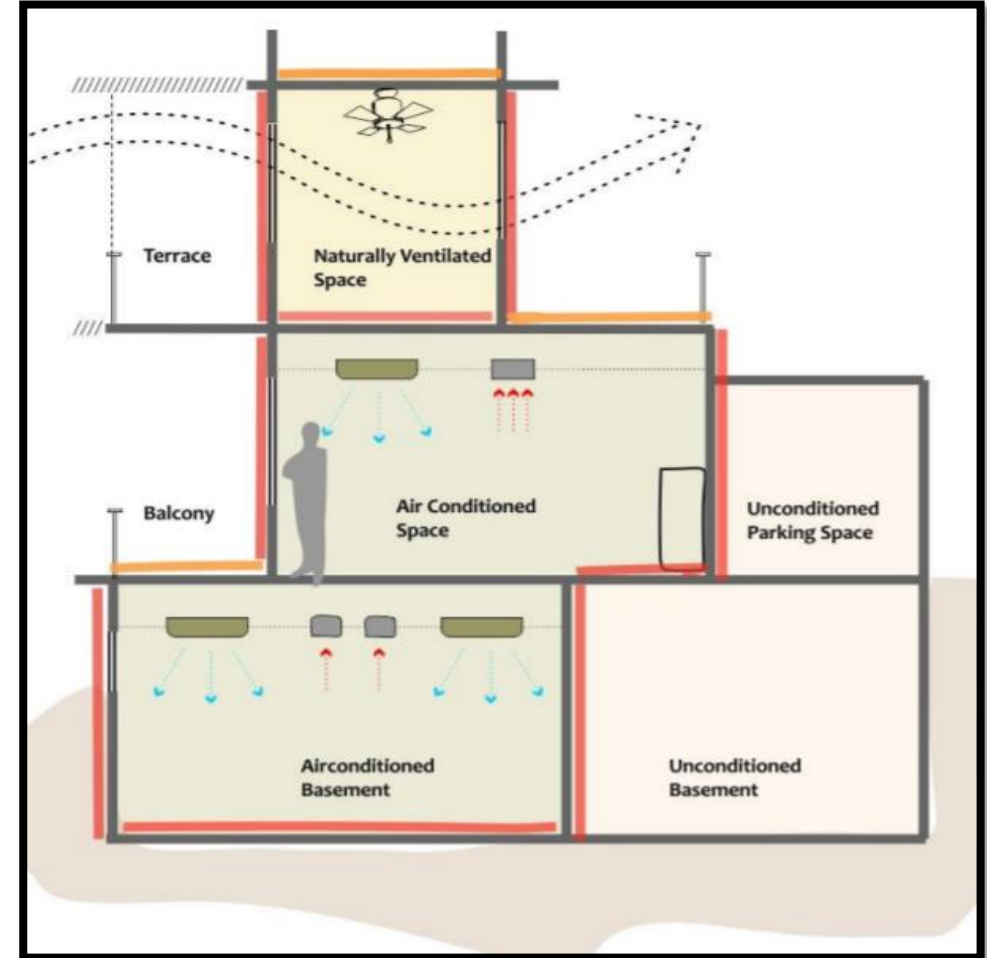


## Unit Level

### Heating / Cooling

#### Insulation

- Insulation should always be placed on the warmer side of the envelope.
- In warm climates, insulation should be installed on the outside and in cold climates, on the inside.
- Insulation is rated in terms of R-value. Higher R-values denote better insulation and translate into more energy savings.
- Providing insulation beyond 100mm thickness does not provide a much further benefit in terms of energy efficiency. Provision of the initial 25mm of insulation, provides the highest incremental energy saving.
- As the insulation material becomes incrementally thicker, the incremental energy saved becomes smaller and smaller until it is almost insignificant, especially after an insulating thickness of 100mm onwards.



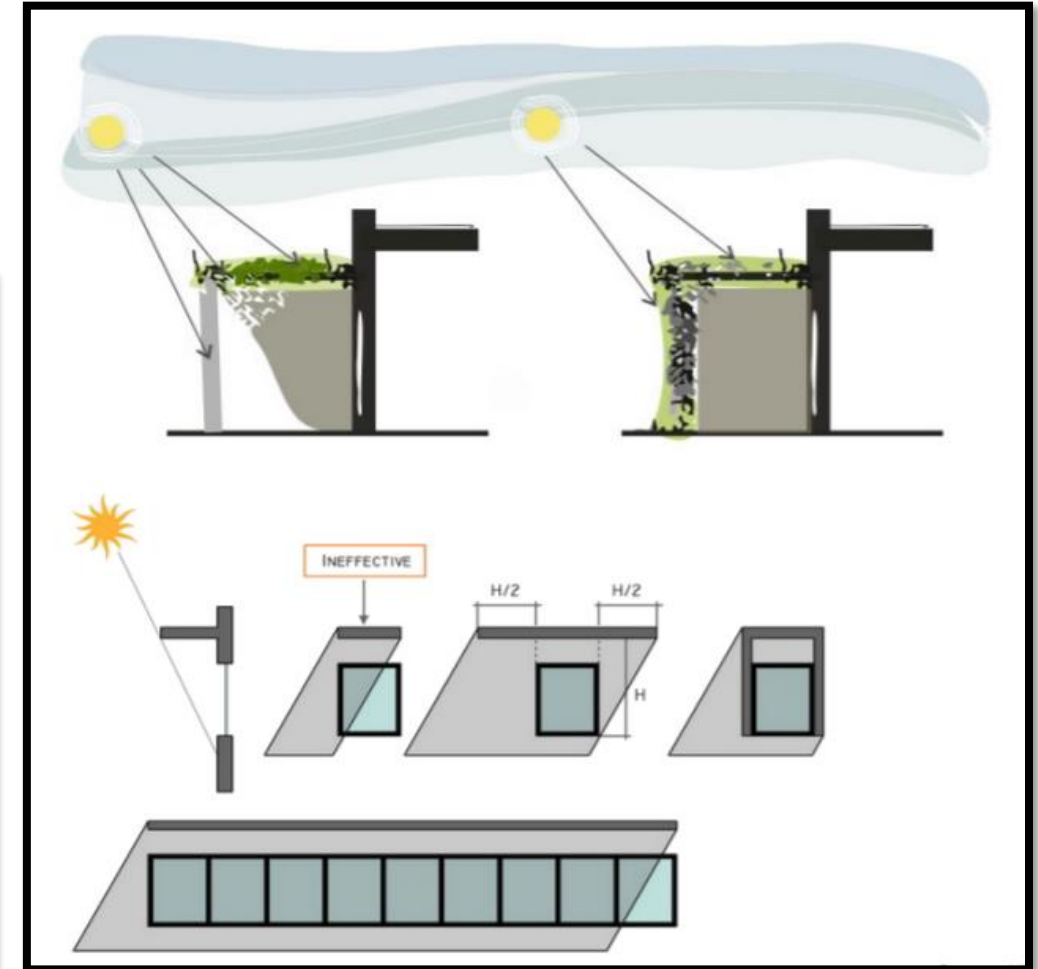
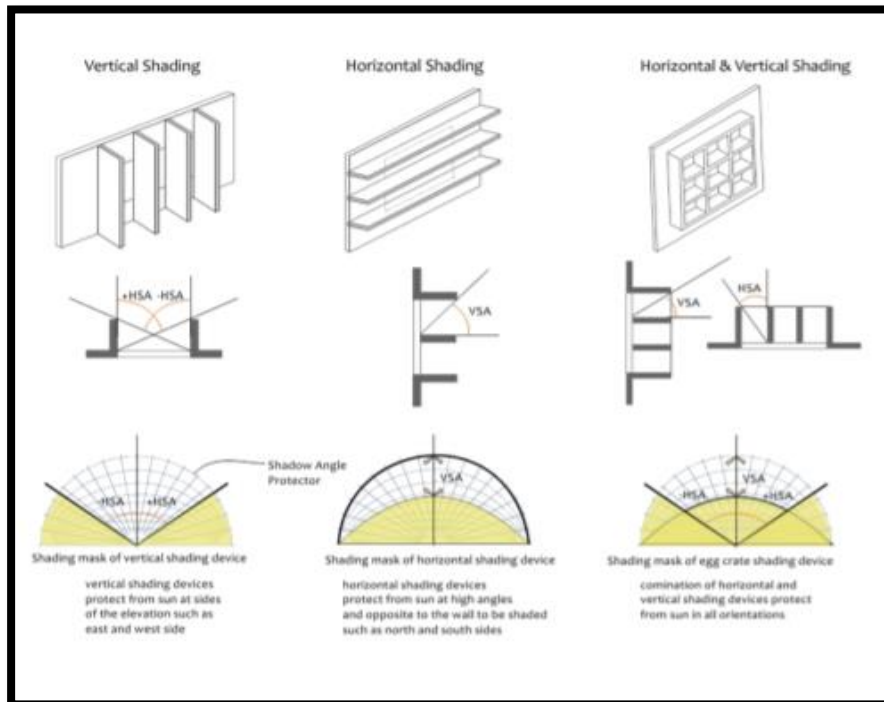


## Unit Level

### Heating / Cooling

#### Shading

- Plants like creepers may be used to promote shading.
- Fenestrations and shades / chajjas may be designed to optimize solar radiation as per climate type.



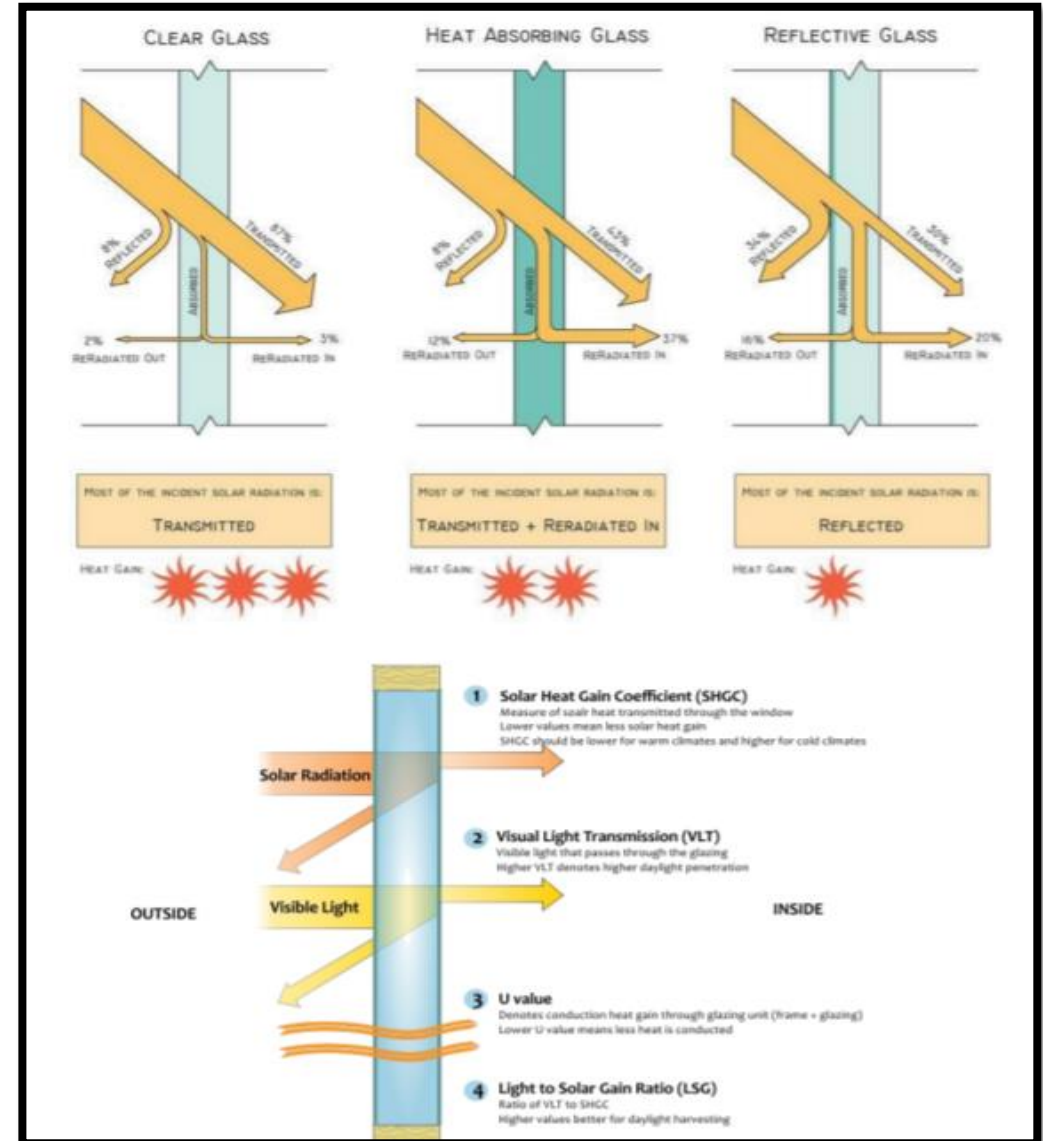


## Unit Level

### Heating / Cooling

#### Glazing

- Location, sizing and glazing of windows can be used judiciously to reducing cooling load, and resultantly, smaller building cooling systems.
- Achieving a balance between daylight penetration and heat gain requires a careful calibration between visual and heat transmission qualities of glazing and the orientation and sizing of opening.
- Reduce Solar Heat Gain Coefficient (SHGC) as less heat will be transferred into the building.
- Reduce the U-Value of glazing and also lower the SHGC except for the cold climate where higher SHGC is recommended.







## Unit Level

### Ventilation

#### Orientation

- Buildings can be oriented at an angle between 0° to 30° with respect to the prevailing wind direction.
- Buildings that feature a courtyard (in cinemas where cooling is desired), orienting the courtyard 45° from the prevailing wind maximizes wind flow into the courtyard and entrances cross ventilation in the building.

#### Creating Pressure Differences

- When wind enters through a smaller opening and exits through a bigger opening, that's a squeeze point. This creates a natural vacuum which increases wind velocity.
- Total area of openings should be a minimum of 30% of floor area.
- Window-wall-ratio (WWR) should not be more than 60%.





## Unit Level

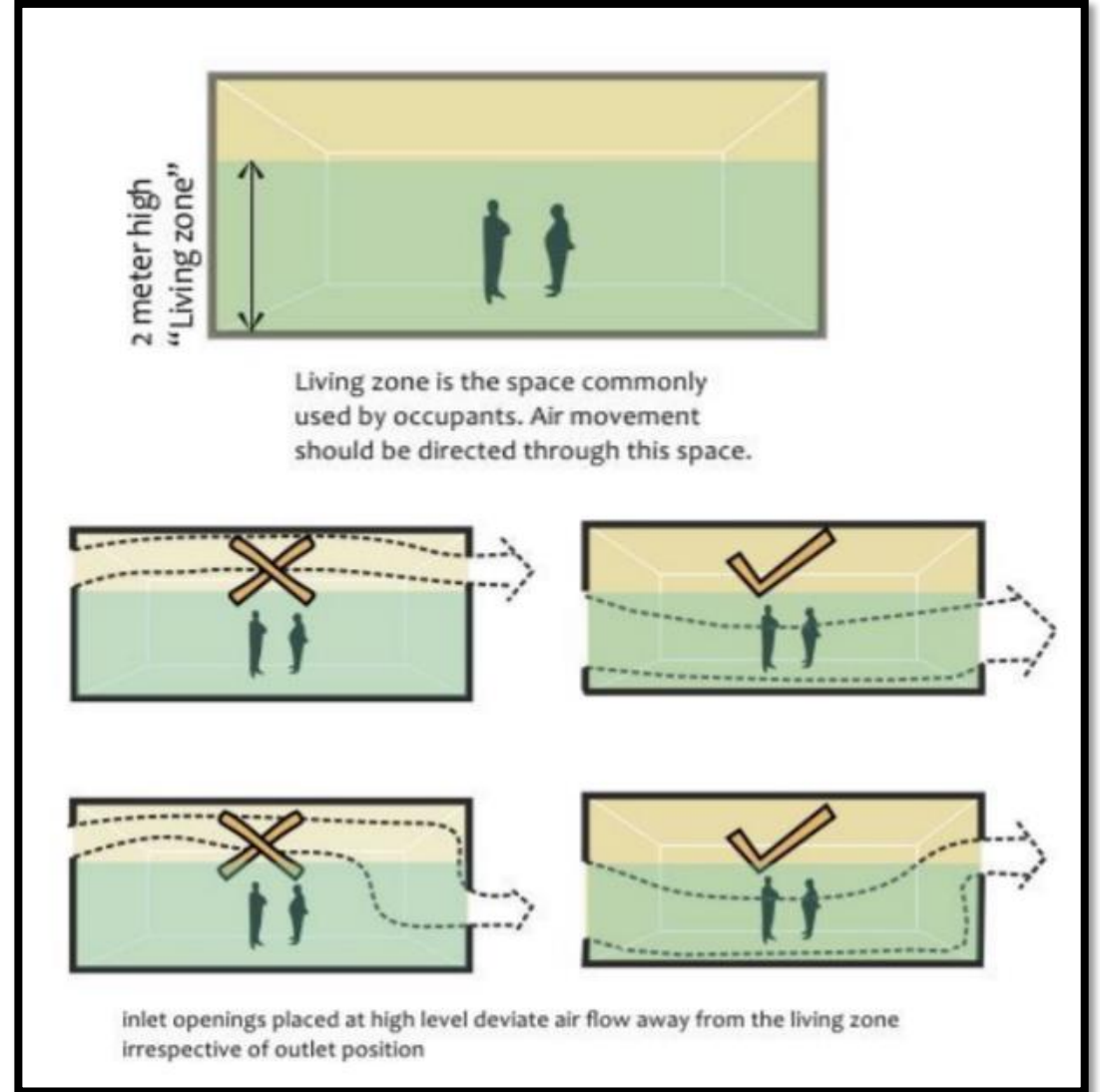
### Ventilation

#### Openings

- Maximum air movement is achieved by keeping the sill height at 85% of the critical height.
- Greatest flow per unit area of the opening is achieved by keeping the inlet and outlet of nearby same sizes at nearly same levels.

#### Stack Ventilation

- Stack ventilation is a form of cross ventilation that enhances air circulation inside a space by combination of buoyancy and venturi effect. It is good for cooler temperatures.
- The lighter warm air rises to escape the building through window openings at high level and is replaced by cool night time air or day time air drawn from shaded external areas from inlets at lower level.







## Unit Level

### Ventilation

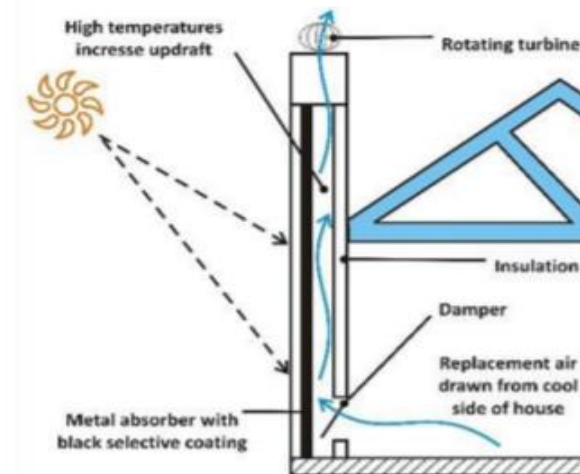
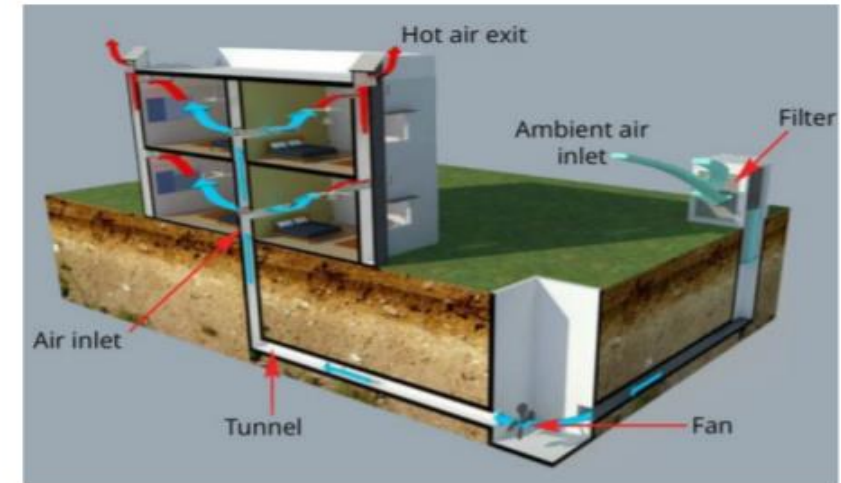
#### Air Earth Exchanger

- A precooling or preheating system which consists of a pipe or network of pipes buried at reasonable depth below the ground surface. It either cools the air by rejecting heat to the ground or heats the air absorbing heat from the ground. It utilizes the fact that deep earth temperature remains almost same as the annual average mean air temperature of the location.

#### Solar Chimney Wall

- Solar Chimney, on an external wall, enhances stack ventilation by providing additional height and well-designed air passages thereby increasing the air pressure differential.
- Via solar radiation, the chimneys warm the rising air which increases the difference between the temperatures of incoming and outflowing air. These measures increase the natural convection and enhance the draw of air through the building.

Source: MaS-SHIP, BEEP

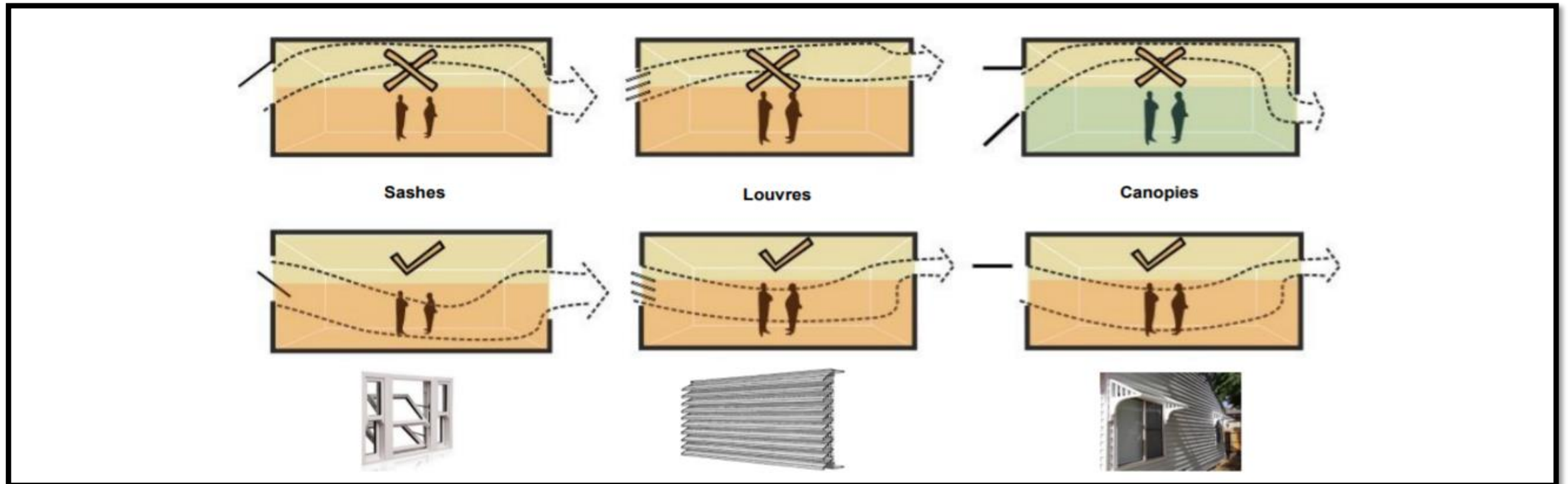


## Unit Level

### Ventilation

#### Directing airflow through openings

- Louvres and shades can be so designed as to direct air in specific directions, while protecting from sun and air.

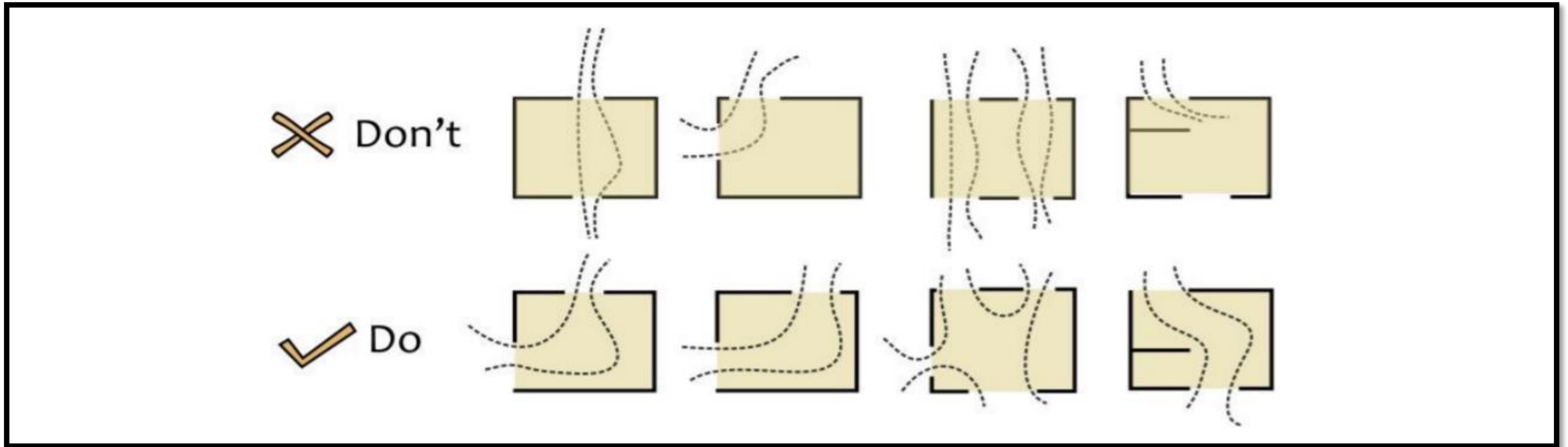


## Unit Level

### Ventilation

#### Positioning of Openings

To encourage ample ventilation, openings should be positioned on opposite walls, diagonally across rooms.





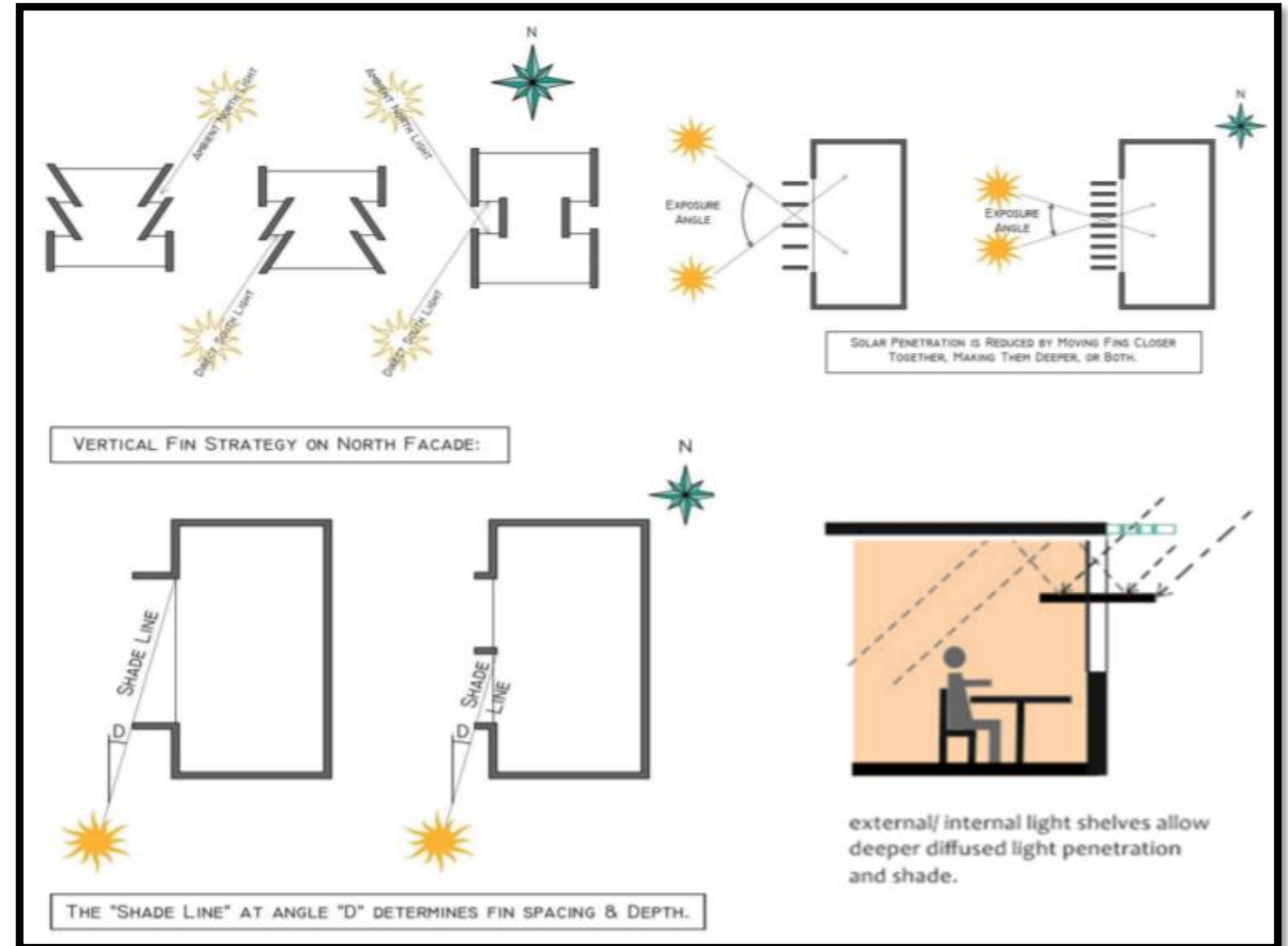
## Unit Level

### Lighting

#### Directional Modifications

- Ambient, glare free light comes from the North, while direct light comes from the south.
- East/West light has a lot of glare as it is generally at a lower angle.
- Orient windows along the east and west façade such that they are angled toward North/South.
- Alternatively, incorporate fins along East/West façade windows.
- Shading is generally not required along North facades, or only minimal shading interventions may be necessary.
- Window shades can be used to optimize light coming from the south.

Source: NZEB







GLOBAL  
HOUSING  
TECHNOLOGY  
CHALLENGE INDIA



Ministry of Housing and Urban Affairs  
Government of India



**giz** Deutsche Gesellschaft  
für Internationale  
Zusammenarbeit (GIZ) GmbH

## Existing Standards for improving Thermal Comfort



ASHRAE - 55



National Building Code - 2016



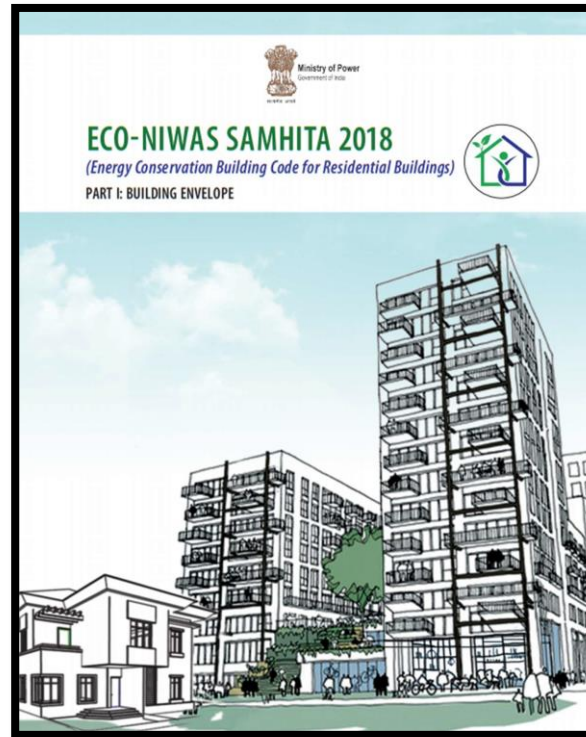
Handbook of Functional Requirements of  
Buildings 1987 by BIS



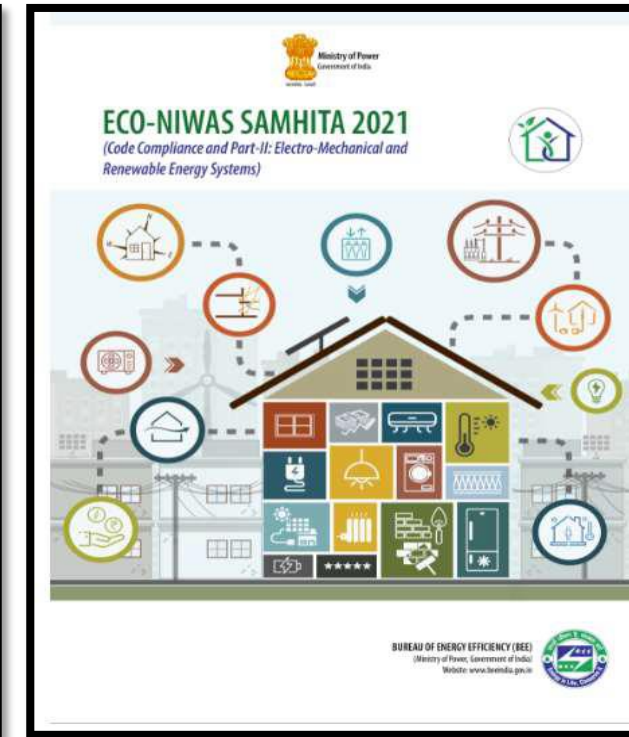
Eco Niwas Samhita Part 1 and Part 2



ISHRAE – Indoor Environmental Quality  
Standards 2018-19



Eco Niwas Samhita 2018  
Part 1: Building Envelope

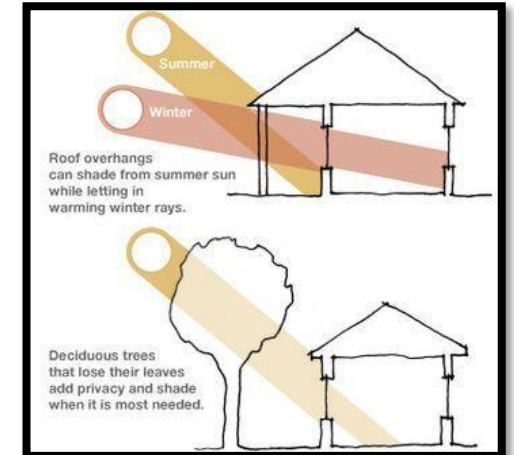
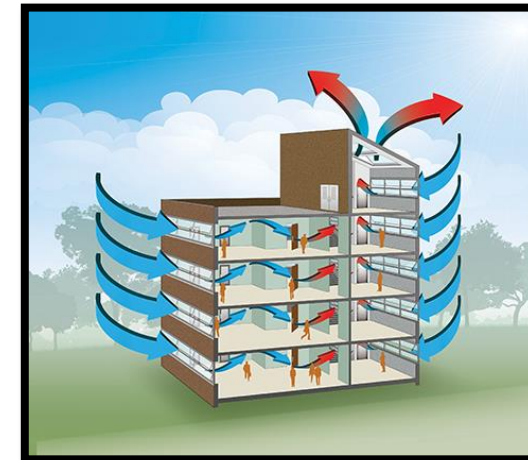
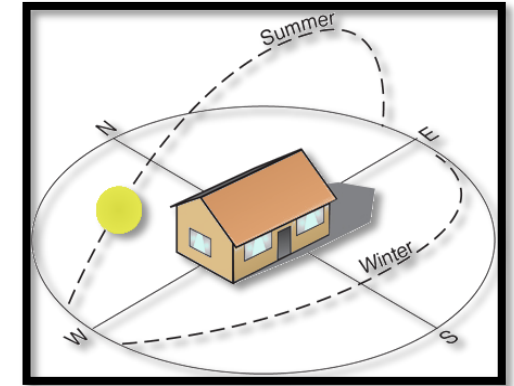
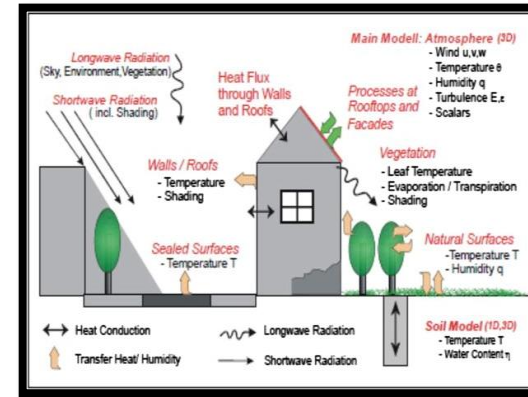
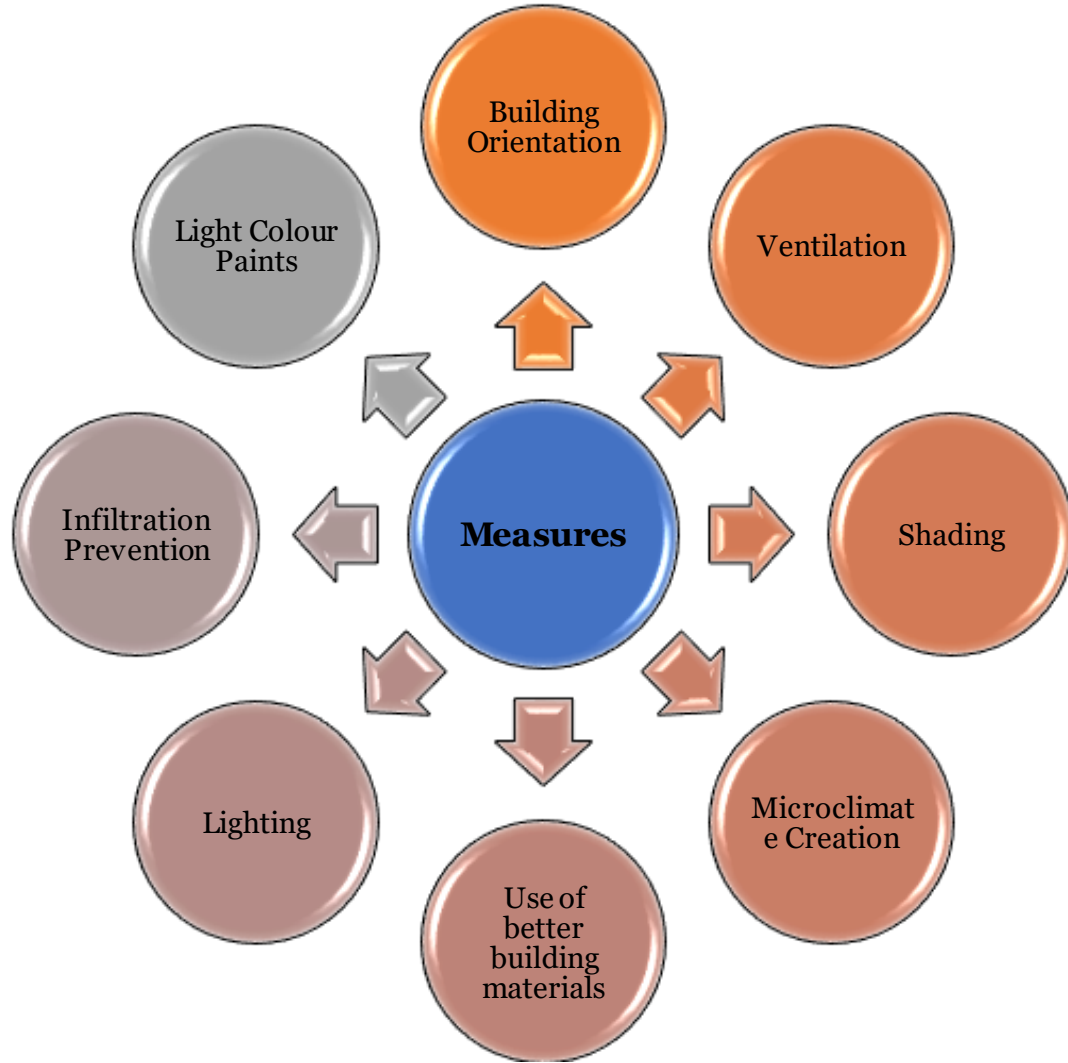


Eco Niwas Samhita 2021  
Code Compliance and Part 2





# Thermal Comfort Design for Affordable Housing

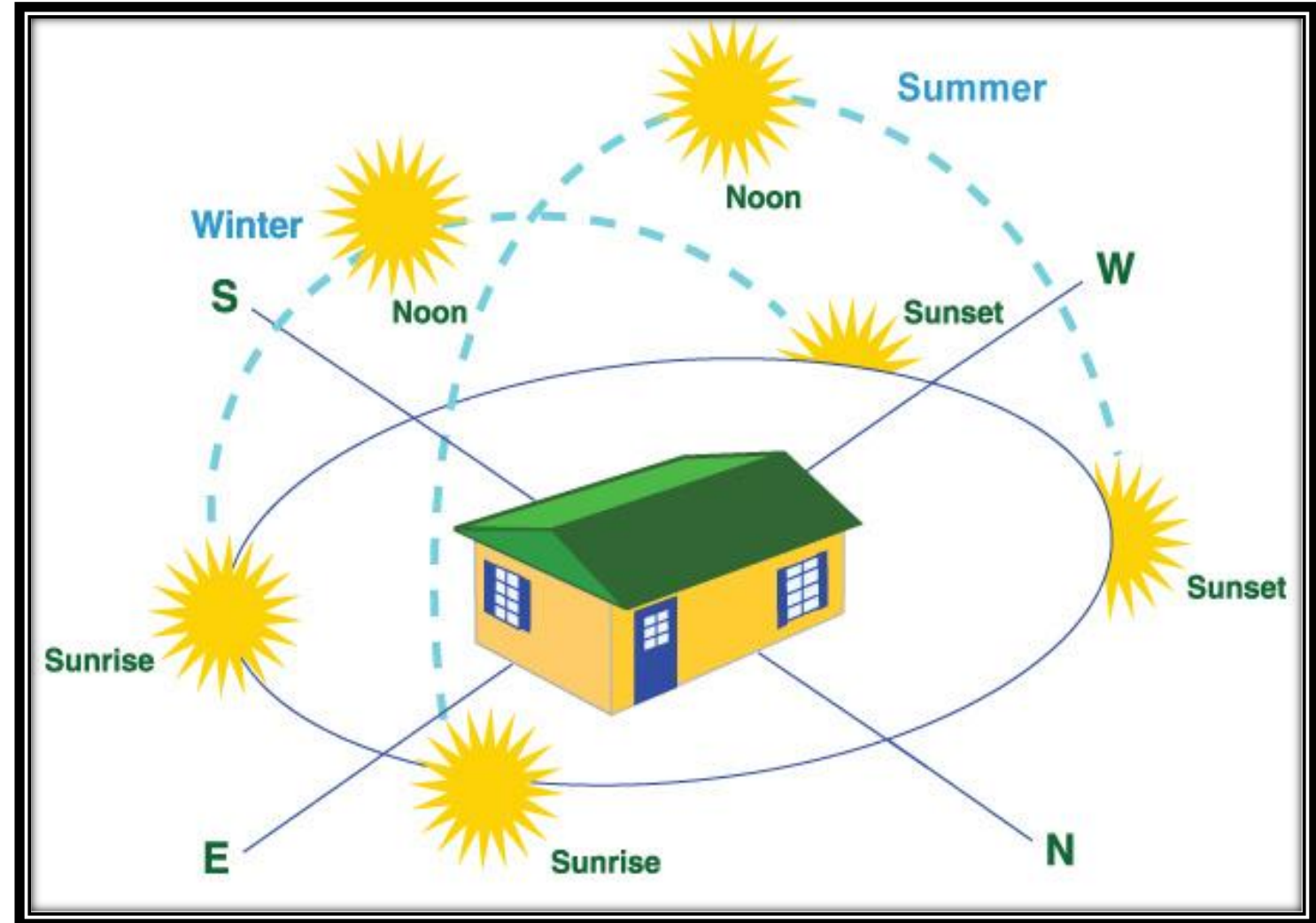




## Building Orientation

Proper orientation of buildings is essential to reduce the impact of unfavorable weather conditions like solar radiation, driving rain and thunderstorm.

In the house, the rooms should be located in such a way that the ones frequently used should be elongated along the east-west dimensions to mitigate heat gain in summer and also making efficient use of winter's sun.



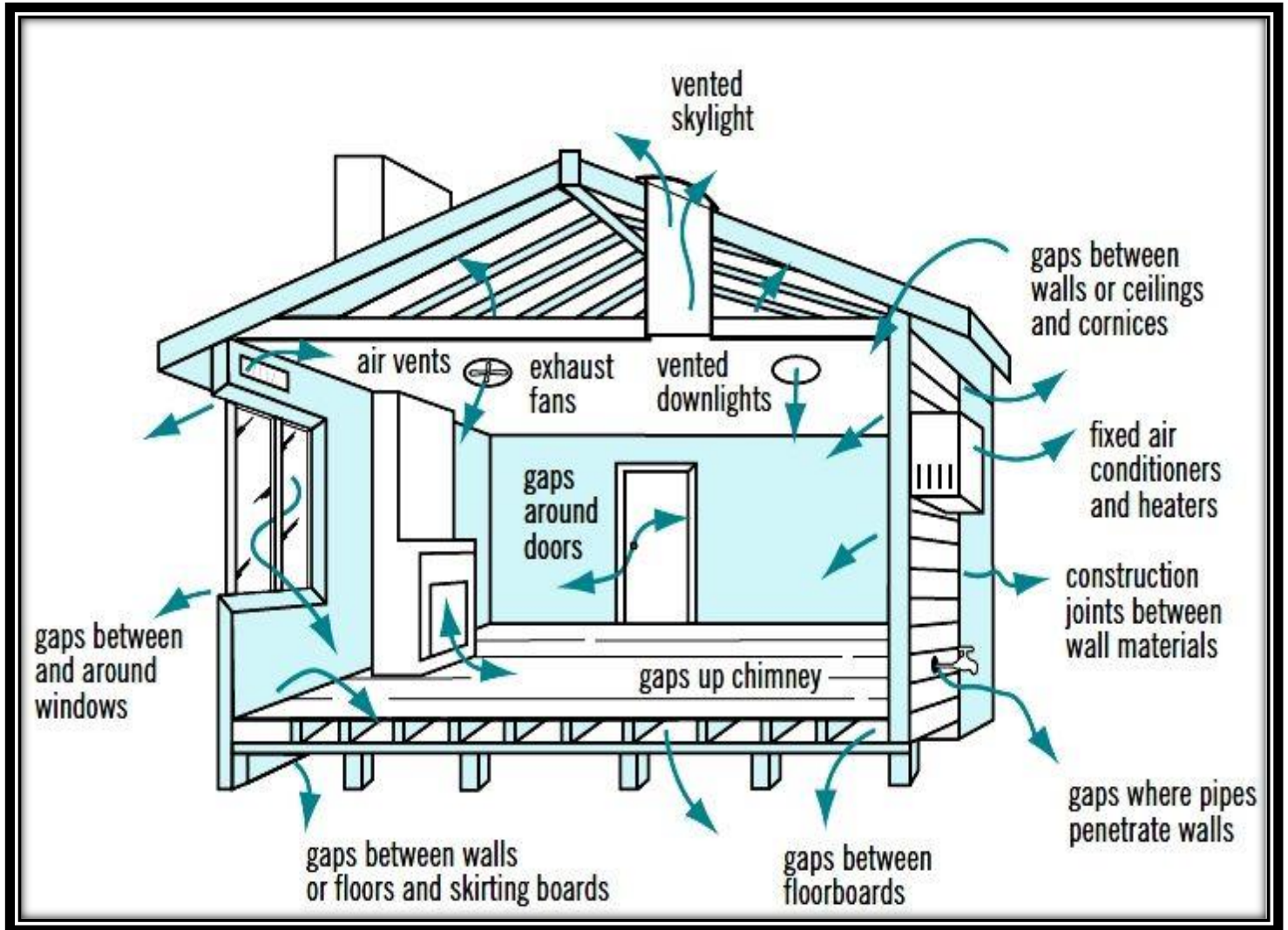


## Proper Ventilation

By proper positioning the windows and opening, air movement can be created in the rooms.

Walls and vegetation should not be too close to the building in order to avoid diversion of wind away from the openings, thereby reducing air flow within the building.

If possible, the rooms should be cross-ventilated.



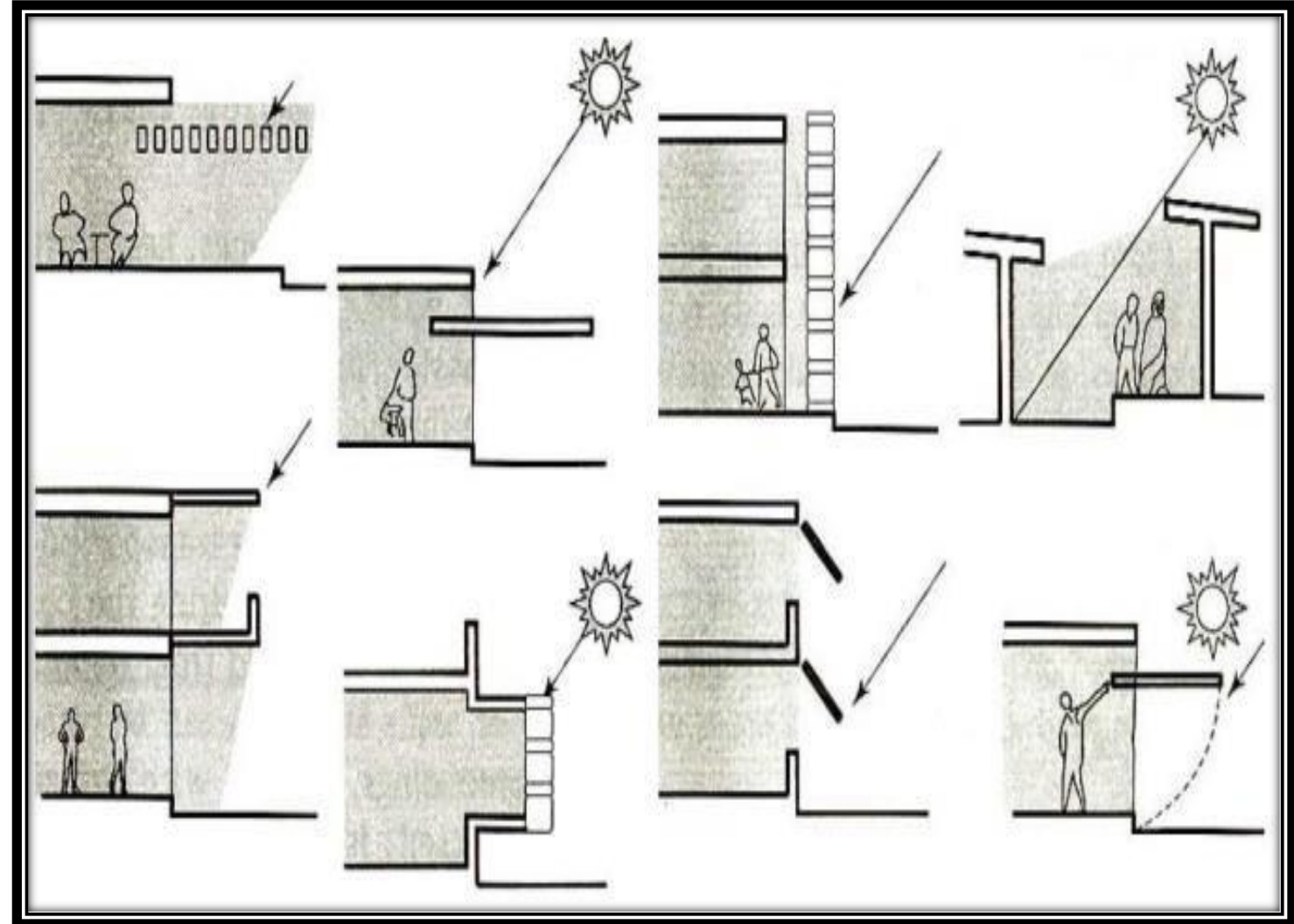




## Shading Devices

The most effective way of improving thermal comfort is to shade the windows, walls and roofs of buildings from direct solar radiation. The windows can be internally shaded by using overhangs or a horizontal projection to block off sun's rays completely in summer while letting in most of them in winter.

The roof of buildings can be shaded effectively by using removable canvass which can be used during the daytime and rolled up during the nighttime to allow radiative cooling.





## Creation of Microclimate

Trees can be planted to create micro-climate, i.e., a small-scale climatic condition at a spot or area or site. The micro-climate of the adjoining trees can be explored to provide a cool comfortable environment

The living rooms and other areas which are frequently used by inhabitants should be carefully placed for micro-climate so that they are comfortable and more enjoyable and can be used for a longer length of time.







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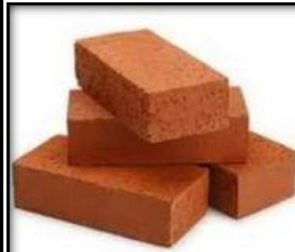


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## Usage of better Building Materials

Building materials play a vital role in buildings from the energy efficiency & thermal comfort point of view.

Usage of the local building materials from a specified region not only promotes the indigenous business but also reduces the CO<sub>2</sub> emission; thereby playing a major role in creating a better environment for the occupants of the locality.



Bricks



Cement



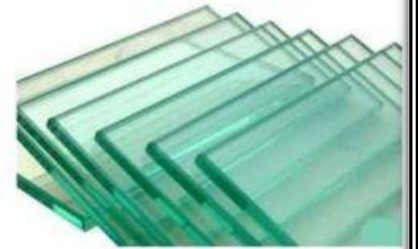
Concrete



Sand



Reinforcement



Glass



Plastic



Wood



Tiles



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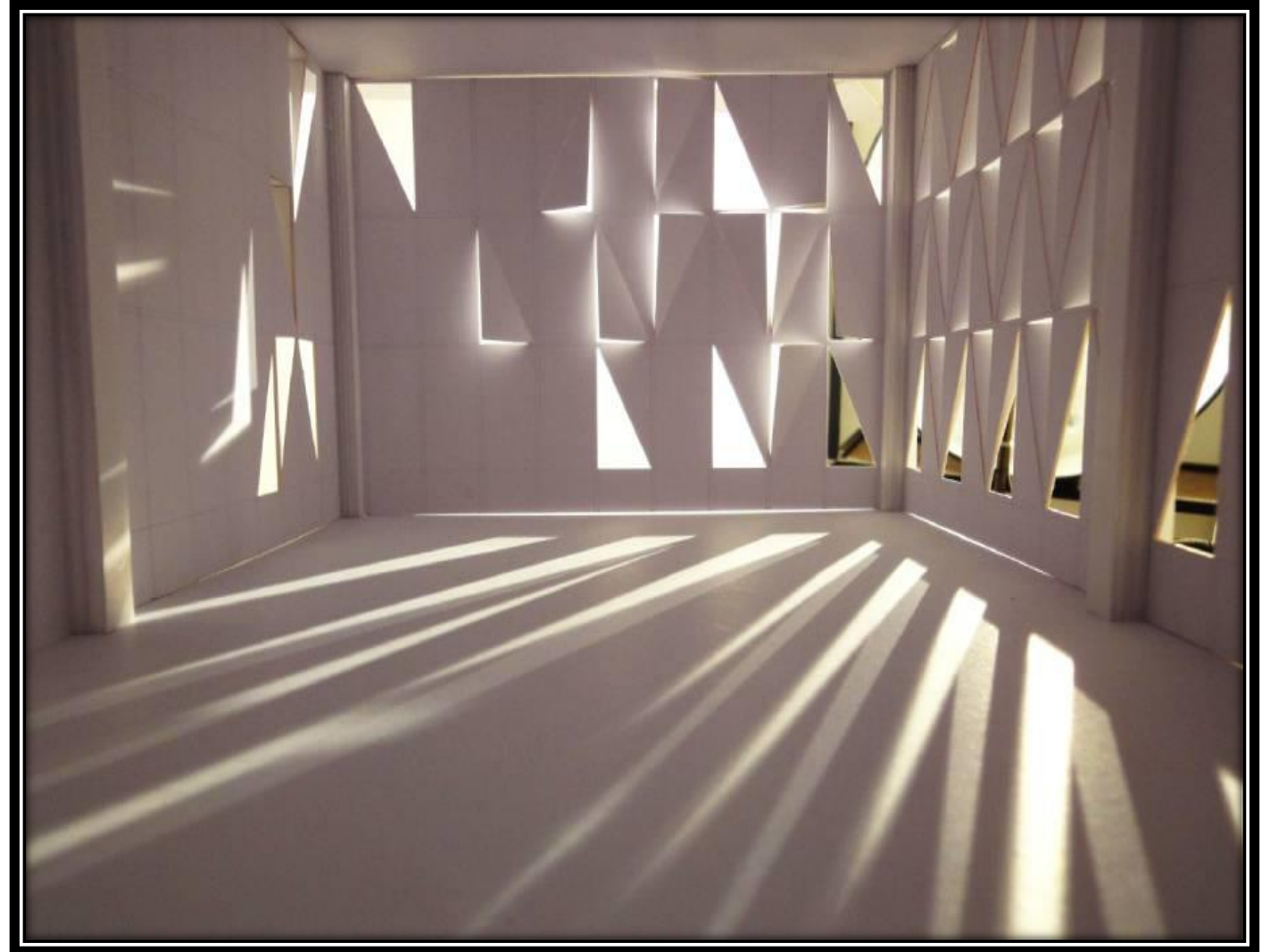


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## Proper Lighting

Using day light as much as possible will reduce cooling load because day light contains the least amount of heat per lumen of light. Light Emitting Diode (LED) can be used as a replacement of incandescent bulbs and kerosene lamps because they emit heat into the cooling space.

The LEDs have different color spectrum & uses 75% less energy than incandescent bulbs; it's also cheap and last 10 times longer than the incandescent bulbs.

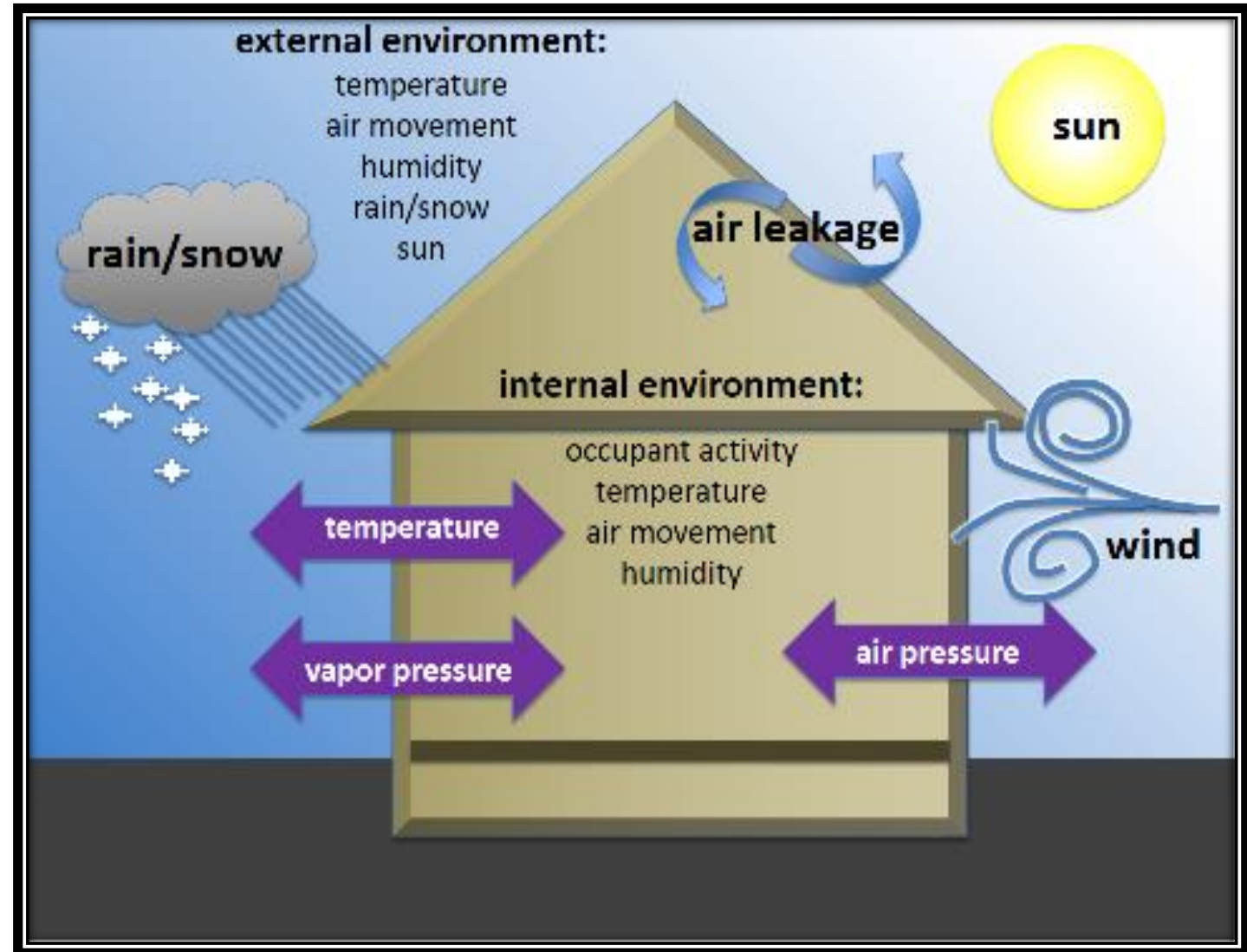




## Prevent Infiltration

Infiltration is a natural phenomenon that occurs when the pressure on the exterior of a building is higher than the interior, causing outside air leaks through the building envelope from outside to inside.

Infiltration can be prevented by sealing the sites of air leaks. This can be achieved by caulking, weatherizing, good workmanship, and replacing some aged parts of buildings.





## Usage of Light Color Paints

When using colors to reduce the temperature inside your home, one should avoid colors that tend to absorb more of the sun's energy, which then results into a warmer home. Dark and dull colors have a tendency to absorb all that heat.

Painting on the walls and roof with light colors will help in the reduction of heat gain. Whitewash which can cheaply be done on walls and roof is an effective way of reducing heat gain.





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# THERMAL COMFORT STANDARDS



# Thermal Comfort Standards



ASHRAE - 55



National Building Code - 2016



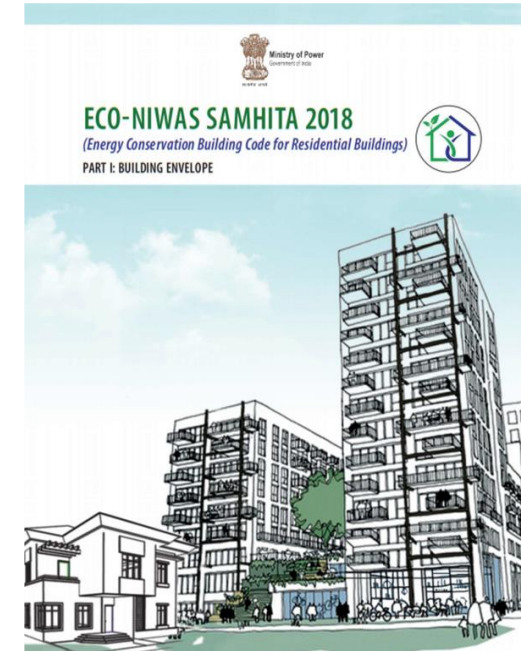
Handbook of Functional Requirements of Buildings  
1987 by BIS



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



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## 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



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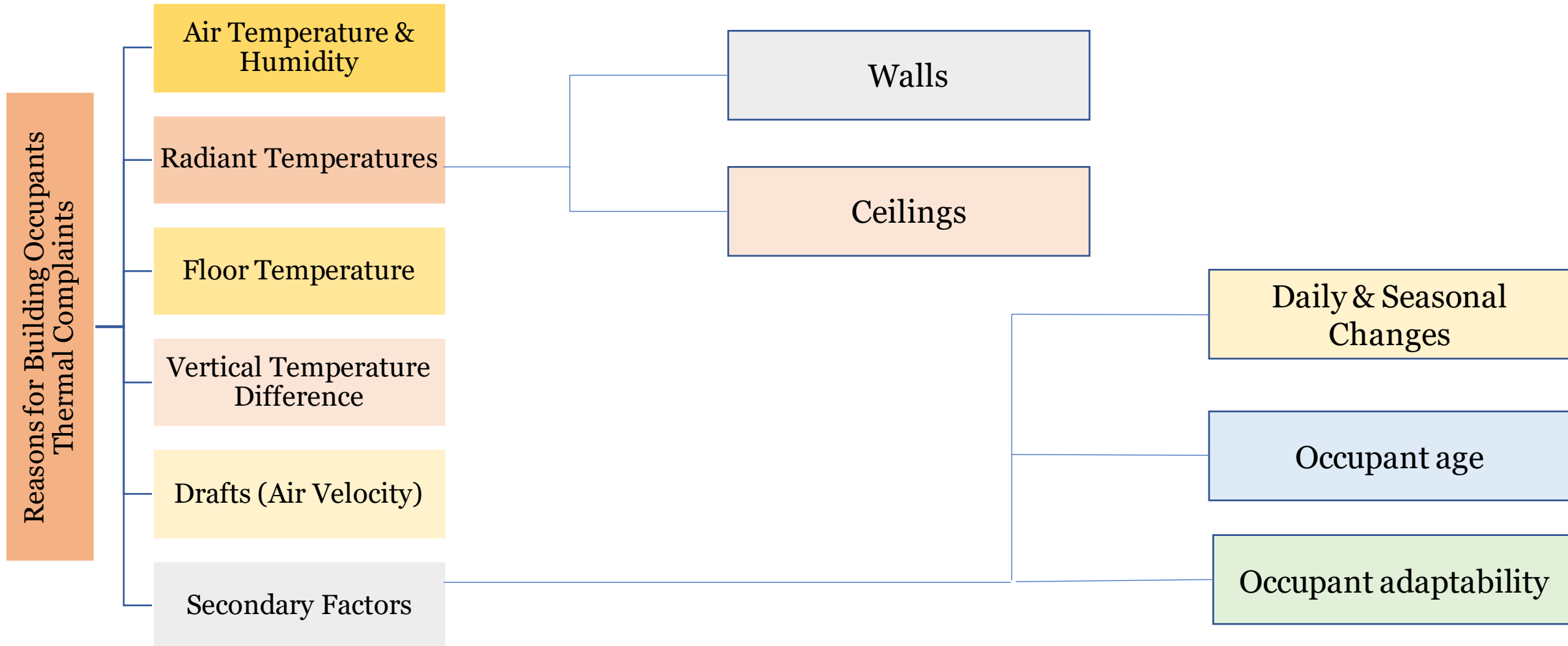


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# ASHRAE 55





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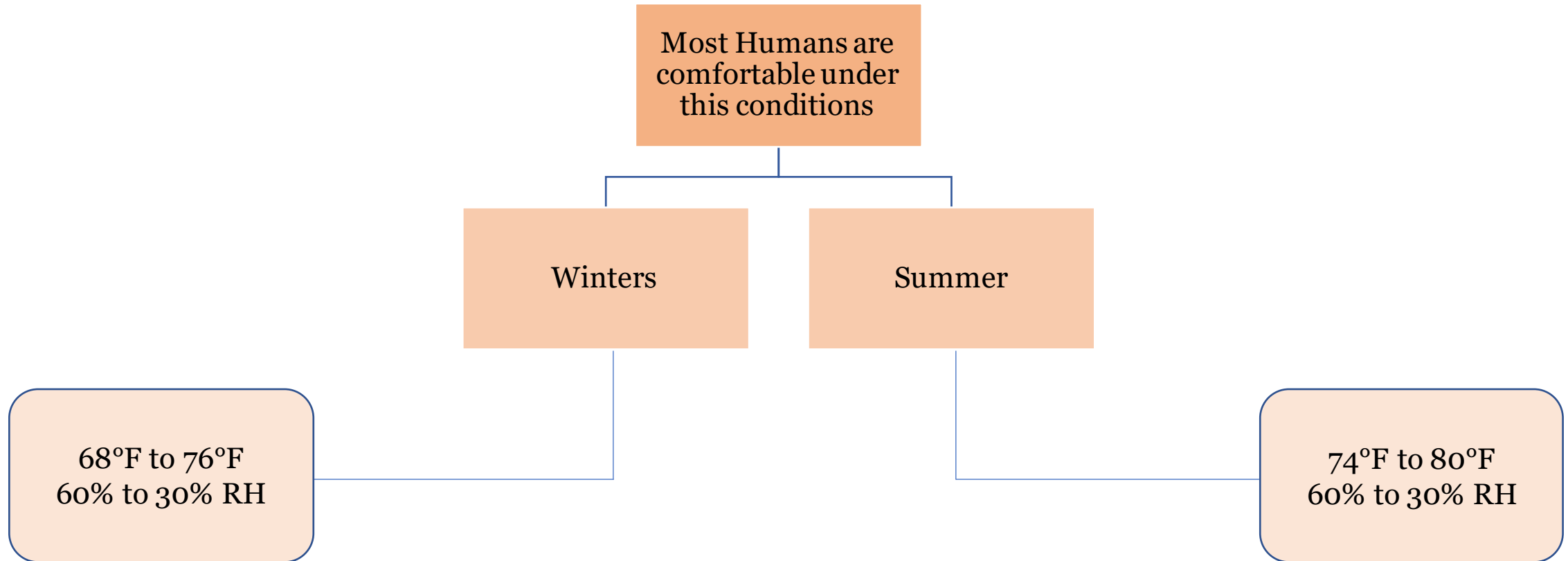
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# ASHRAE 55

## Human Comfort Range





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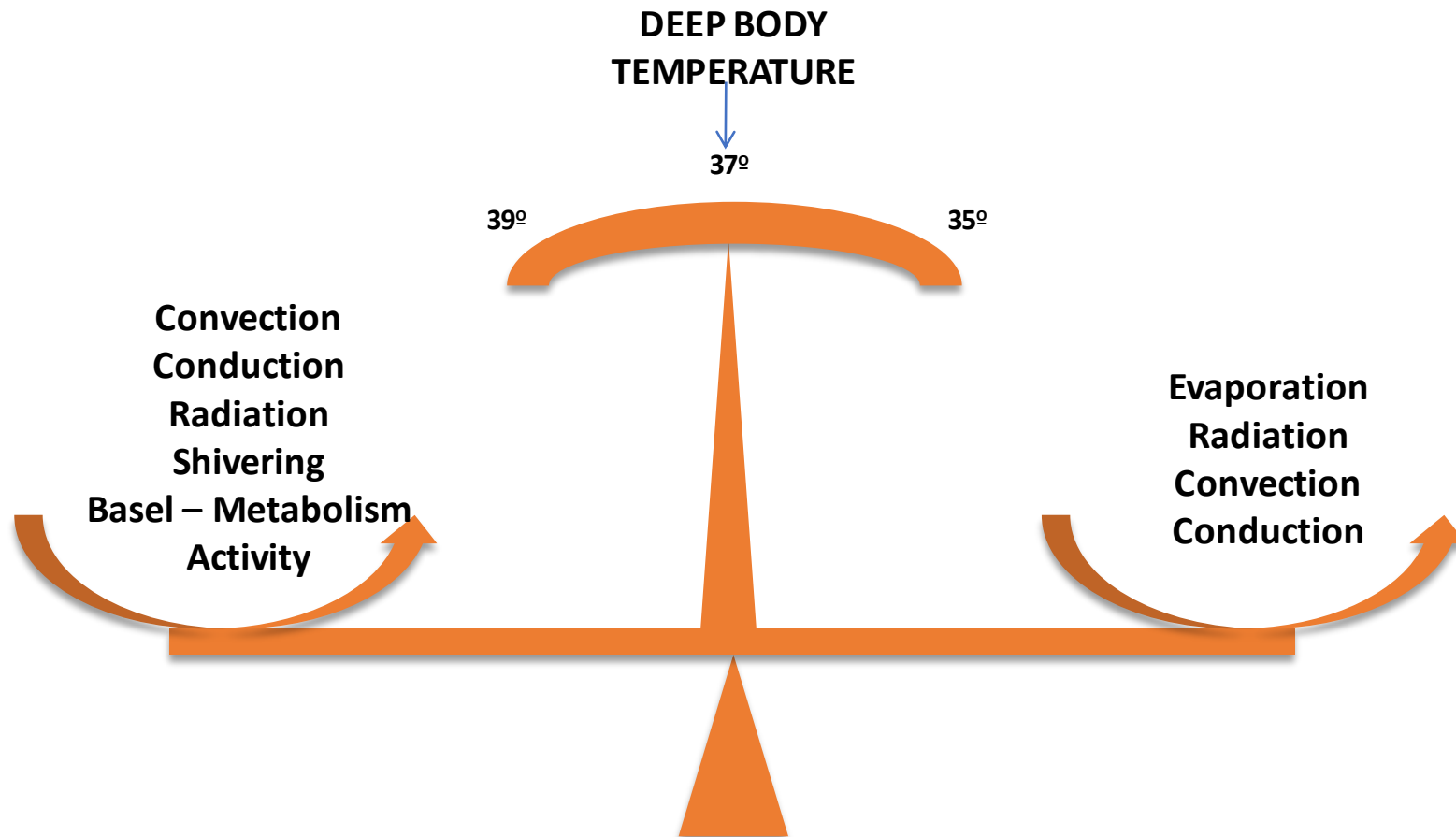


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## Body Regularity Mechanism







# 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:

$$\text{Met} - \text{Evp} + \text{Cnd} + \text{Cnv} + \text{Red} = 0$$

## 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

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 – 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

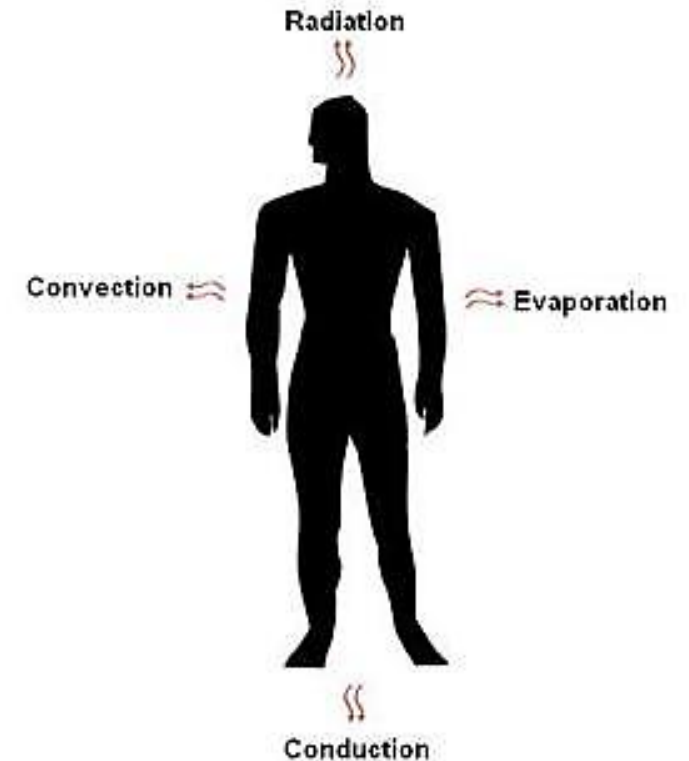
- The temperature of the body surface and the temperature of the opposing surface affects radiant heat loss.

## 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  $37^{\circ}$ . But skin temperature is  $31-34^{\circ}$ .

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 ( $34^{\circ}$ ), 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 ( $\leq 0.25$  m/s)**

**Humidity is near 100%**

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

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 45°, death is unavoidable.

At adverse situation



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# 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**





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## 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)

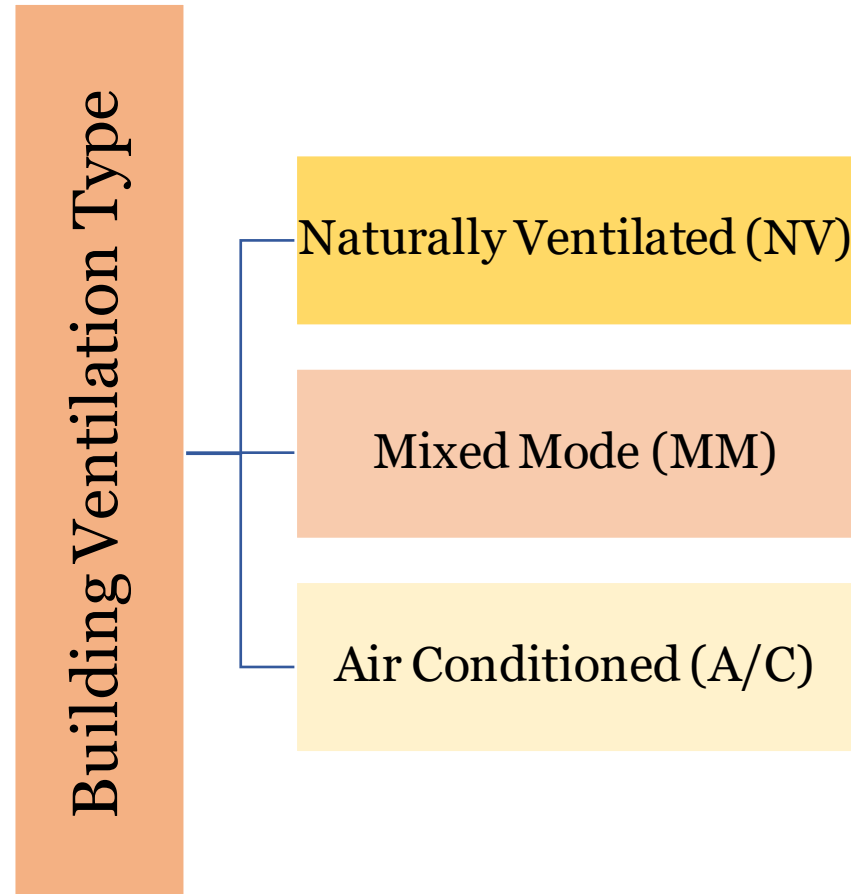
5

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





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## 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



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# 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 below equation.

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

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





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# 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.

$$\text{Indoor Operative Temperature (}^{\circ}\text{C)} = \mathbf{0.28 \times \text{Mean Monthly Outdoor DBT} + 17.87}$$

Acceptability range for Mixed Mode ventilated buildings is  $\pm 3.46^{\circ}\text{C}$



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# 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**



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# EFFECTS OF MATERIALS ON THERMAL COMFORT

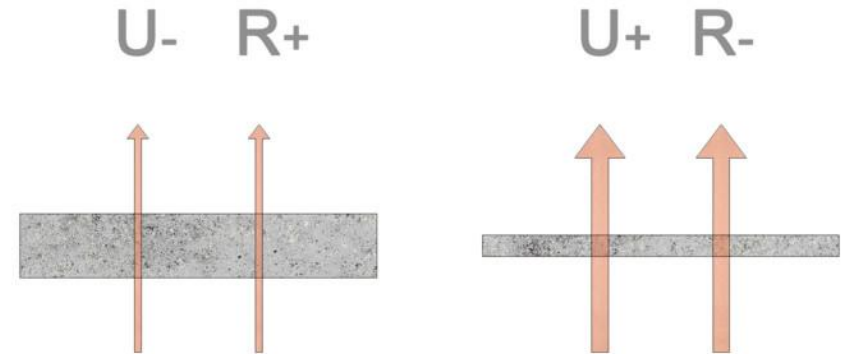


## U-Value or Thermal Transmittance

### 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**.



- $W/m^2K$  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



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# U-Value Calculation

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

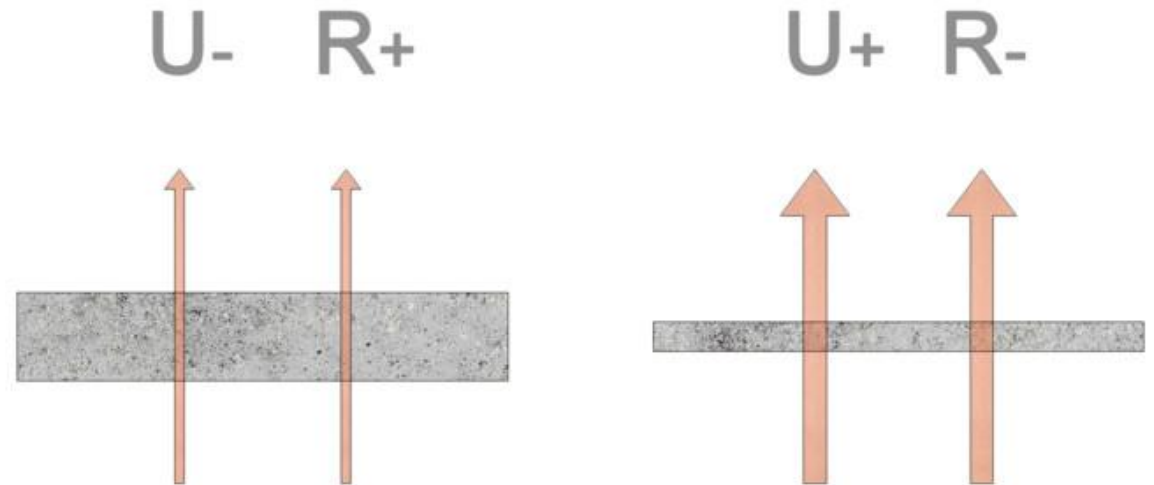
Thermal transmittance is the rate of heat transfer through materials

Unit of U value is  $W/(m^2K)$

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

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

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







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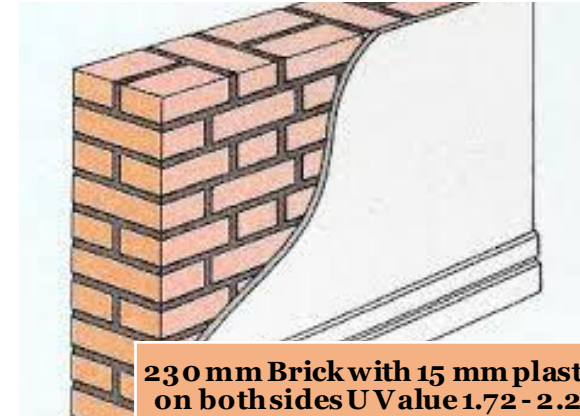
## Comparative in terms of U-Value



**150 mm RCC (No plaster) – U  
Value 3.77 W/m<sup>2</sup>K**



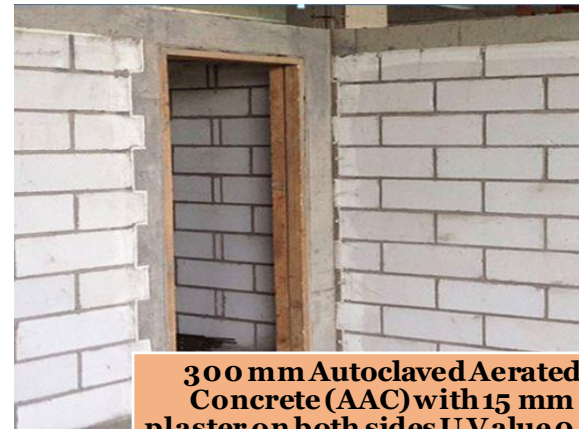
**200 mm Solid Concrete Block with  
15 mm plaster on both sides – U  
Value 2.8 W/m<sup>2</sup>K**



**230 mm Brick with 15 mm plaster  
on both sides U Value 1.72 - 2.24  
W/m<sup>2</sup>K**



**200 mm Autoclaved Aerated  
Concrete (AAC) with 15 mm  
plaster on both side U Value 0.77  
W/m<sup>2</sup>K**



**300 mm Autoclaved Aerated  
Concrete (AAC) with 15 mm  
plaster on both sides U Value 0.54  
W/m<sup>2</sup>K**

# Conventional Materials vs Local Materials vs Materials used at LHP

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



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# CASE STUDIES



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## INFOSYS – POCHARAM CAMPUS

LOCATION	HYDERABAD, TELANGANA
COORDINATES	17° N, 78° E
OCCUPANCY TYPE	OFFICE
TYPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	HOT AND DRY
PROJECT AREA	27,870 m <sup>2</sup>



**Given the high-standards in terms of building design achieved at the SDB1 in Hyderabad, it has now been showcased in the 'Best Practices Guide for High Performance Indian Office Buildings' by Lawrence Berkeley National Lab, a U.S. Department of Energy (DoE) National Laboratory.**





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# INFOSYS – POCHARAM CAMPUS

It has been built keeping in mind a holistic approach to sustainability in five key areas

Sustainable site development

Water savings

Energy efficiency

Materials selection

Indoor  
environment  
quality

- The Indian Green Building Council (IGBC) has given Infosys, a worldwide consulting and technology firm, the LEED (Leadership in Energy and Environmental Design) India 'Platinum' designation for its Software Development Block 1 (SDB 1) at its Pocharam site in Hyderabad, India.
- The SDB 1 is the first commercial building in India to deploy unique Radiant-cooling technology, setting new norms for energy efficiency in building systems design.

**EPI –  
75kWh/m<sup>2</sup>/yr**





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## GODREJ PLANT 13 ANNEXE

LOCATION

MUMBAI,  
MAHARASHTRA

COORDINATES

19° N, 73° E

OCCUPANCY TYPE

OFFICE – PRIVATE

TYOLOGY

NEW CONSTRUCTION

CLIMATE TYPE

WARM AND HUMID

PROJECT AREA

24,443 m<sup>2</sup>





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## GODREJ PLANT 13 ANNEXE

The Plant 13 Annexe Building at Godrej & Boyce (G&B) in Mumbai has been designated as India's first **CII-IGBC accredited Net Zero Energy Building**.

Its **mixed-use office/convention center** (with office spaces, conference and meeting rooms, auditoriums (90 to 250 seats), banquet hall, 300-person eating facilities, and an industrial kitchen), making certification extremely difficult.

**EPI –  
75kWh/m<sup>2</sup>/yr**

In 2015, the building received an **IGBC Platinum grade in the EB (Existing Building)** category, which was recertified in 2019. In 2016, it was also awarded the **BEE 5 Star Rating**. In 2019, he received the '**Energy Performance Award**' for meticulous energy measuring and monitoring. At the CII National Energy Management Award event in 2020, it was named "**Excellent Energy Efficient Unit.**"



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## INDIRA PARYAVARAN BHAWAN, MoEF

LOCATION	NEW DELHI
COORDINATES	29° N, 77° E
OCCUPANCY TYPE	OFFICE & EDUCATIONAL
TPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	COMPOSITE
PROJECT AREA	9565 m <sup>2</sup>



**The Indira Paryavaran Bhawan is now India's most environmentally friendly structure. GRIHA 5 Star and LEED Platinum certifications were awarded to the project. The structure has already received accolades, including the MNRE's Adarsh/GRIHA Award for Outstanding Integration of Renewable Energy Technologies.**



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# INDIRA PARYAVARAN BHAWAN, MoEF

To reach **net zero criterion**, several energy saving measures were implemented to lower the building's energy loads, with the residual demand being satisfied by producing energy from **on-site installed high efficiency solar panels**.

The project team focused on measures for lowering energy demand, such as **ample natural light, shade, landscape to reduce ambient temperature, and energy-efficient active building technologies**

When compared to a conventional building, **Indira Paryavaran Bhawan utilizes 70% less energy**. The project used green building principles, such as water conservation and optimization through site waste water recycling.

The new office building for the Ministry of Environment and Forest (MoEF), Indira Paryavaran Bhawan, is a significant departure from traditional architectural design

**EPI –  
44kWh/m<sup>2</sup>/yr**

**Renewable Energy Integration 930 kW PV panels with a total area of 4650m<sup>2</sup> for on-site generation, tilted at 23° facing south to generate equivalent to 70kWh/m<sup>2</sup>/yr**



# JAQUAR HEADQUARTERS

LOCATION	MANESAR HARYANA
COORDINATES	28° N, 77° E
OCCUPANCY TYPE	CORPORATE AND MANUFACTURING
TPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	COMPOSITE
PROJECT AREA	48000 m <sup>2</sup>







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# JAQUAR HEADQUARTERS

**The building is a perfect blend of modern design sensibilities, biophilic inspiration, and a brand ambition of soaring high.**

The **Jaguar Headquarters in Manesar** is not only a stunning structure, but also a painstakingly constructed complex with cutting-edge technology that has resulted in a **net zero campus** with a **LEED Platinum (USGBC) rating**. This project is known for its complex organic design and space arrangement, making it a visual pleasure.

Through its characteristic wing-shaped architecture, the design redefines a business workplace by giving it a memorable experience. The spreading wings of a symbolic eagle, poised to take flight, are atop the horizontal glass edifice, suggesting a firm with worldwide ambitions.

## ST. ANDREWS BOYS HOSTEL BLOCK, GURUGRAM

LOCATION	GURUGRAM HARYANA
COORDINATES	28° N, 76° E
OCCUPANCY TYPE	HOSTEL
TPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	HOT AND DRY
PROJECT AREA	5574 m <sup>2</sup>





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## ST. ANDREWS BOYS HOSTEL BLOCK, GURUGRAM

The goal of the design process was to increase student interaction within the indoor areas, which then spilled outdoors and interacted with the surrounding landscape.

On the south and north facades, the linear block was twisted to create a shaded entry (summer court) and an open terrace (winter court), respectively, to stimulate activities at all times of the day and season. The ramp serves as a buffer between the hot outdoors and the cooler interior, preventing kids from experiencing heat shock.

# ST. ANDREWS GIRLS HOSTEL BLOCK, GURUGRAM

## LOCATION

**GURUGRAM  
HARYANA**

## COORDINATES

28° N, 76° E

## OCCUPANCY TYPE

**HOSTEL**

## TPOLOGY

**NEW CONSTRUCTION**

## CLIMATE TYPE

**HOT AND DRY**

## PROJECT AREA

2322 m<sup>2</sup>





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## ST. ANDREWS GIRLS HOSTEL BLOCK, GURUGRAM

**Indoor and outdoor spaces** that connect physically and aesthetically at different levels to encourage interactions and social activities are incorporated into the building's plan.

The **entrance foyer and lobby** were planned as outdoor spaces facing west and connected to the pantry so that students can enjoy their nights outside with a spill-out into the green landscape.



## AKSHAY URJA BHAWAN HAREDA

LOCATION	PANCHKULA HARYANA
COORDINATES	30° N, 76° E
OCCUPANCY TYPE	OFFICE - PUBLIC
TPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	COMPOSITE
PROJECT AREA	5100 m <sup>2</sup>





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## AKSHAY URJA BHAWAN HAREDA

**Mechanical air conditioning is used to guarantee thermal comfort in apical zones at all times.**

Zones are created based on the intended temperature set points. 25.1 °C for apex offices, 25.3 °C for regulated office and public areas, and 25.5 °C for passive zones.

In the summer, controlled zones are cooled, and in the monsoon, they are chilled. In the summer, passive zones are cooled, while in the monsoon, they are aired. The centre atrium has a mist system for cooling the controlled and passive zones. Water that has been chilled to a temperature of 15°C.

# SUN CARRIER OMEGA

**LOCATION**

**BHOPAL M.P.**

**COORDINATES**

23° N, 77° E

**OCCUPANCY TYPE**

**OFFICE – PRIVATE**

**TPOLOGY**

**NEW CONSTRUCTION**

**CLIMATE TYPE**

**HOT AND DRY**

**PROJECT AREA**

9888 ft<sup>2</sup>



# GRIDCO BHUBANESWAR

**LOCATION**

**BHUBANESWAR.**

**COORDINATES**

20° N, 85° E

**OCCUPANCY TYPE**

**OFFICE**

**TPOLOGY**

**NEW CONSTRUCTION**

**CLIMATE TYPE**

**WARM AND HUMID**

**PROJECT AREA**

15,793.5 m<sup>2</sup>





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## GRIDCO BHUBANESWAR

**The structure was created using computer simulation to determine how long direct sunshine or radiation was tolerable for human habitat based on the sun-path of Bhubaneswar.**

The structure encourages natural light and screen radiation. It would feature photovoltaic glass panels and geothermal cooling systems strategically placed, as well as indigenous solar producing technologies, to ensure that it is self-sustaining.

Rainwater can be collected, purified, and utilised as drinkable water. Grey water that has been treated can be reused for flushing and landscape irrigation.





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# ECONIVAS SAMHITA 2018



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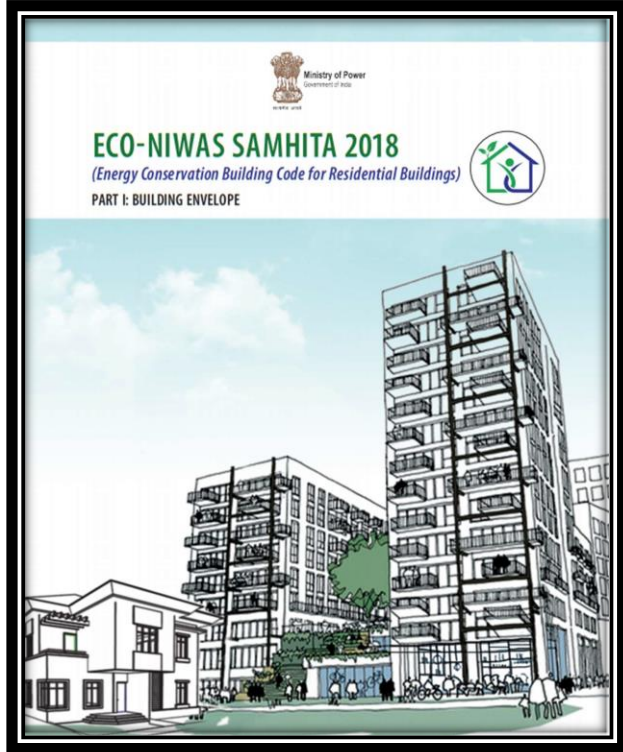
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## About Eco Niwa Samhita

An initiative of MoP and Bureau of Energy Efficiency

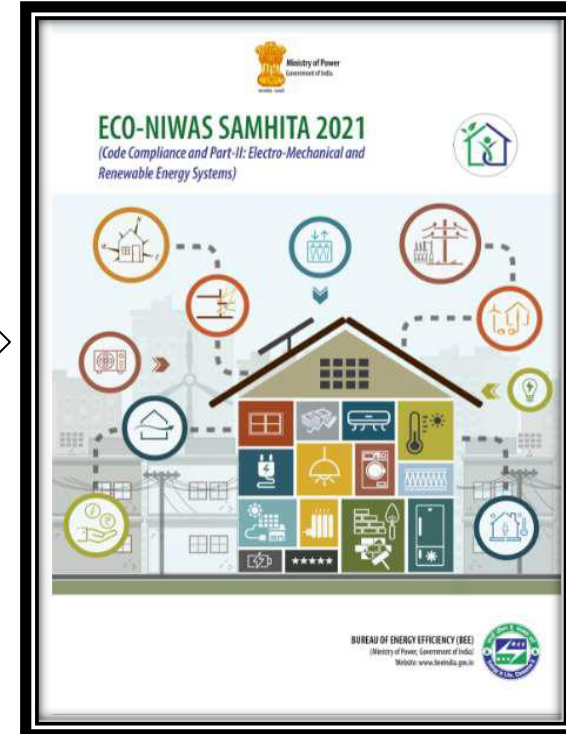


- Building Envelope

ECO Niwas Samhita  
Part 1 was launched on  
**14 December 2018**  
on National Energy  
Conservation Day 2018

- Indoor electrical end use
- Renewable Energy Systems
- Building Services

ECO Niwas Samhita  
Part 2 was launched on  
**16 July 2021**



Eco Niwas Samhita 2018  
Part 1: Building Envelope

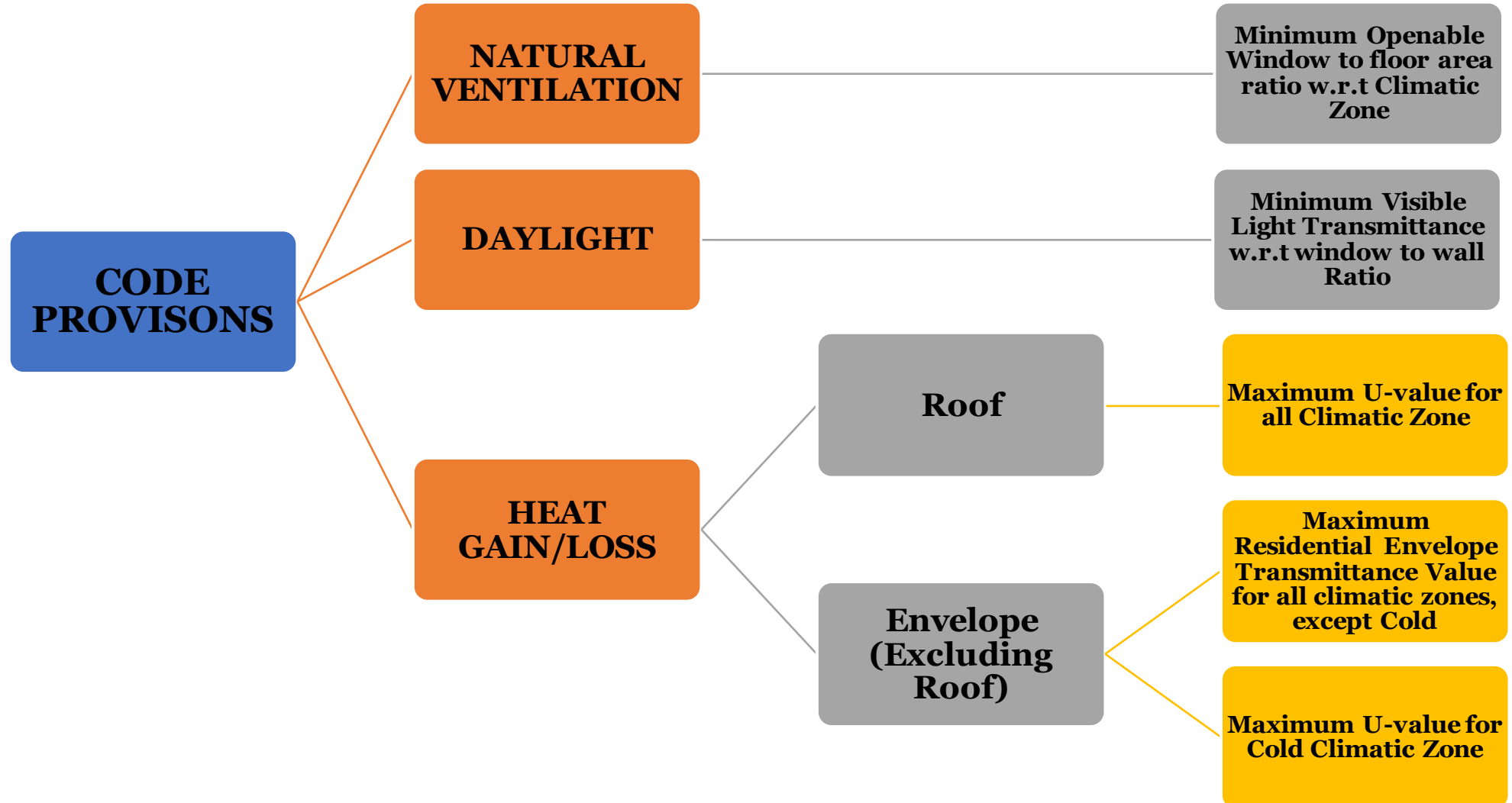
Eco Niwas Samhita 2021  
Part 2: Code Compliance

The code applies to –

- Residential buildings built on a plot area of  $\geq 500 \text{ m}^2$
- Residential part of Mixed land-use building projects, built on a plot area of  $\geq 500 \text{ m}^2$ .



## Eco Niwas Samitha 2018 Part 1





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## Code Provisions by Eco Niwas Samitha

SR.NO.	CODE PROVISIONS
1	Openable Window to Floor Area Ratio
2	Visible Light Transmission
3	Thermal Transmittance of Roof
4	Residential Envelope Transmittance Value for Building Envelope (Except Roof) for four Climate Zones, namely, Composite Climate, Hot-Dry Climate, Warm-Humid Climate, and Temperature Climate
5	Thermal Transmittance of Building Envelop (Except Roof) for Cold Climate



## Openable window to floor area ratio (WFR):

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

The openable window-to-floor area ratio (WFR) shall not be less than the values given in Table. (Source Adapted from Bureau of Indian Standards (BIS). 2016. National Building Code of India 2016. New Delhi: BIS.)

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





# Openable window to floor area ratio (wfr):

## EQUATION FOR WFR

$$\text{WFR} = \frac{A_{\text{openable}}}{A_{\text{carpet}}}$$

### WFR

### Openable Window to Floor Area Ratio

$A_{\text{Openable}}$

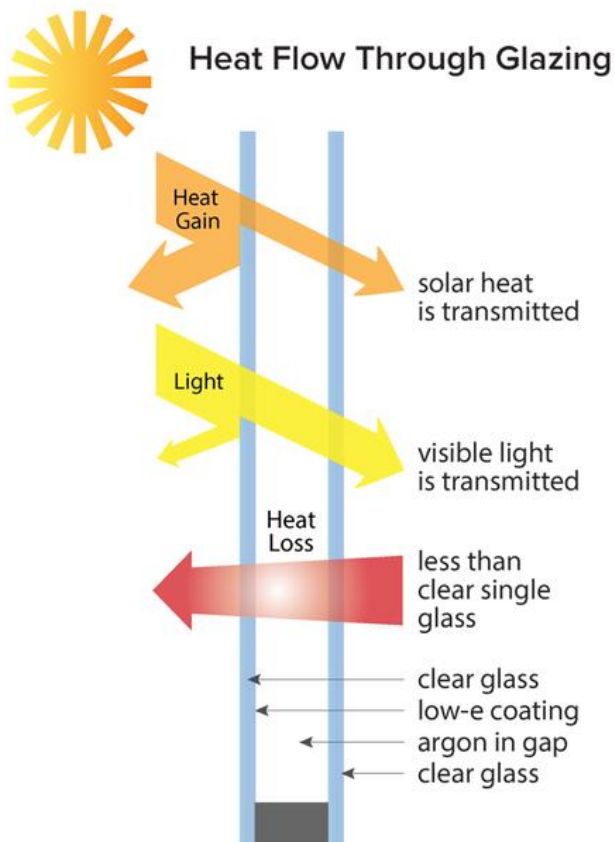
Openable area (m<sup>2</sup>); it includes the openable area of all windows and ventilators, opening directly to the external air, an open balcony, 'verandah', corridor or shaft; and the openable area of the doors opening directly into an open balcony. Exclusions: All doors opening into corridors. External doors on ground floor, for example, ground-floor entrance doors or back-yard doors.

$A_{\text{Carpet}}$

carpet area of dwelling units; it is the net usable floor area of a dwelling unit, excluding the area covered by the external walls, areas under services shafts, exclusive balcony or verandah area and exclusive open terrace area, but includes the area covered by the internal partition walls of the dwelling unit



## VISIBLE LIGHT TRANSMITTANCE (VLT):



Visible light transmittance (VLT) of non-opaque building envelope components (transparent/translucent panels in windows, doors, ventilators, etc.), indicates the potential of using daylight. Ensuring minimum VLT helps in improving day lighting, thereby reducing the energy required for artificial lighting

### EQUATION FOR VLT

$$WWR = \frac{A_{non\_opaque}}{A_{envelope}}$$

The VLT requirement is applicable as per the window-to-wall ratio (WWR) of the building. WWR is the ratio of the area of non-opaque building envelope components of dwelling units to the envelope area (excluding roof) of dwelling units.



## VISIBLE LIGHT TRANSMITTANCE (VLT):

### MINIMUM VISIBLE LIGHT TRANSMITTANCE (VLT) REQUIREMENT:

The glass used in non-opaque building envelope components (transparent/translucent panels in windows, doors, etc.) shall comply with the requirements given in Table .(Source Bureau of Indian Standards (BIS). 2016. National Building Code of India 2016. New Delhi: BIS)

Window-to-wall Ratio (WWR)	Minimum VLT
0 - 0.30	0.27
0.31 - 0.40	0.20
0.41 - 0.50	0.16
0.51 - 0.60	0.13
0.61 - 0.70	0.11



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## THERMAL TRANSMITTANCE OF ROOF - $U_{\text{roof}}$ :

Thermal transmittance ( $U_{\text{roof}}$ ) characterizes the thermal performance of the roof of a building. Limiting the  $U_{\text{roof}}$  helps in reducing heat gains or losses from the roof, thereby improving the thermal comfort and reducing the energy required for cooling or heating.

**Thermal transmittance of roof  
shall comply with the maximum  
 $U_{\text{roof}}$  value of 1.2 W/m<sup>2</sup> K.**



# THERMAL TRANSMITTANCE OF ROOF - $U_{\text{roof}}$ :

## EQUATION FOR $U_{\text{roof}}$ :

$$U_{\text{roof}} = \frac{1}{A_{\text{roof}}} \sum_{i=0}^n (U_i \times A_i)$$

$U_{\text{roof}}$

**Thermal Transmittance of Roof (W/M<sup>2</sup>.K)**

$A_{\text{roof}}$

Total Area of the Roof (m<sup>2</sup>)

$U_i$

Thermal Transmittance values of different roof constructions  
(W/m<sup>2</sup> .K)

$A_i$

Areas of different Roof Constructions (m<sup>2</sup>)





## RESIDENTIAL ENVELOPE TRANSMITTANCE VALUE FOR BUILDING ENVELOPE (EXCEPT ROOF):

**RETV formula takes into account  
the following:**

**Residential envelope heat transmittance (RETV) is the net heat gain rate (over the cooling period) through the building envelope (excluding roof) of the dwelling units divided by the area of the building envelope (excluding roof) of the dwelling units. 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 FOR BUILDING ENVELOPE (EXCEPT ROOF):

Residential Envelope Transmittance Value (RETV) can be calculated by using the following formula:-

$$RETV = \frac{1}{A_{envelope}} \times \left[ \begin{aligned} &\left\{ a \times \sum_{i=1}^n \left( A_{opaque_i} \times U_{opaque_i} \times \omega_i \right) \right\} \\ &+ \left\{ b \times \sum_{i=1}^n \left( A_{non-opaque_i} \times U_{non-opaque_i} \times \omega_i \right) \right\} \\ &+ \left\{ c \times \sum_{i=1}^n \left( A_{non-opaque_i} \times SHGC_{eq_i} \times \omega_i \right) \right\} \end{aligned} \right]$$

Wall Conductive Heat Gains

Window Conductive Heat Gain

Window Radiation Heat Gain

The RETV of 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/m<sup>2</sup>



## RESIDENTIAL ENVELOPE TRANSMITTANCE VALUE FOR BUILDING ENVELOPE (EXCEPT ROOF):

### RETV EQUATIONS TERMS

$A_{\text{envelope}}$	envelope area (excluding roof) of dwelling units ( $\text{m}^2$ ). It is the gross external wall area (includes the area of the walls and the openings such as windows and doors).
$A_{\text{opaque}}$	areas of different opaque building envelope components ( $\text{m}^2$ )
$U_{\text{opaque}}$	thermal transmittance values of different opaque building envelope components ( $\text{W}/\text{m}^2 \cdot \text{K}$ )
$A_{\text{non-opaque}}$	areas of different non-opaque building envelope components ( $\text{m}^2$ )
$U_{\text{non-opaque}}$	thermal transmittance values of different non-opaque building envelope components ( $\text{W}/\text{m}^2 \cdot \text{K}$ )
$\text{SHGC}_{\text{eq}}$	equivalent solar heat gain coefficient values of different non-opaque building envelope components
$\omega_I$	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 FOR BUILDING ENVELOPE (EXCEPT ROOF ):

The coefficients of RETV formula, for different climate zones, are given in Table

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		



# THERMAL TRANSMITTANCE OF BUILDING ENVELOPE:

**$U_{\text{envelope,cold}}$  takes into account the following**

**Thermal transmittance  $U_{\text{envelope,cold}}$  characterizes the thermal performance of the building envelope (except roof). Limiting the  $U_{\text{envelope,cold}}$  helps in reducing heat losses from the building envelope, thereby improving the thermal comfort and reducing the energy required for heating**

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.)





## THERMAL TRANSMITTANCE OF BUILDING ENVELOPE:

The Thermal transmittance of the building envelope (except roof) for cold climate shall comply with the maximum of  $1.8 \text{ W/m}^2 \cdot \text{K}$

**$U_{\text{envelope,cold}}$**  thermal transmittance of building envelope (except roof) for cold climate ( $\text{W/m}^2 \cdot \text{K}$ )

### EQUATION FOR $U_{\text{envelope,cold}}$ :

$$U_{\text{envelope,cold}} = \frac{1}{A_{\text{envelope}}} \sum_{i=1}^n (U_i \times A_i)$$

**$A_{\text{envelope}}$**  envelope area (excluding roof) of dwelling units ( $\text{m}^2$ ). It is the gross external wall area (includes the area of the walls and the openings such as windows and doors)

**$U_i$**  thermal transmittance of different opaque and non-opaque building envelope components ( $\text{W/m}^2 \cdot \text{K}$ )

**$A_i$**  area of different opaque and non-opaque opaque building envelope components ( $\text{m}^2$ )



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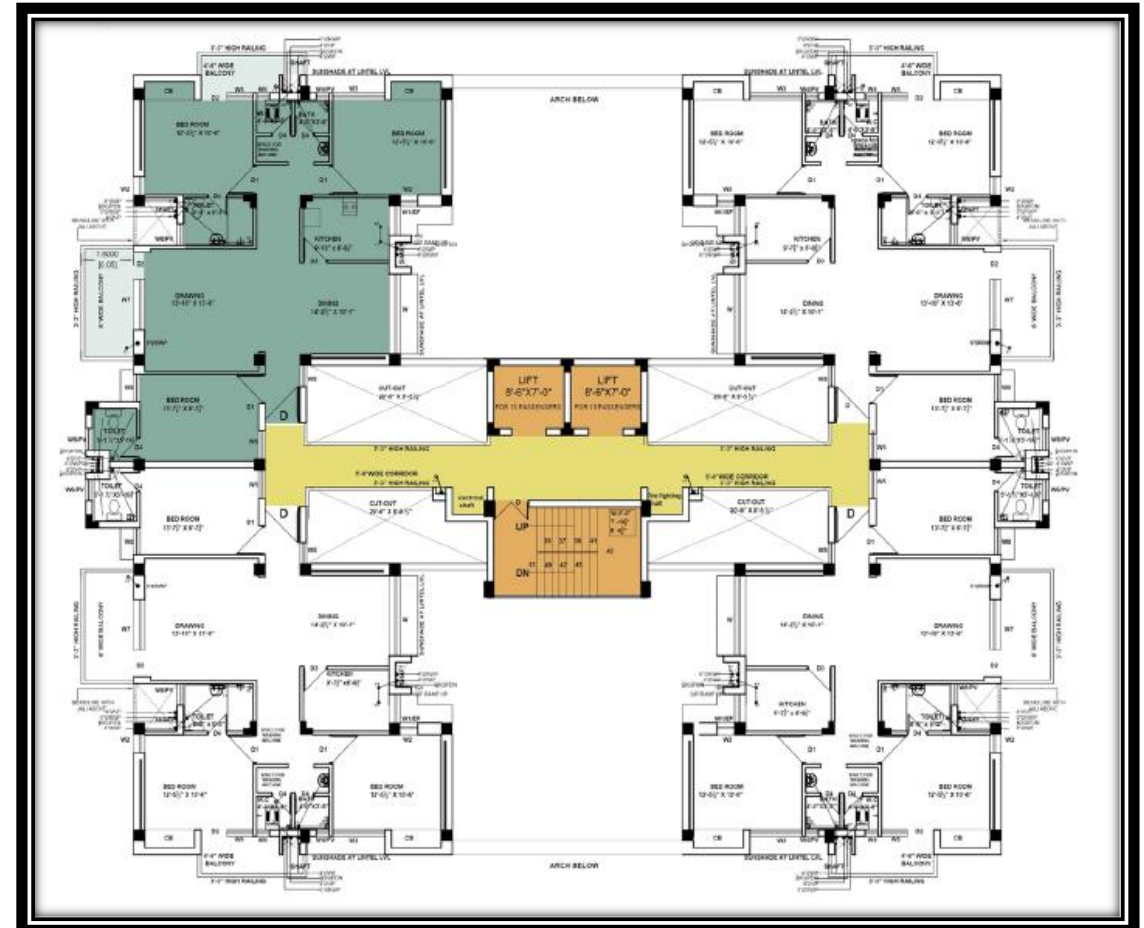
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# CASE STUDY



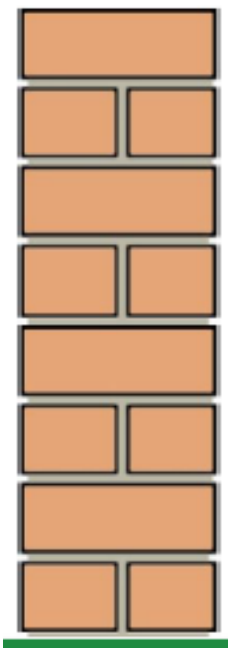
## Case Study Project Details

- Residential quarters built for the NABARD (*National Bank For Agriculture & Rural Development*) staff at Mohali.
- The climate type is composite and is similar to that of Chandigarh.
- No. of dwelling units in Block II (DU): 20 (all 2 BHK) Stilt + 5 storied**





## Case I: 230 mm brick wall + Normal WWR + Single Clear Glazing + No Shading of Windows



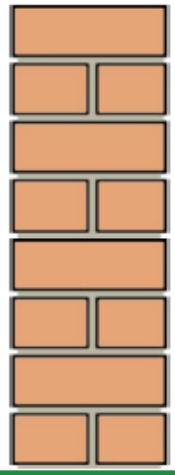
230mm Normal  
Brick wall with U  
value – 2 w/m<sup>2</sup>k

	RETV Wall conduction	RETV Window conduction	RETV Window Radiation	RETV (TOTAL)
Case.1 <ul style="list-style-type: none"><li>• Brick Wall</li><li>• No Shading</li><li>• Single clear glazing</li><li>• WWR: ~14%</li></ul>	10.1	1.8	9.6	<b>21.5</b>

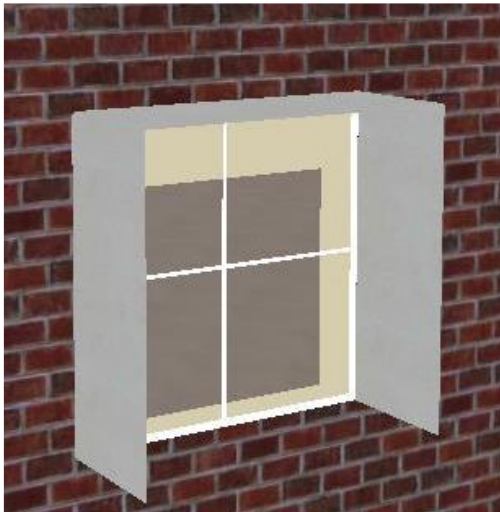
- **RETV: 21.5 W/m<sup>2</sup> higher than 15 W/m<sup>2</sup> (Non-compliant)**
- **Heat conduction through wall is high and high heat gain through windows with no shading**



## Case II: Case I + Proper Shading of Windows



230mm Normal  
Brick wall with U  
value – 2 w/m<sup>2</sup>k

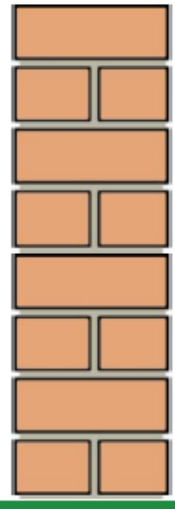


	RETV Wall conduction	RETV Window conduction	RETV Window Radiation	RETV (TOTAL)
Case.2 <ul style="list-style-type: none"> <li>Brick Wall</li> <li><b>Shading with overhang &amp; Fins</b></li> <li>Single clear glazing</li> <li>WWR: ~14%</li> </ul>	10.1	1.8	6.7	<b>18.6</b>

- RETV = 18.6 W/m<sup>2</sup>**
- Shading helps in reducing heat gain through windows**



## Case III: Case II + Single Reflective Glass

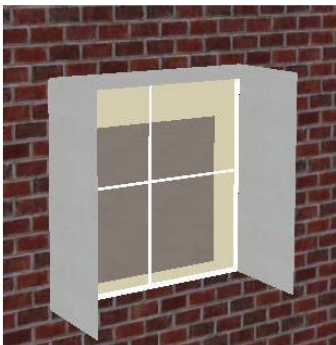


230mm Normal  
Brick wall with U  
value – 2 W/m²K

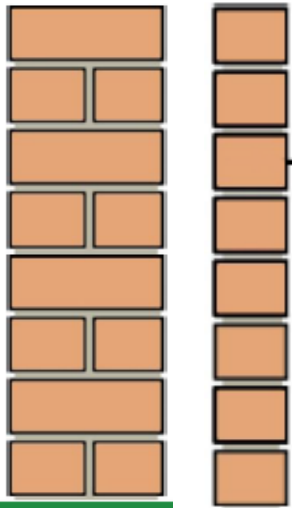
	RETV Wall conduction	RETV Window conduction	RETV Window Radiation	RETV (TOTAL )
Case.3 <ul style="list-style-type: none"> <li>• Brick Wall</li> <li>• Shading with overhang &amp; Fins</li> <li>• <b>Single reflective glazing</b></li> <li>• WWR: ~14%</li> </ul>	10.1	1.8	4.5	<b>16.3</b>

• **RETV = 16.3 W/m²**

• High Reflective Glass also helps in reducing heat gain through windows



## Case IV: (Final Design Constructed) Brick cavity wall+ Shading+ Single reflective glass

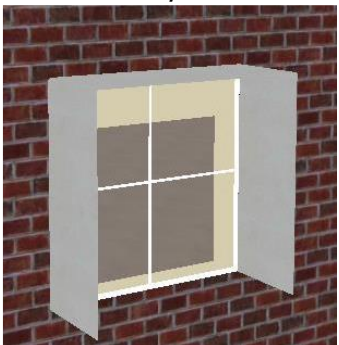


230 mm + 40 mm cavity + 115 mm brick with U value – 1.1 w/m<sup>2</sup>k

	RETV Wall conductio n	RETV Window conduction	RETV Window Radiation	RETV (TOTAL)
Case.4 <ul style="list-style-type: none"> <li><b>Brick Cavity Wall</b></li> <li>Shading with overhang &amp; Fins</li> <li>Single reflective glazing</li> <li>WWR: ~14%</li> </ul>	6.6	1.8	4.5	12.8

• **RETV = 12.8 W/m<sup>2</sup>**

• **Cavity in Brick reduces the conduction heat gain**

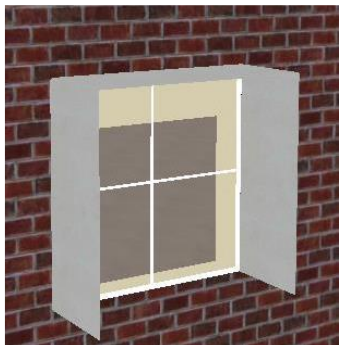


## Case V: Extra measure - AAC block wall + Shading of Windows+ Single reflective glass)



200 mm AAC block with U value –  $0.7 \text{ W/m}^2\text{K}$

+



+



	RETV Wall conductio n	RETV Window conductio n	RETV Window Radiatio n	RETV (TOTAL)
Case.5 <ul style="list-style-type: none"> <li>AAC Block</li> <li>Shading with overhang &amp; Fins</li> <li>Single reflective glazing</li> <li>WWR: ~14%</li> </ul>	4.7	1.8	4.5	10.9

• **RETV =  $10.9 \text{ W/m}^2$**

• AAC Walls further reduced thermal conduction from walls as compared to cavity brick wall



## Key Envelope Parameters & it's impact on RETV

	RETV Wall conduction	RETV Window conduction	RETV Window Radiation	RETV (TOTAL)
Case.1 <ul style="list-style-type: none"> <li>Brick Wall</li> <li>No Shading</li> <li>Single clear glazing</li> <li>WWR: ~14%</li> </ul>	10.1	1.8	9.6	<b>21.5</b>
Case.2 <ul style="list-style-type: none"> <li>Brick Wall</li> <li><b>Shading with overhang &amp; Fins</b></li> <li>Single clear glazing</li> <li>WWR: ~14%</li> </ul>	10.1	1.8	<b>6.7</b>	<b>18.6</b>
Case.3 <ul style="list-style-type: none"> <li>Brick Wall</li> <li>Shading with overhang &amp; Fins</li> <li><b>Single reflective glazing</b></li> <li>WWR: ~14%</li> </ul>	10.1	1.8	<b>4.5</b>	<b>16.3</b>



## Key Envelope Parameters & it's impact on RETV

	RETV Wall conduction	RETV Window conduction	RETV Window Radiation	RETV (TOTAL)
Case.4 <ul style="list-style-type: none"> <li>• <b>Cavity Brick Wall</b></li> <li>• Shading with overhang &amp; Fins</li> <li>• Single reflective glazing</li> <li>• WWR: ~14%</li> </ul>	6.6	1.8	4.5	12.8
Case.5 <ul style="list-style-type: none"> <li>• <b>AAC Block</b></li> <li>• Shading with overhang &amp; Fins</li> <li>• Single reflective glazing</li> <li>• WWR: ~14%</li> </ul>	4.7	1.8	4.5	10.9





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Pradhan Mantri Awas Yojana-Urban



Ministry of Housing and Urban Affairs  
Government of India

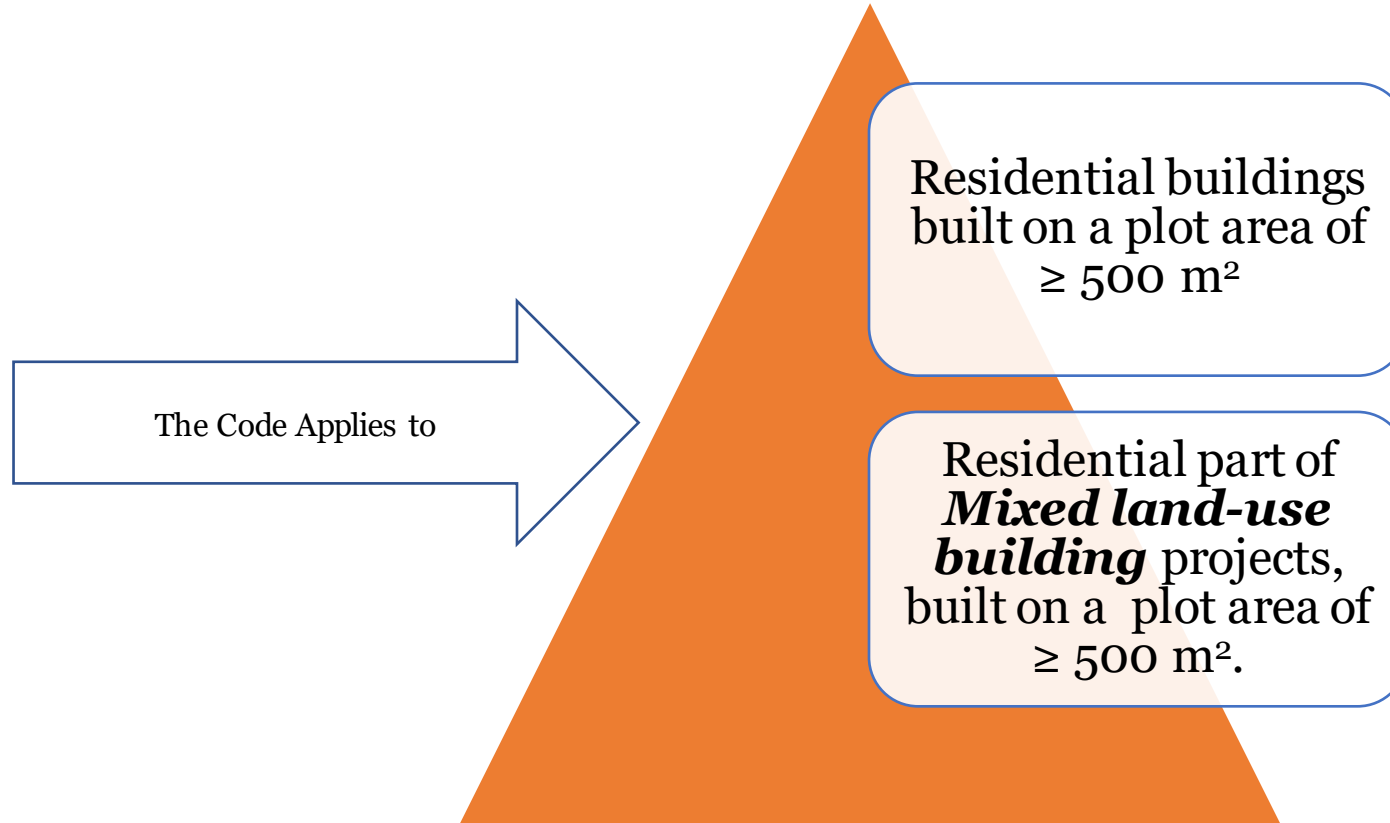


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# ECONIVAS SAMHITA 2021



## Eco – Niwas Samhita 2021 Scope





# ENS 2021 Code Compliance

Prescriptive Method

Compliance  
Mandatory +

Point System Method

Additional Score

Components	Minimum Points	Additional Points	Maximum Points
Building Envelope			
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

- Minimum Points
- Additional Points
- Maximum Points

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



## ENS 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).

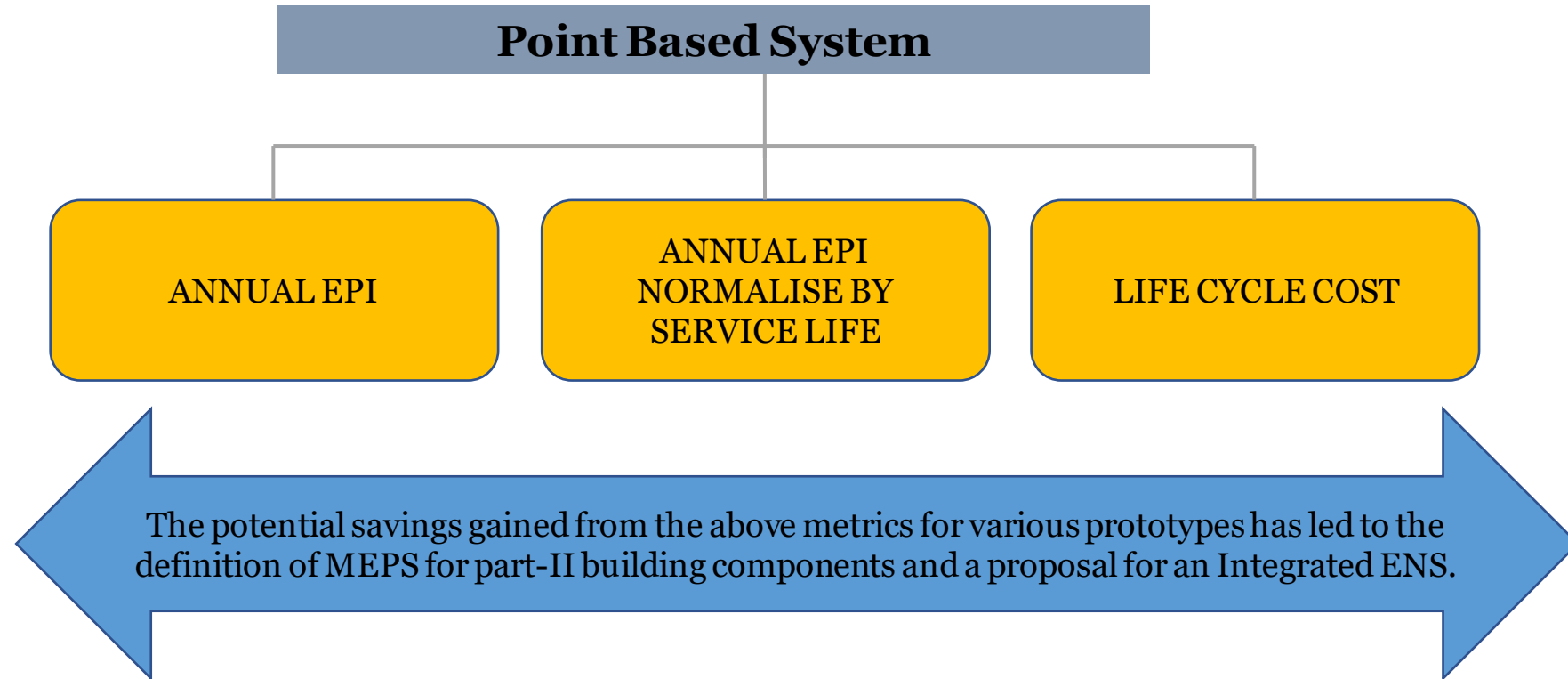
### **Affordable Housing Projects:**

- for Affordable houses are 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 System Method – ENS 2021 Compliance







## Point System Method – ENS 2021 Compliance

### Advantages of Point system

- ❑ A point system is a simpler approach to give weightage to building components that are important from energy efficiency and compliance perspective. Each point doesn't necessarily represent percentage energy savings.

#### 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



## 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- ENS 2021 Code Compliance

## 1. Building Envelope:

- VLT and WFR – as per ENS Part 1
- RETV (for all climate except cold) – max 12 W/m<sup>2</sup>
- Thermal Transmittance for cold – max 1.3W/m<sup>2</sup>K
- Roof – 1.2W/m<sup>2</sup>K

## 2. Common Area & Exterior Lighting: Either LPD or Efficacy and use of PhotoSensor

Common Areas	Maximum LPD (W/m <sup>2</sup> )	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 <sup>2</sup> )
Driveways and parking (open/ external)	1.6
Pedestrian walkways	2.0
Stairways	10.0
Landscaping	0.5
Outdoor sales area	9.0



## Prescriptive Method- ENS 2021 Code Compliance

### 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			
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	
<p>Minimum: Thermal transmittance of roof shall comply with the maximum Uroof value of 1.2 W/m<sup>2</sup>·K.</p>	Up to 4 Points
<p>Additional: 1 Point for every reduction of 0.23 W/m<sup>2</sup>·K in thermal transmittance of roof from the Minimum requirement prescribed under §6.1(a).</p>	Maximum 3Points

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/m <sup>2</sup> .	44 Points
<p>For RETV less than 15 and upto 12 W/m<sup>2</sup>, score will be calculated by following equation:</p> <p>74 – 2 x (RETV) (@ 2 points per RETV reduction)</p>	Up to 50 Points
<p>Additional: For RETV less than 12 and upto 6 W/m<sup>2</sup>, score will be calculated by following equation:</p> <p>110 – 5 x (RETV) (@ 5 points per RETV reduction)</p>	Up to 80 points
<p>Additional: For RETV less than 6 W/m<sup>2</sup></p>	80 Points



# Point System Method – ENS 2021 Compliance

## 2 – Common Area and Exterior Lighting (9 Points)

Common Areas	Maximum LPD (W/m <sup>2</sup> )	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 <sup>2</sup> )
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	2Points 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**



# 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:

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:

Additional points can be obtained by providing all oil type transformers with BEE 5 star rating.

**5 Points**



# 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:

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 m<sup>3</sup>/minute·Watt
    - For sweep size >1200 mm: equal or greater than 5 m<sup>3</sup>/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 dwelling units 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

**9 Points**

iii. Chiller: Minimum ECBC+ Level as mentioned in ECBC 2017

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

**21 Points**

iii. Chiller: Minimum SuperECBC Level as mentioned in ECBC 2017



# 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/m<sup>2</sup>.year of electricity; or
- Equivalent to at least 20% of roof area.

**5 Points**

**The REGZ shall be free of any obstructions within its boundaries and from shadows cast by objects adjacent to the zone.**

### Additional:

Additional points can be obtained by installing solar photo voltaic as per following:

- Equivalent to a minimum of 3 kWh/m<sup>2</sup>.year of electricity or Equivalent to at least 30% of roof area (2 points)
- Equivalent to a minimum of 4 kWh/m<sup>2</sup>.year of electricity or Equivalent to at least 40% of roof area (5 points)

**Upto 5 Points**





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# ENS 2021 COMPLIANCE



## Simulation Tool



**Basic Tool:** Quick evaluation platform for homeowners, contractors, and builders to quickly evaluate the project's preliminary design intent on the scale of energy efficiency, carbon footprint, and monetary savings with the selected project location, user specified area and orientation, building envelope (wall, roof, and window), and air-conditioning and ventilation techniques with the selected project location, user specified area and orientation, and building envelope (wall, roof, and window).



## Simulation Tool

The screenshot displays the 'Simulation Tool' interface. On the left is a 'NAVIGATION' sidebar with icons for BASIC INFORMATION, LAYOUT, ENVELOPE, LIGHTING, EQUIPMENTS, HVAC, and ECONOMICS. The main area is titled 'LAYOUT' and contains the following elements:

- Layout Shape:** A dropdown menu set to 'T-Shape'.
- Building Orientation:** A dropdown menu set to 'North'.
- T Shape Diagram:** A diagram of a T-shaped building footprint with dimensions labeled X1, X2, X3, Y1, and Y2.
- Dimensions (in meters):**
  - X1: 16
  - X2: 10
  - X3: 3
  - Y1: 10
  - Y2: 5
- Number of Floors:** A text input field containing the value '3'.
- Floor Height:** A text input field containing the value '2.00'.

**Advanced Tool:** Experts (Architects, Engineers, MEP consultants, project developers, industry professionals) who want to do extensive study of project design aspects in terms of energy efficiency, economic feasibility, and environmental effect would benefit from this simulation-based application.



## Simulation Tool

NAVIGATION

BASIC INFORMATION

CONSTRUCTION

CONSTRUCTION DETAIL

Wall

Type of Wall

110 mm Red Brick Wall

Wall Section Thickness (mm)

110

Wall Construction Cost (₹/m<sup>2</sup>)

4000

Type of Wall Insulation

Expanded Polystyrene Foam

Wall Insulation Cost (₹/m<sup>2</sup>)

20000

Roof

Type of Roof

150mm RCC slab with False ceiling

Roof Section Thickness (mm)

150

Roof Construction Cost (₹/m<sup>2</sup>)

3000

Type of Roof Insulation

Polyurethane Foam

Roof Insulation Cost (₹/m<sup>2</sup>)

20000

**Envelope Optimization Tool:** Based on the life cycle cost of the envelope alternatives, a rapid envelope evaluation module computes the most optimum set of U-values and SHGC for best wall, best roof, and best window for the given location.





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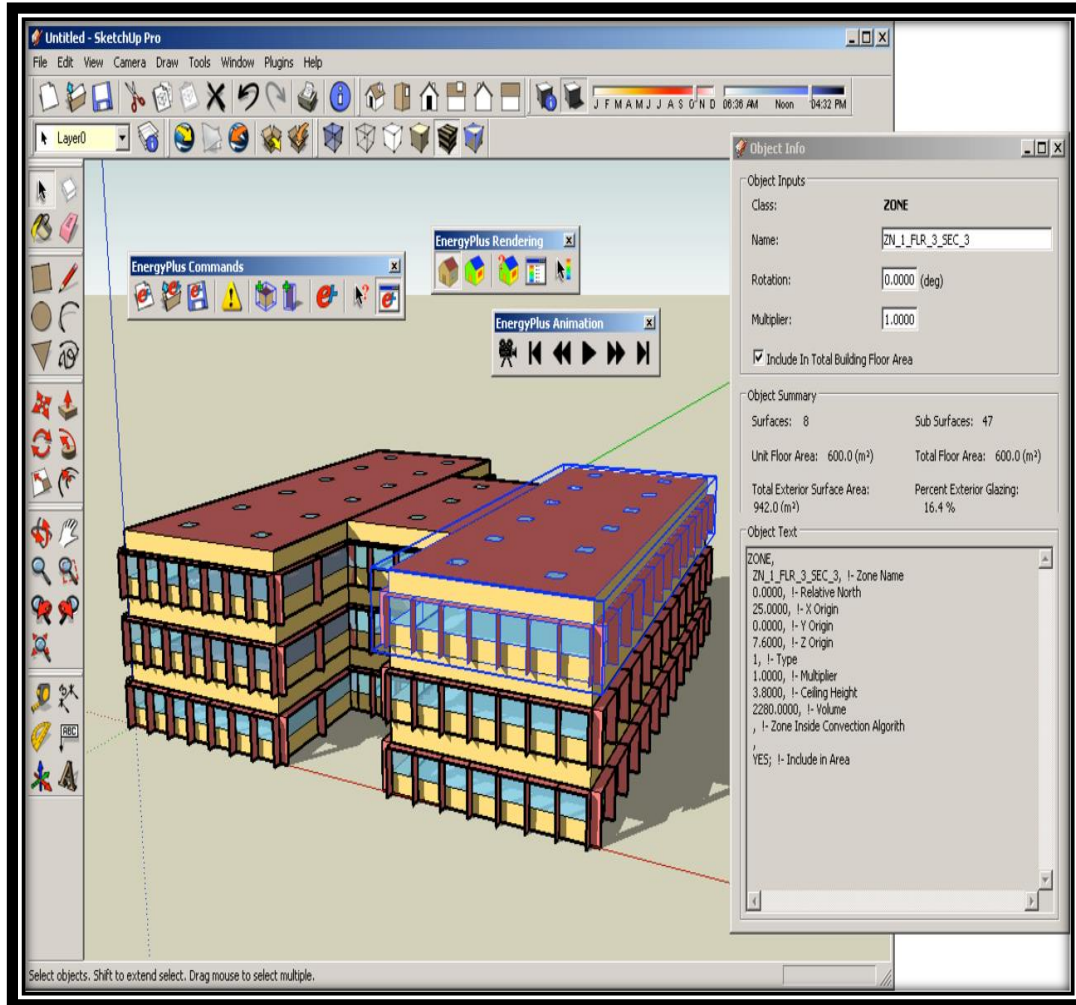


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## Simulation Tool



**EnergyPlus:** It's an entire building energy simulation software that engineers, architects use to model both: energy consumption (heating, cooling, energy, ventilation, lighting, process loads) & water use in buildings.





## Eco Niwas Samhita – Compliance Tool

Quick design and compliance checks on the benchmarks of ECO NIWAS 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





## Eco Niwas Samhita – Compliance Tool

Ministry of Power  
Government of India

File

Help

Demo Building

TEST (Demo Building)

Affordable High-Rise

TEST (Affordable High-Rise)

Low Rise

TEST (Low Rise)

High Rise

TEST (High Rise)

Upload Siteplan

Project Name

Demo Building

State

Chandigarh

City

Chandigarh

Latitude

>= 23.5° N

Project Construction Type

New Building

Plot Area (m²)

1500.0

Compliance Method Used

☒ Points System ☐ Prescriptive System

Housing Category

High Rise

Total no. of Residential Blocks

5

Add Category

Project Relocate

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

Total No. of Block16

ECO-NIWAS SAMHITA COMPLIANCE TOOL

ENS Compliance

HELP !

Climate zones of India

CompositeDoes not have a predominant season for more than six months

LEGENDS  
HOT DRY  
WARM HUMID  
COMPOSITE  
TEMPERATE  
COLD

Project Construction type for compliance check

ENS Code Purpose & Applicability

Project Construction Type

ENS Compliance Criteria

Plot Area

Housing Category

Total no. of Residential Blocks



## Eco Niwas Samhita – Compliance Tool

Project Name	Demo Building	State	New Delhi ▼
City	New Delhi ▼	Climate	COMPOSITE
Latitude	>= 23.5° N		
Project Construction Type	New Building ▼	Housing Category	Affordable ... ▼
Plot Area (m <sup>2</sup> )	10000	Total no. of Residential Blocks	10
Compliance Method Used	<input checked="" type="radio"/> Points System	<input type="radio"/> Prescriptive System	

- Easy project definition.
- Provisions for point system as well as prescriptive system approach for compliance evaluation.



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## Eco Niwas Samhita – Compliance Tool – Landing Page

ECO-NIWAS SAMHITA COMPLIANCE TOOL

Ministry of Power  
Government of India

File Help

**Demo Building** TEST (Demo Building)

Affordable High-Rise TEST (Affordable High-Rise)

Site Level Information

b1

Envelope

Building Services

Indoor Electrical Use

Renewable Energy System

Low Rise TEST (Low Rise)

Site Level Information

b1k

Envelope

High Rise TEST (High Rise)

Site Level Information

b1HR

Envelope

Building Services

Indoor Electrical Use

Renewable Energy System

Upload Building Data

Project Name: Demo Building

State: Chhattisgarh

City: Chhattisgarh

Climate: COMPOSITE

Latitude: >= 23.5° N

Project Construction Type: New Building

Housing Category: High Rise

Plot Area (m²): 1500.0

Total no. of Residential Blocks: 5

Compliance Method Used: ☒ Points System ☐ Prescriptive System

**Tree View Navigation**

Add Category Project Relocate

S.No	Housing Category	Plot Area (m²)	Total Residential
1	Affordable High-Rise	1000.0	10
2	Low Rise	1000	1
3	High Rise	1500	5

Total No. of Block: 16

**Help Section**

ENS Compliance

HELP !

Climate zones of India

Project Construction type for compliance check

Orientation	Range (0° being north and 90° being east)
North	337.5° – 22.5°
North-east	22.5° – 67.5°
East	67.5° – 112.5°
South-east	112.5° – 157.5°
South	157.5° – 202.5°
South-west	202.5° – 247.5°
West	247.5° – 292.5°
North-west	292.5° – 337.5°

North

North West 337.5° 22.5° North East 67.5°

West 292.5° 247.5° South West 202.5° 157.5° South East 112.5°

Angle measurement is taken clockwise with North

ENS Code Purpose & Applicability

Project Construction Type

ENS Compliance Criteria

Plot Area

Housing Category

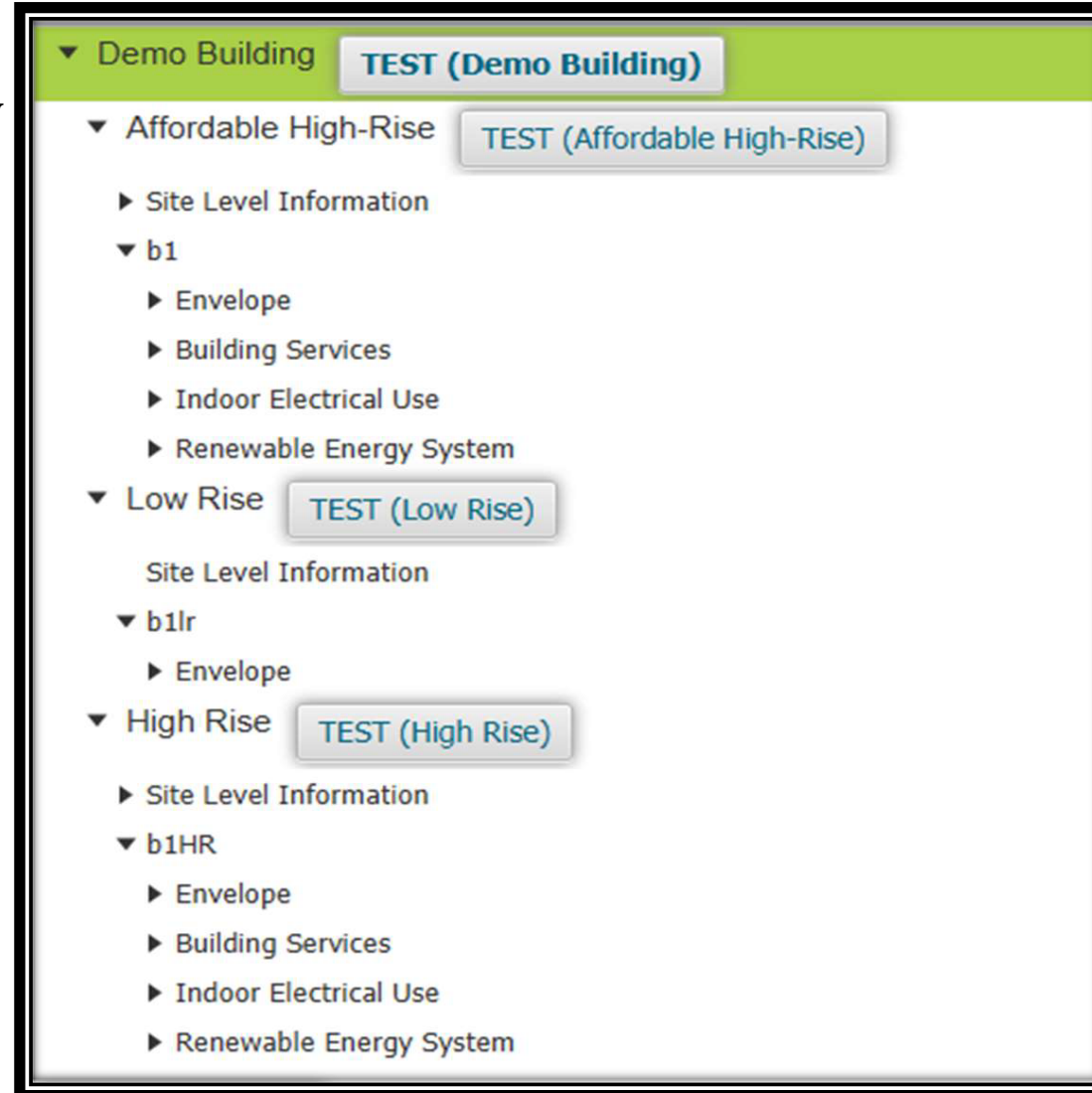
Total no. of Residential Blocks





## Eco Niwas Samhita – Compliance Tool – Key Features

Easy to navigate tree-view structure





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## Eco Niwas Samhita – Compliance Tool – Key Features

Project relocation feature  
for multiple domain use

Project Name	<input type="text" value="Demo Building"/>	State	<input type="text" value="New Delhi"/>
City	<input type="text" value="New Delhi"/>	Climate	<input type="text" value="COMPOSITE"/>
Latitude	<input type="text" value="≥ 23.5° N"/>		
Project Construction Type	<input type="text" value="New Building"/>	Housing Category	<input type="text" value="Affordable ..."/>
Plot Area (m <sup>2</sup> )	<input type="text" value="10000"/>	Total no. of Residential Blocks	<input type="text" value="10"/>
Compliance Method Used	<input type="radio"/> Points System	<input type="radio"/> Prescriptive System	
		<input type="button" value="Add Category"/>	<input type="button" value="Project Relocate"/>



## Eco Niwas Samhita – Compliance Tool – Key Features

Comprehensive help panel on each form for easy user referencing

▼ Demo Building **TEST (Demo Building)**

▼ Affordable High-Rise **TEST (Affordable High-Rise)**

▼ Site Level Information

- Basement Lighting
- Exterior Lighting
- Pumps
- Diesel Generator Set
- Power Factor
- Energy Monitoring
- EV Supply Equipment
- Transformer
- Power Distribution Loss
- Solar Photovoltaic System

▼ b1

- Envelope
- Building Services
- Indoor Electrical Use
- Renewable Energy System

► Low Rise **TEST (Low Rise)**

► High Rise **TEST (High Rise)**

**HELP !**

► Climate zones of India

▼ Project Construction type for compliance check

Orientation	Range (0° being north and 90° being east)
North	337.6° – 22.5°
North-east	22.6° – 67.5°
East	67.6° – 112.5°
South-east	112.6° – 157.5°
South	157.6° – 202.5°
South-west	202.6° – 247.5°
West	247.6° – 292.5°
North-west	292.6° – 337.5°

North

North West 337.5° 22.5° North East 67.5°

West 292.5° 112.5° East

South West 247.5° 157.5° South East

202.5°

Angle measurement in clockwise direction from North

► ENS Code Purpose & Applicability

► Project Construction Type

► ENS Compliance Criteria

► Plot Area

► Housing Category

► Total no. of Residential Blocks

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



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[illegible]

### Component level display for mandatory provisions and points achieved

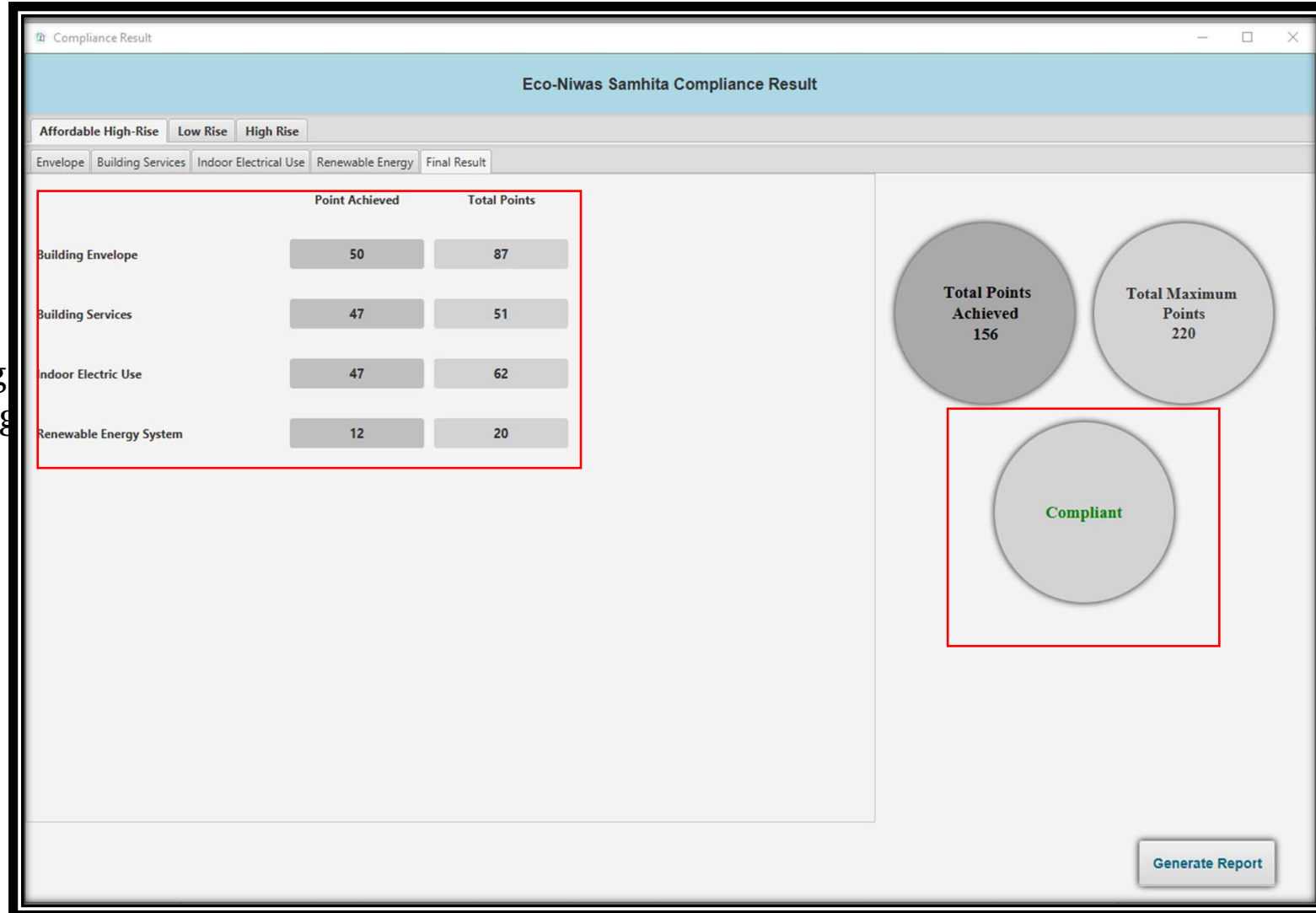






## Eco Niwas Samhita – Compliance Tool – Key Features

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





## Eco Niwas Samhita – Compliance Tool – Key Features



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(m <sup>2</sup> )	Total No. of Residential Blocks	Total Basement Area(m <sup>2</sup> )	Total Exterior Light Area(m <sup>2</sup> )	Total Roof Area(m <sup>2</sup> )
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	RET <sub>V</sub> (W/m <sup>2</sup> .K)	NA	14.59	44	80
2	U-Value Roof(W/m <sup>2</sup> .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

Provisions for PDF output reporting for each input and corresponding output



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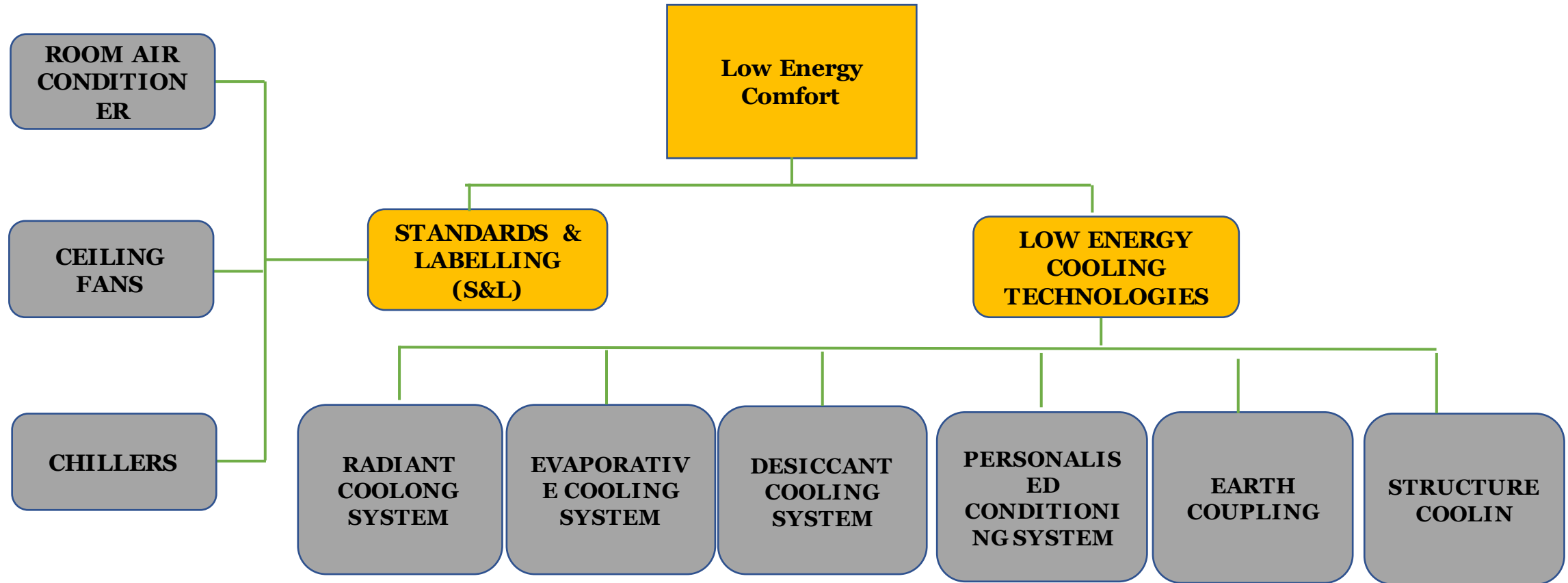


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# LOW ENERGY COMFORT SYSTEM



# 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)

**ROOM AIR  
CONDITIONERS(RACs)**

**CEILING FANS**

**CHILLERS**





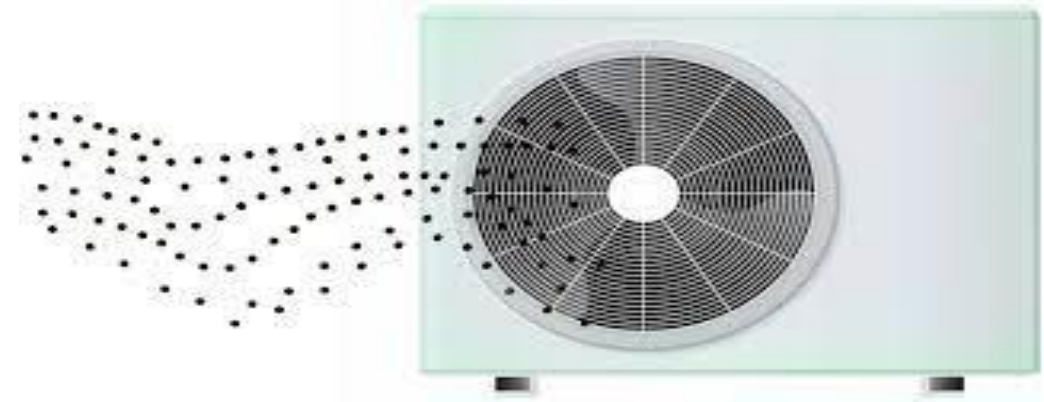
# Standards & Labeling (S&L)

## 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	-

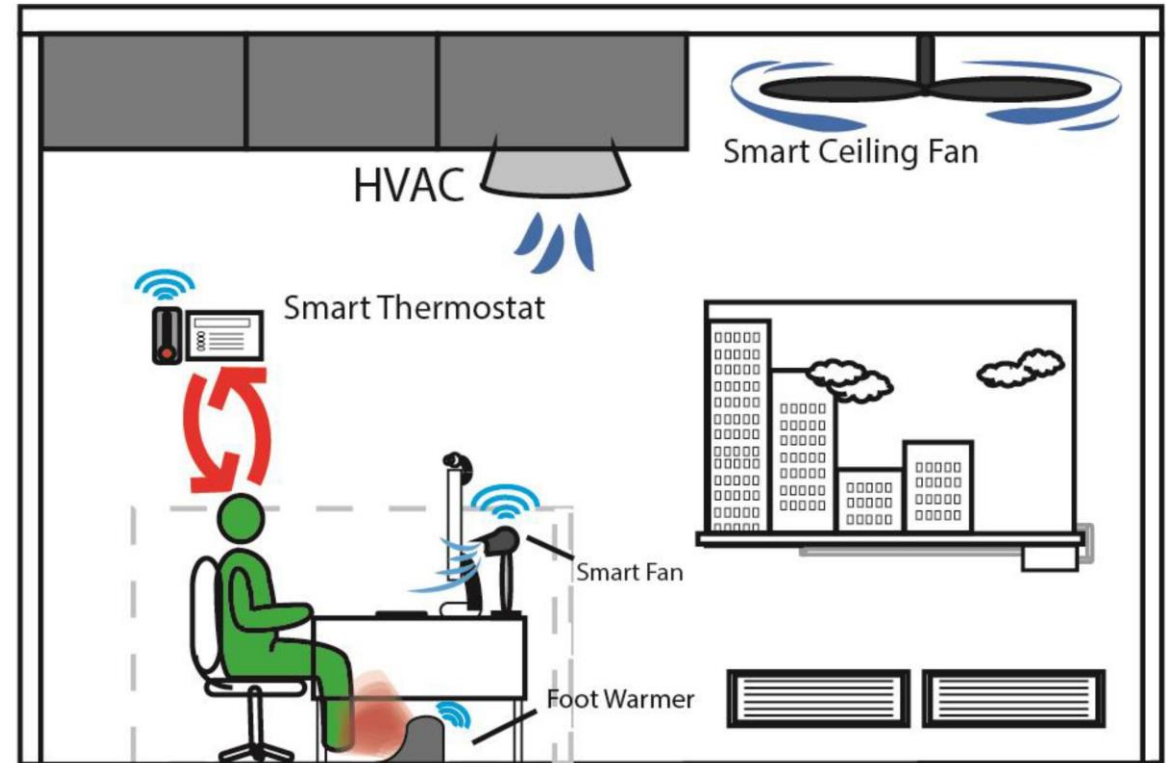
## Standards & Labeling (S&L)

## 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 ( $\text{m}^3$  /minute/W) delivered by a ceiling fan.

Both the BIS and the BEE give ratings to fans.



# Standards & Labeling (S&L)

## 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.

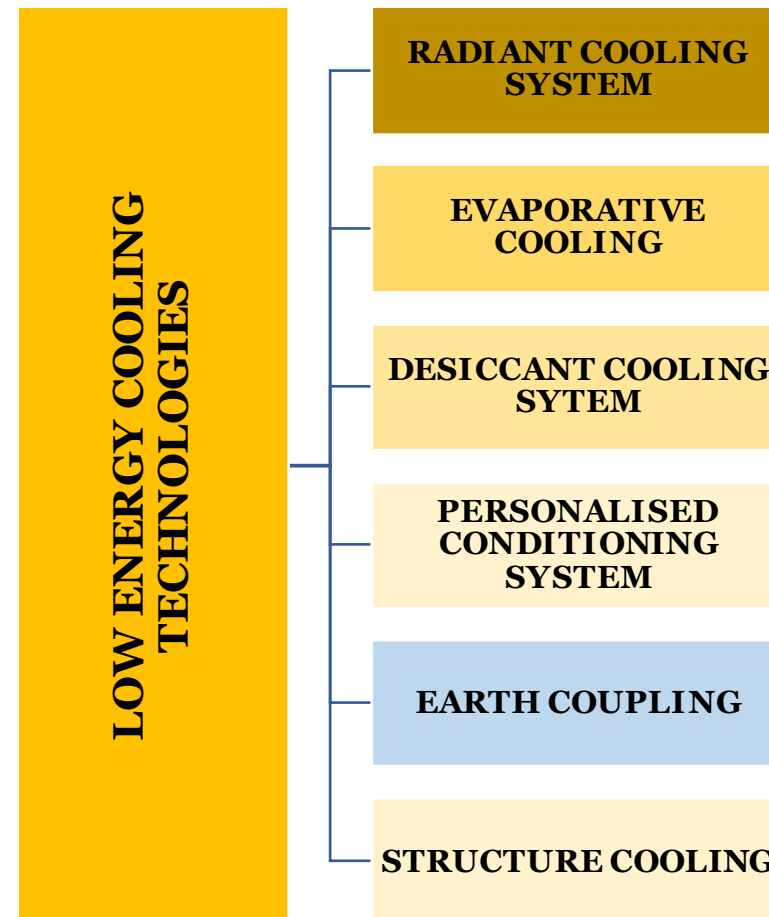
ISHRAE has also created a standard for evaluating and testing variable refrigerant flow (VRF) systems.





# 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.







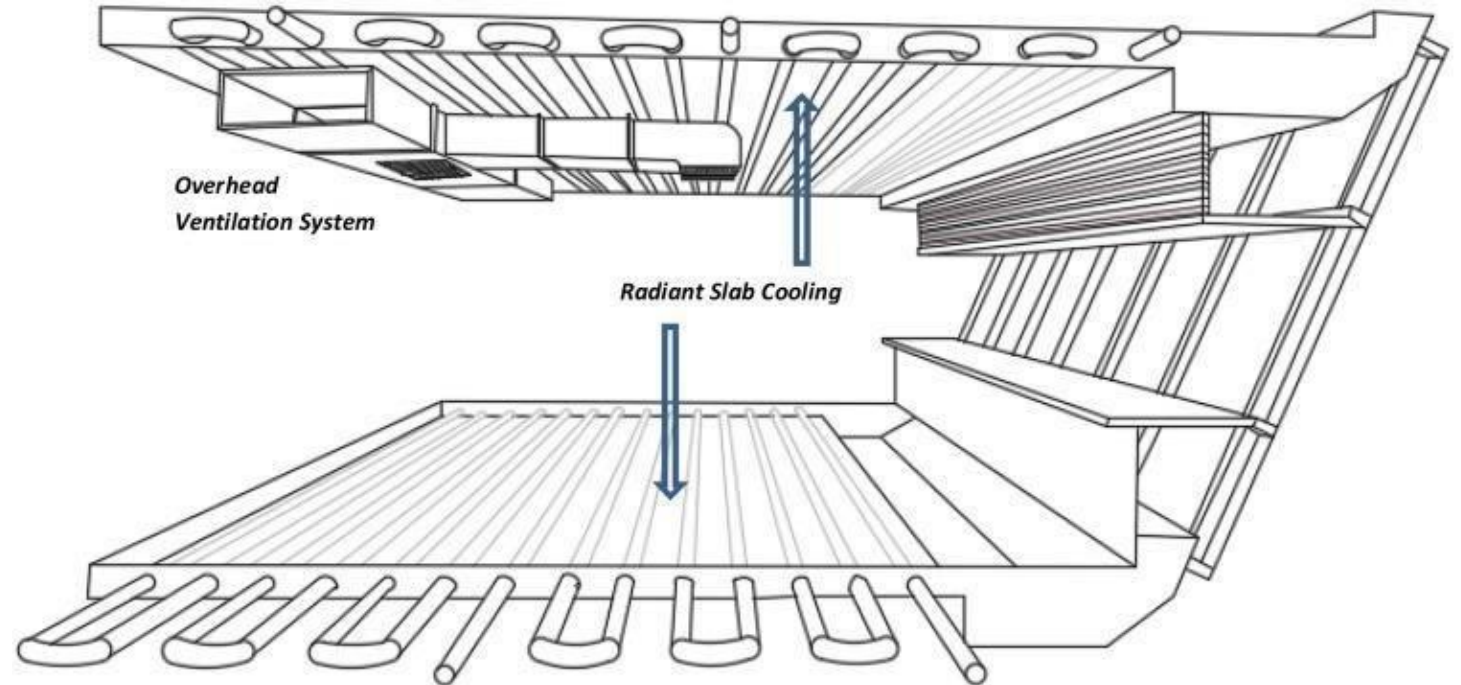
# Low Energy Cooling Technologies

## 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.





# Low Energy Cooling Technologies

## 2 - EVAPORATIVE COOLING:

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

### DIRECT EVAPORATIVE COOLING

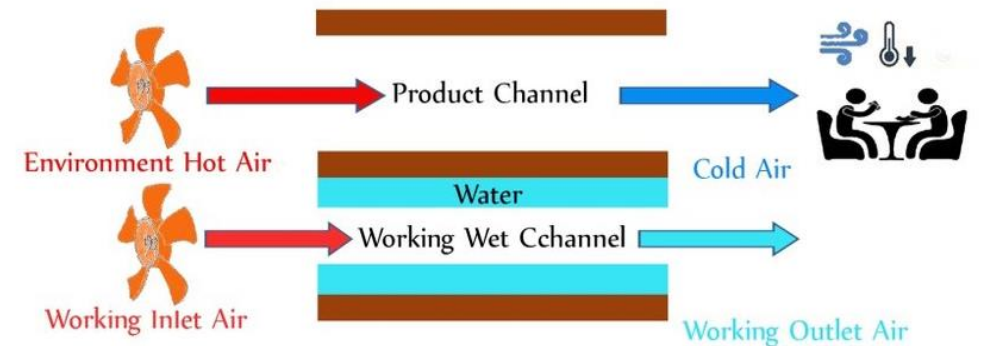
It is based on mechanical and thermal contact between air and water

### 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 Direct Evaporative Cooling System



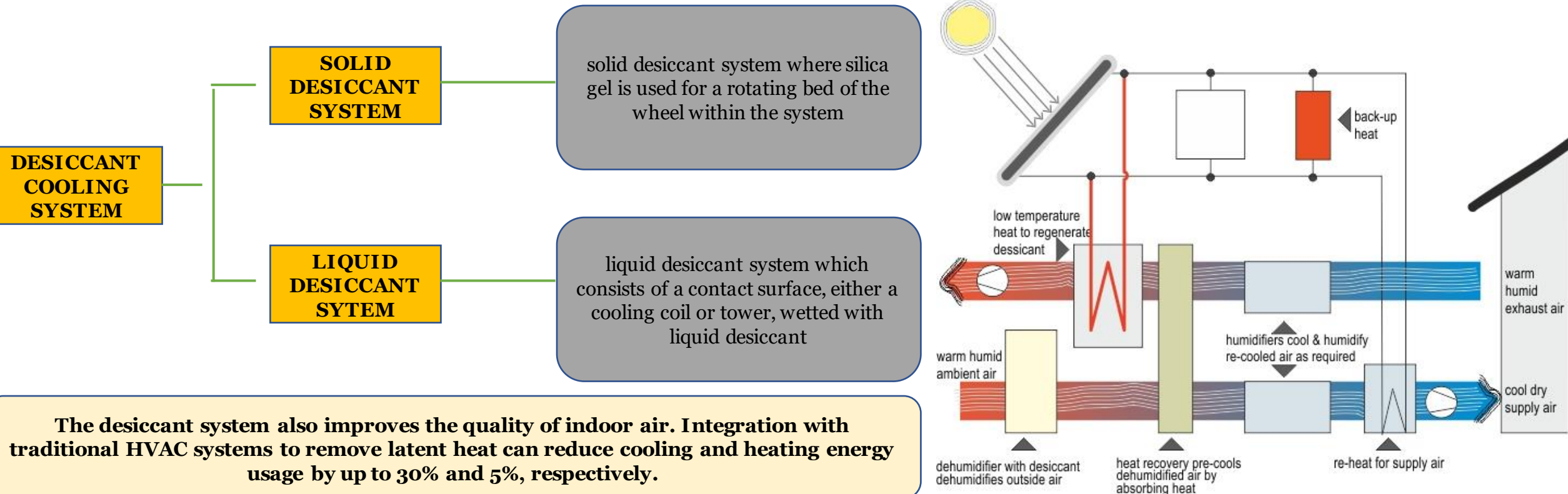
The Indirect Evaporative Cooling System



# 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.





## 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

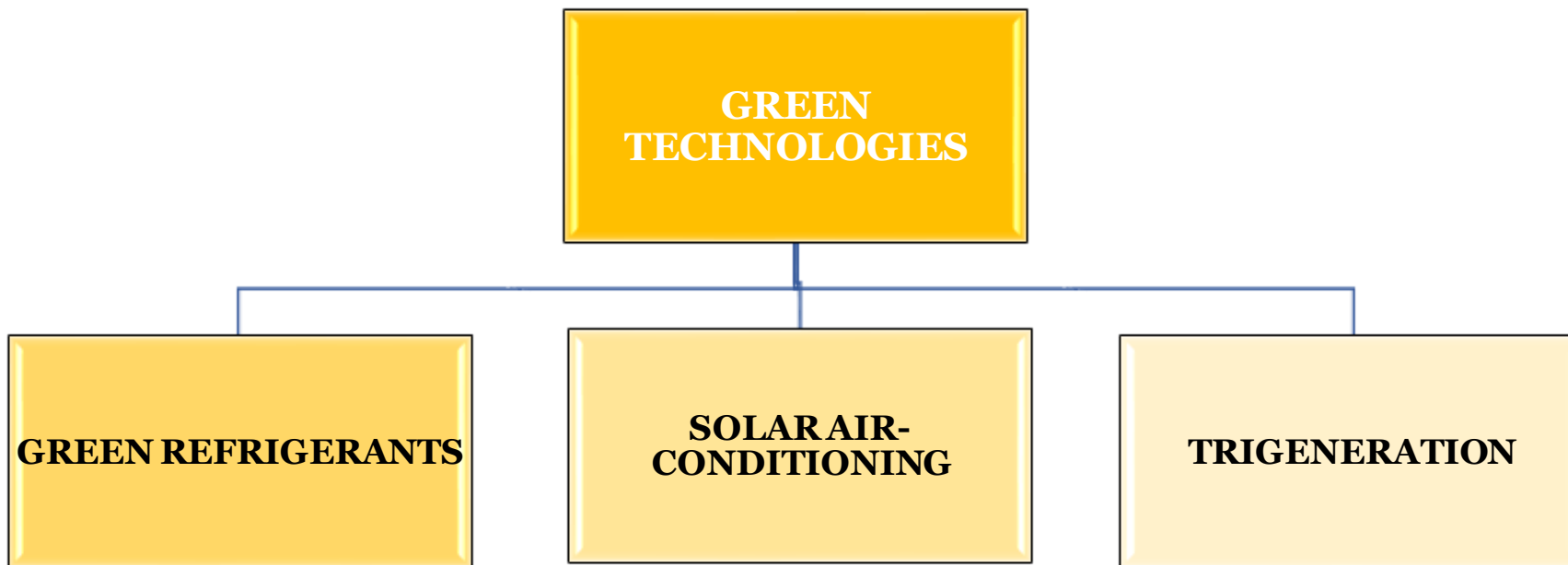
- By removing heat from the structure, structure cooling tries to lower the mean radiant temperature. This is accomplished by circulating water at room temperature through pipes implanted in slabs to drain heat from the building and prevent it from overheating. The larger thermal mass of water slows 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.





# Green Technologies

## **1 - GREEN REFRIGERANTS:**

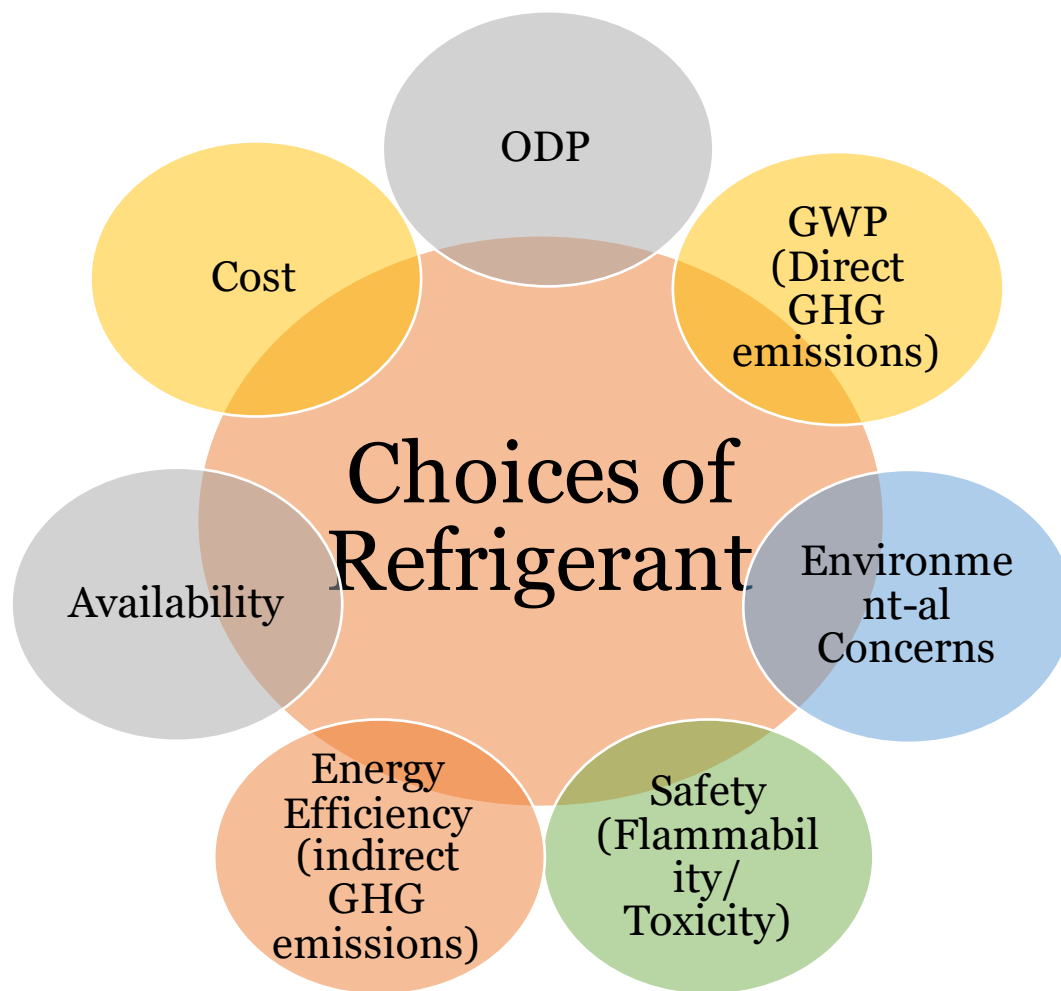
A green refrigerant would have the benefits of natural refrigerants and be energy efficient

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. CO<sub>2</sub>, 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.

**SOLAR AIR-CONDITIONING CAN  
BE DONE THROUGH**

PASSIVE SOLAR

SOLAR THERMAL  
ENERGY CONVERSION

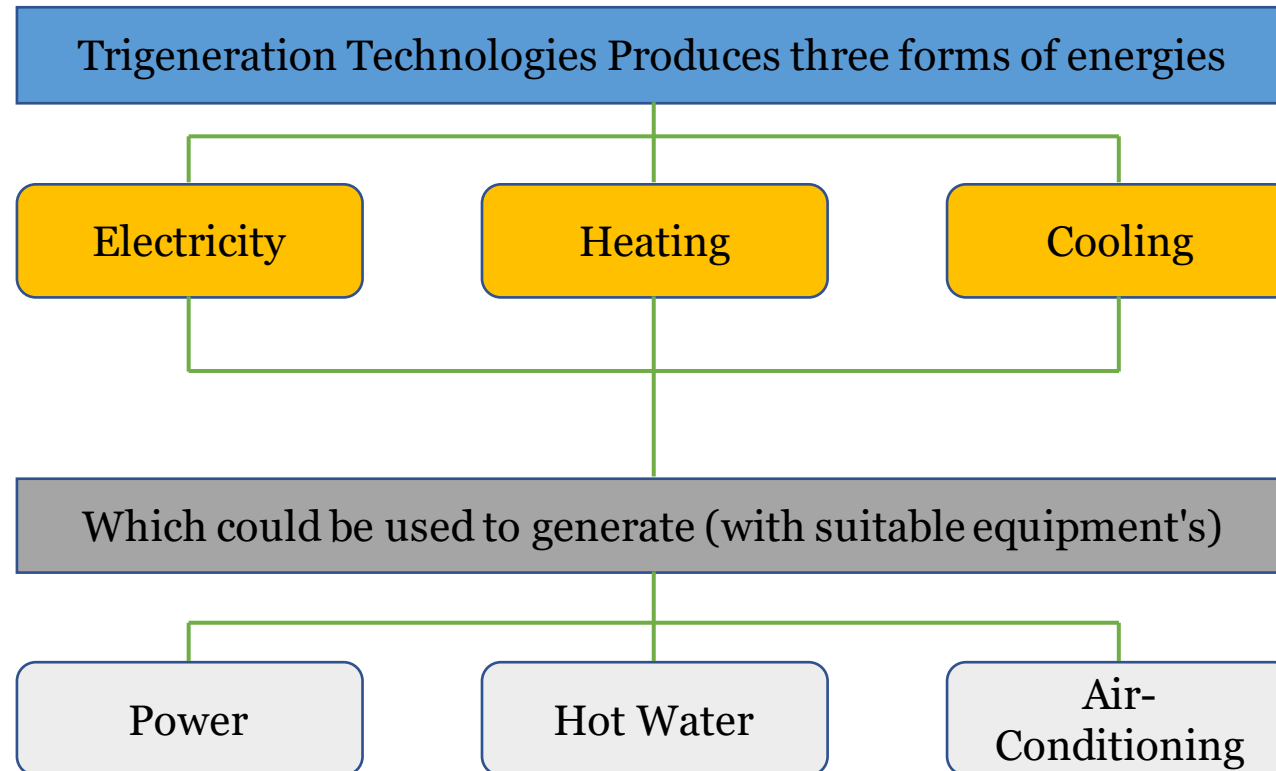
PHOTOVOLTAIC  
CONVERSION





# Green Technologies

## 3 -TRIGENERATION:



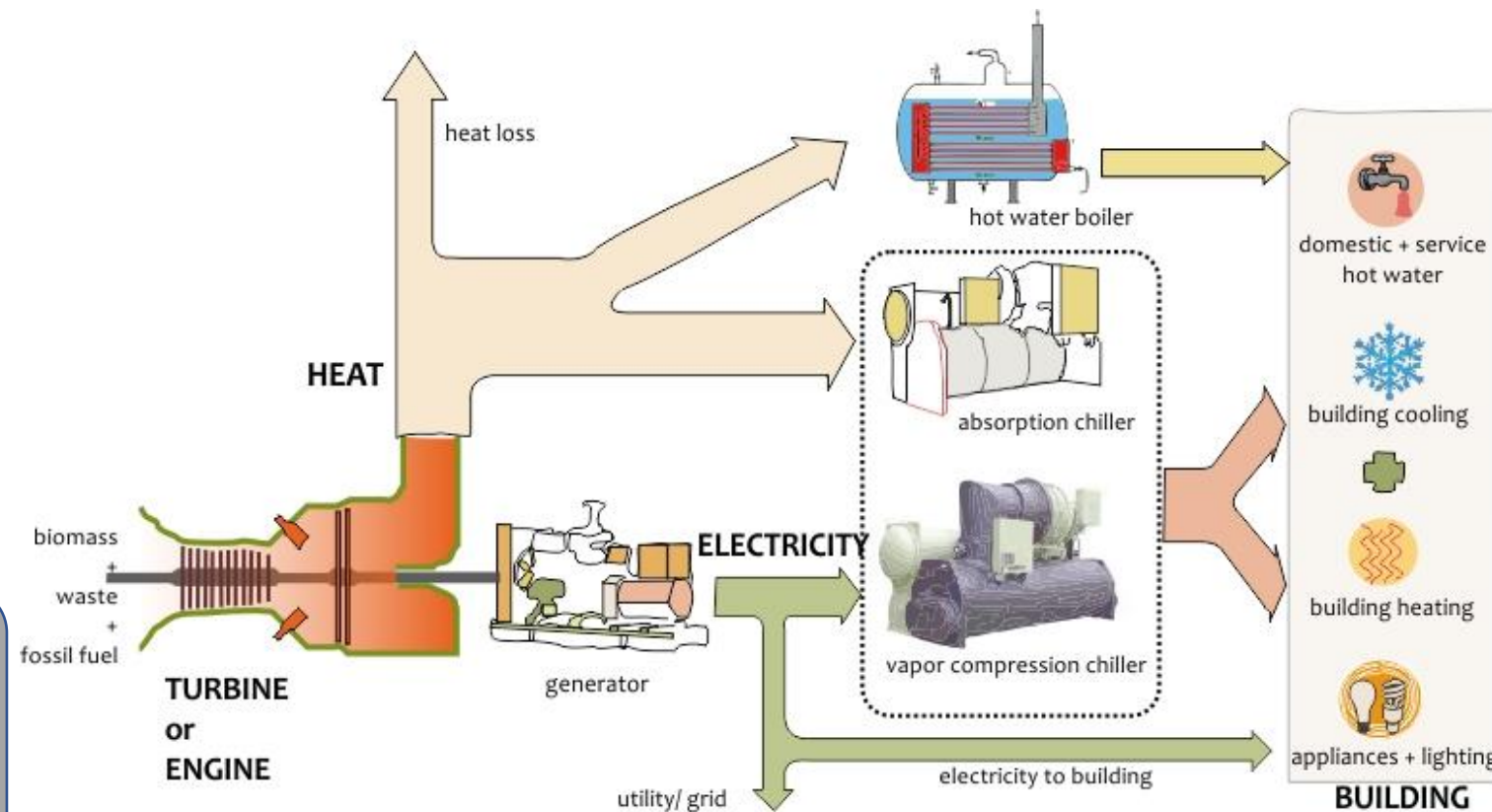


# Green Technologies

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

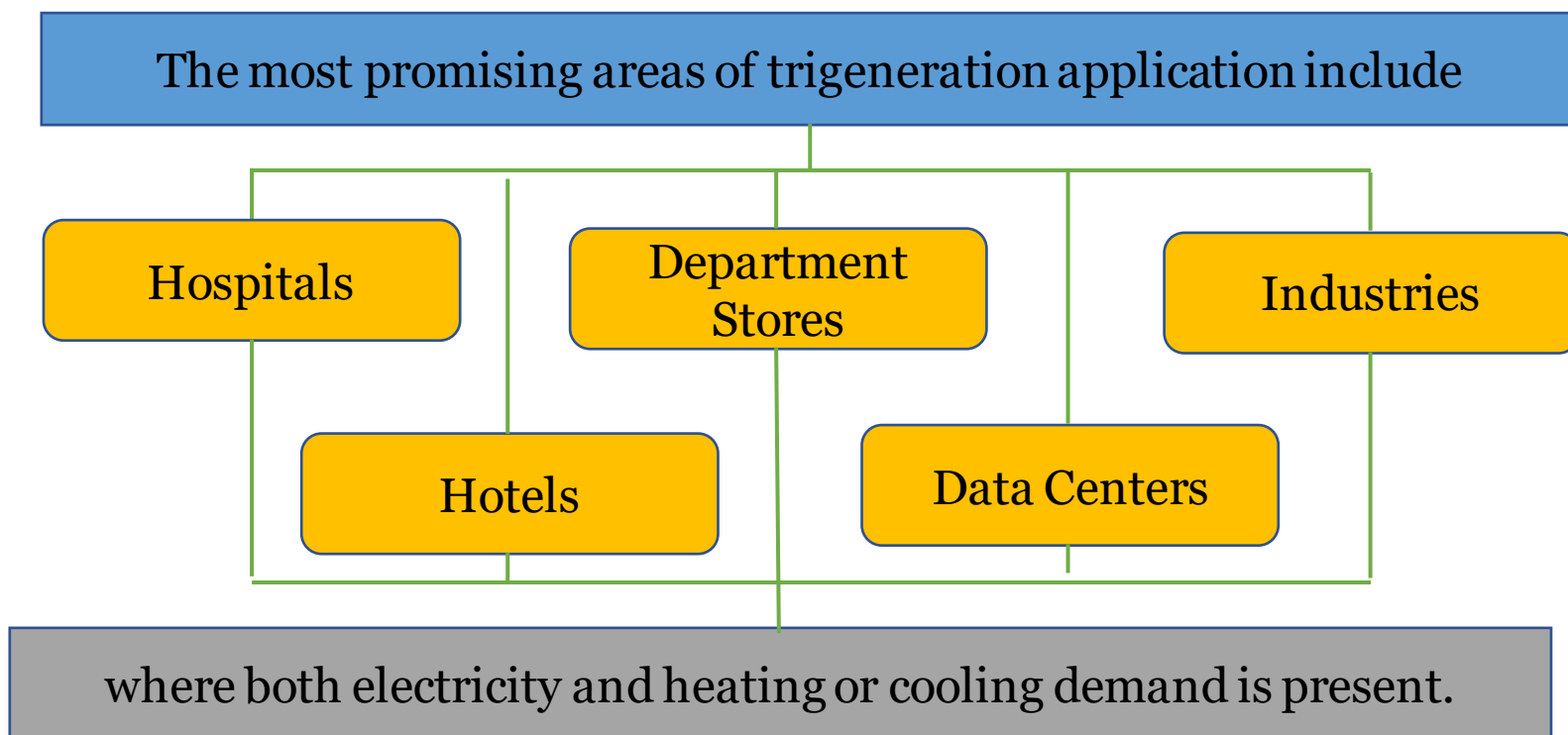
By utilizing a waste heat recovery system at the end user site, trigeneration systems can achieve great efficiency with no transmission losses.

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





# Green Technologies





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# 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

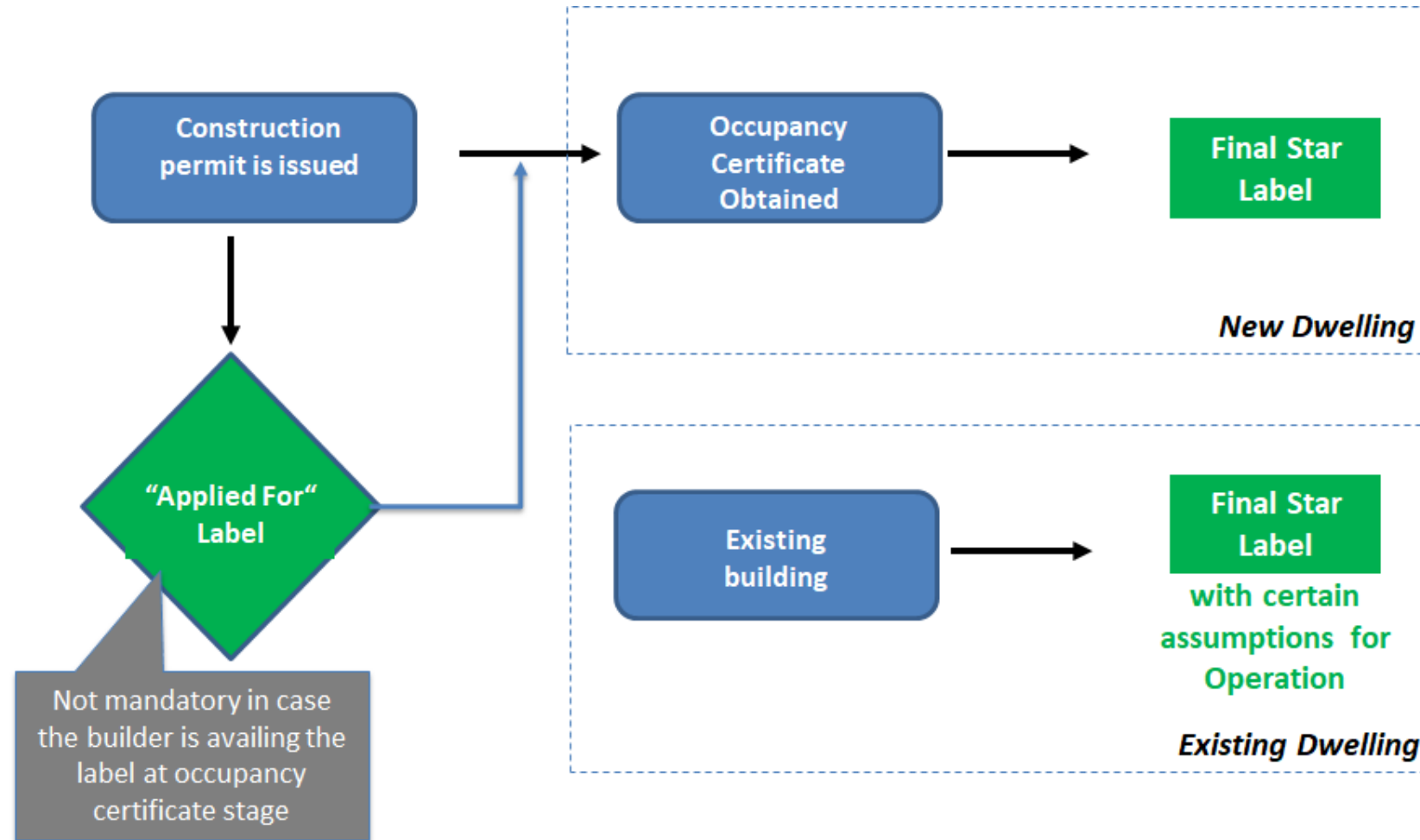
### *Making Energy Efficient Homes*

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 (**m<sup>2</sup>**)

**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.



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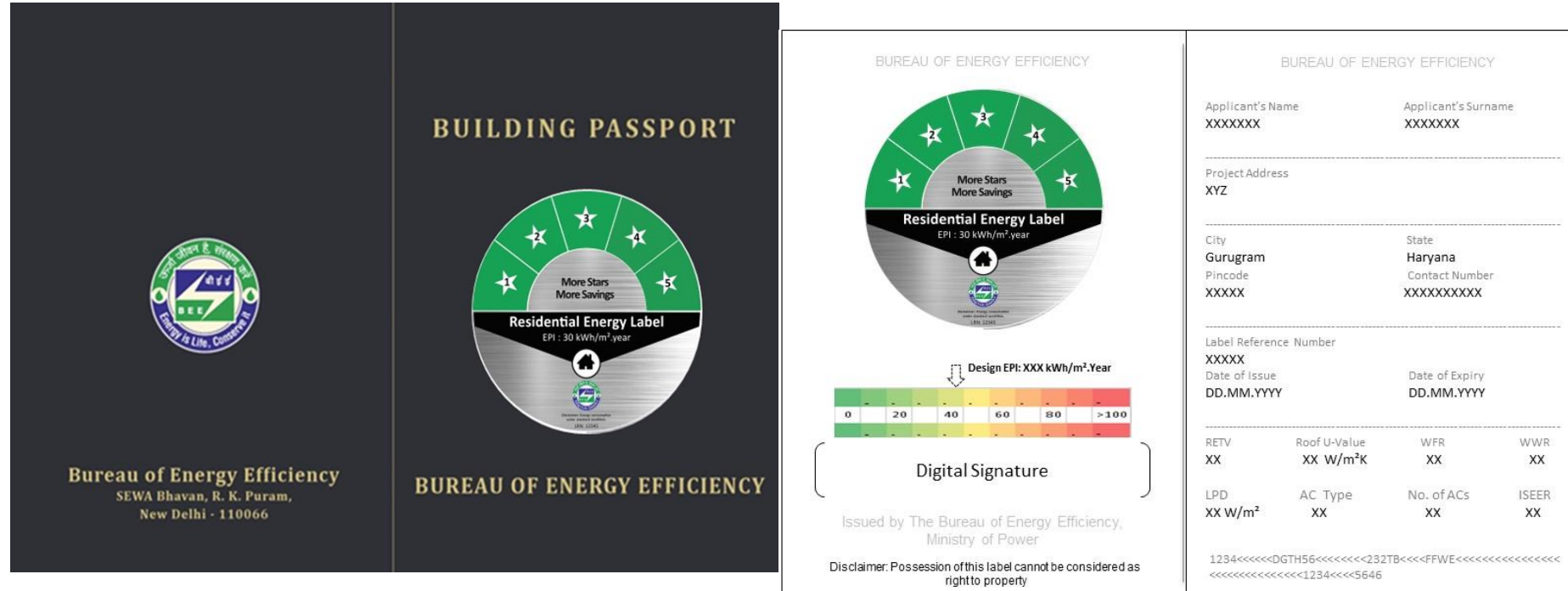
# Passport



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.



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



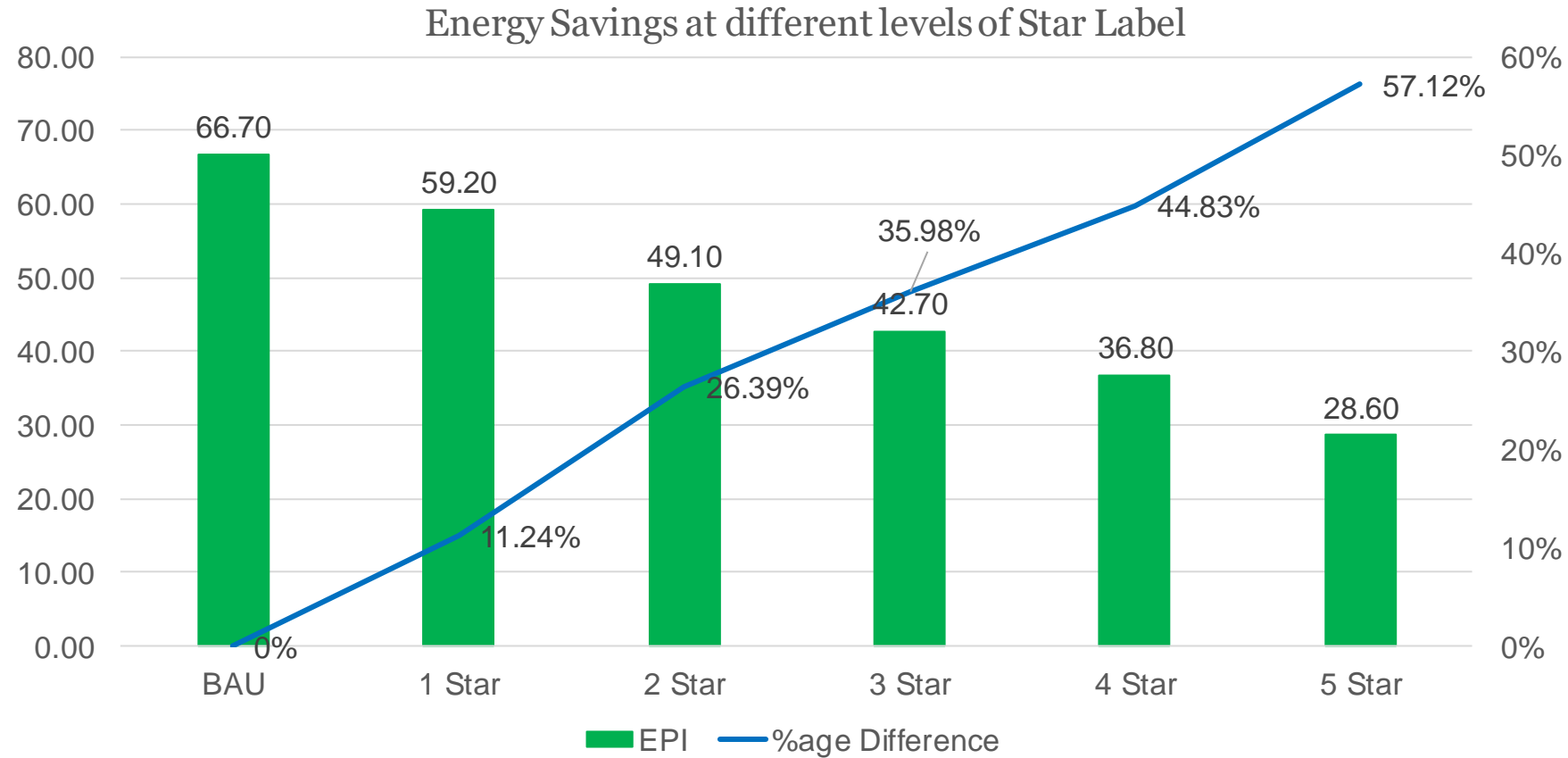


## Indicative measures to achieve different star labels

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



## 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



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# Residential Building Star Rating Plan

## Hot & Dry

★	$55 < \text{EPI} \leq 67$
★★	$47 < \text{EPI} \leq 55$
★★★	$38 < \text{EPI} \leq 47$
★★★★	$29 < \text{EPI} \leq 38$
★★★★★	$\text{EPI} \leq 29$

## Warm & Humid

★	$58 < \text{EPI} \leq 64$
★★	$49 < \text{EPI} \leq 58$
★★★	$39 < \text{EPI} \leq 49$
★★★★	$30 < \text{EPI} \leq 39$
★★★★★	$\text{EPI} \leq 30$

## Composite

★	$52 < \text{EPI} \leq 60$
★★	$45 < \text{EPI} \leq 52$
★★★	$37 < \text{EPI} \leq 45$
★★★★	$29 < \text{EPI} \leq 37$
★★★★★	$\text{EPI} \leq 29$

## Temperate

★	$28 < \text{EPI} \leq 31$
★★	$24 < \text{EPI} \leq 28$
★★★	$21 < \text{EPI} \leq 24$
★★★★	$17 < \text{EPI} \leq 21$
★★★★★	$\text{EPI} \leq 17$

## 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.

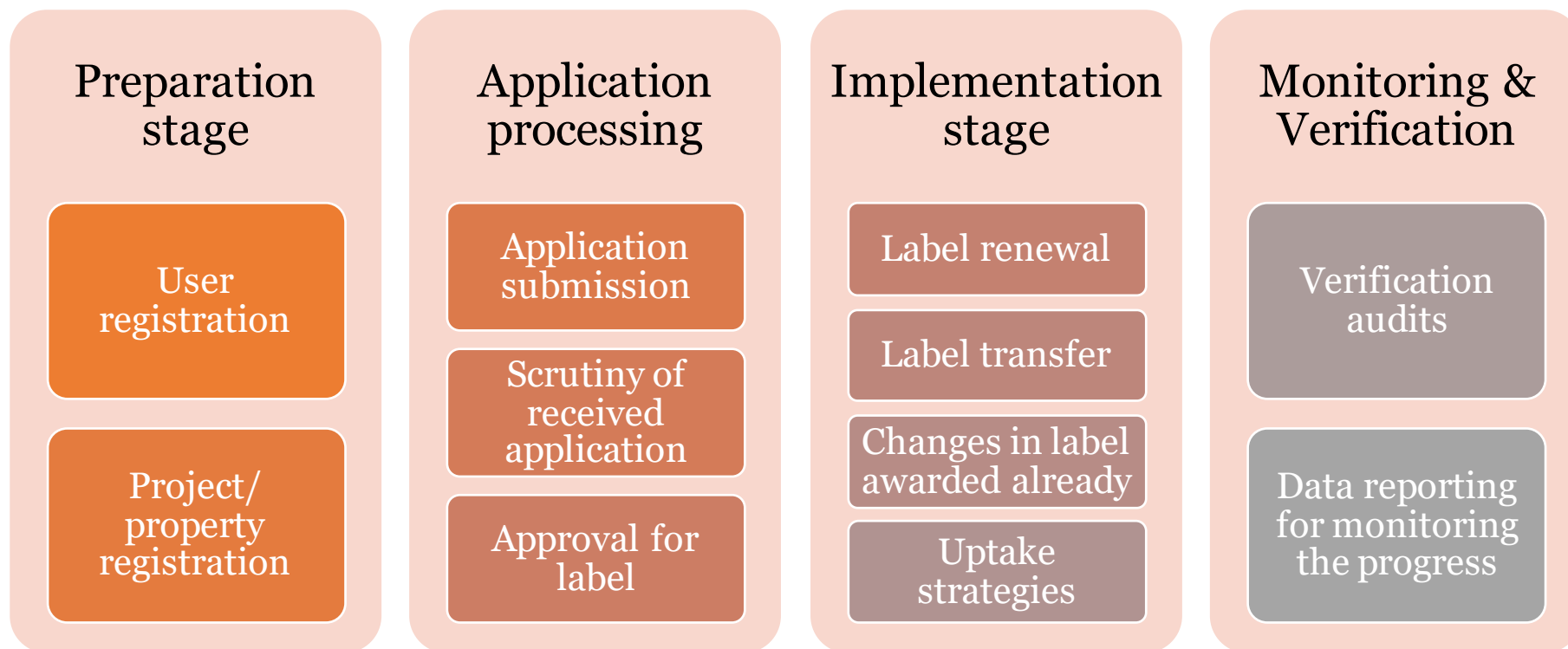
- ☐ Star Rating awarded in the basis on EPI (**Energy Performance Index**)
- ☐ Energy Performance Index = Annual Energy Consumption (**kWh**)/Built up area (**m<sup>2</sup>**)
- ☐ BEE has prepared an **online platform** for the User of Label to apply for seeking an award of label under this program
- ☐ 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





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# 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 m<sup>2</sup>
- Grid Connectivity Grid Connected
- EPI 56 KWh/m<sup>2</sup>/
- 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 CO<sub>2</sub> 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/m<sup>2</sup>/year





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# 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/m<sup>2</sup>/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 m<sup>2</sup>
- Date of Completion- 2018
- Grid Connectivity- Grid-connected
- EPI 60 kWh/m<sup>2</sup>/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



Ground Floor Plan – Office layout





# Unnati Office

OFFICE – Active cooling system



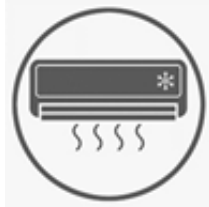
## RADIANT COOLING

Radiant cooling handles the sensible heat load



## FRESH AIR DUCTED SUPPLY

Fresh air supply also handles the latent heat load



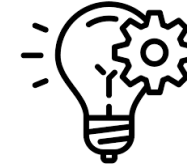
## Air-Conditioning

- 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.



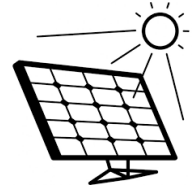
## Building Envelope and Fenestration

- 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

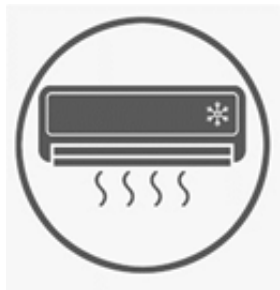
- Location Shenzhen, China
- Coordinates 39° N, 116° E
- Occupancy Type Office + research labs
- Typology New Construction
- Climate Type Humid subtropical
- Project Area 18,169 m<sup>2</sup>
- Grid Connectivity Grid Connected
- EPI 63 kWh/m<sup>2</sup>/yr
- <https://www.hpbmagazine.org/>
- Roof garden (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<sup>2</sup>°F
- Solar Heat Gain Coefficient (SHGC) 0.4
- Visual Transmittance 0.45
- Acoustic Isolation Performance 60 dbA







## Shenzhen Institute of Building Research (IBR) Headquarters



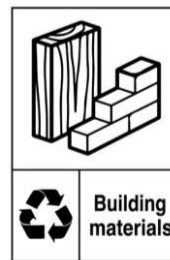
### Air-Conditioning

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.



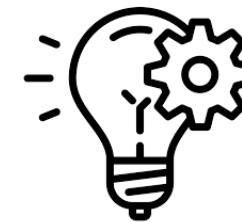
### Roof Garden

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 m<sup>2</sup>
- Date of Completion 2019
- Grid Connectivity: Grid-connected
- EPI- 10 kWh/m<sup>2</sup>/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.

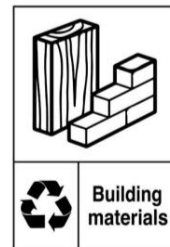
The cross-breezes through courtyards, aided by clerestory ventilation and ceiling fans, promote natural ventilation and improve comfort conditions



## Passive Strategies

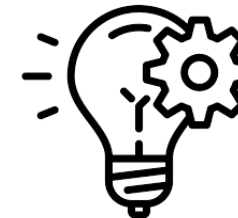
The architecture maintains a vernacular scale through setbacks, gabled roofs, and low-cost heat-storing materials.

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 m<sup>2</sup>
- 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 Tropical wet and dry climate
- Project Area 6,673 m<sup>2</sup>
- Date of Completion Oct 2019
- Grid Connectivity Grid-connected
- EPI (kWh/m<sup>2</sup>/yr)- 58 kWh/m<sup>2</sup>/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.

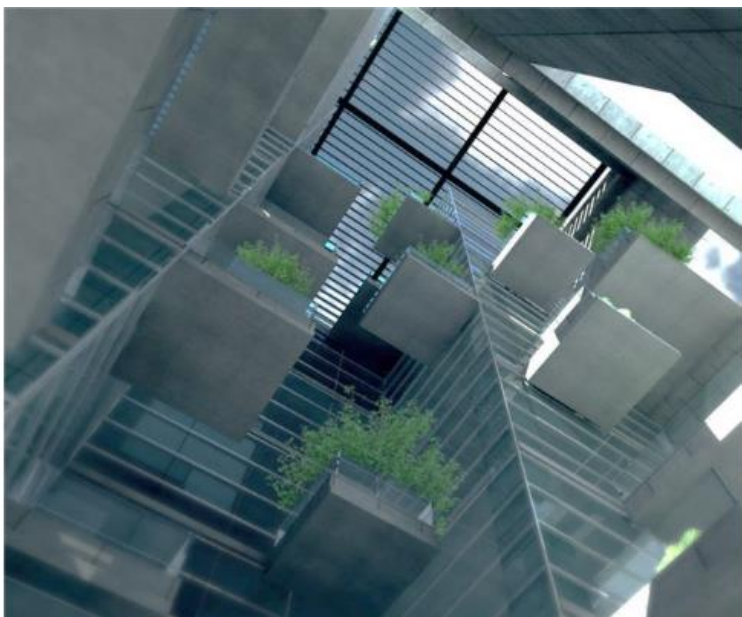
## Climate Responsive Design

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  $1.1 \text{ W/m}^2\text{k}$  – 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





## Design Problem

Design an affordable 1-storey 2BHK, detached residential building adhering to the building bylaws of the State. The carpet area of the dwelling unit must not be more than 1500sq ft. Site area is 4500 sq. ft.

1. Provide passive design strategies that can be considered at Site level and Building level.
2. List details of envelope construction materials that can be used along with construction techniques.
3. Provide calculations showing window to wall ratio (WWR), Window to floor area ratio (WFR), Visible Light Transmittance, Thermal Transmittance, Residential Transmittance Value RETV, Thermal Transmittance of building envelope (roof).
4. Check compliance for Composite Climate, Hot-Dry Climate, Warm Humid Climate, Temperate Climate and Cold Climate .
5. Calculate the total external shading factor and the equivalent SHGC of the fenestration.
6. Design and list various ways to make the building thermally comfortable.

Thank You